AN ENTERPRISE COMPETITION ANALYSIS OF BEEF PRODUCTION IN THE SOUTH

James E. Nix, Neil R. Martin, Jr., and John W. Hubbard

Enterprise competition among beef, hog and crop alternatives in the South[1] has been recognized by a number of analysts; e.g., [1, 5, 12, 13]. Potential enterprise adjustments in this region must be evaluated before reliable decisions affecting the beef industry can be made. This paper is concerned with an appraisal of normative adjustments in southern beef production and related enterprises over an intermediate period of time.

REVIEW OF METHODS

Several methods have been employed in the study of agricultural adjustments and supply response. Econometric analysis of time series data and mathematical programming are probably the most often used formal techniques. Major differences between these two lie in their ability to handle structural change and in the level of aggregation at which analyses can be made. Because of limitations in available data, supply estimates from time series data are generally related to large aggregates, and are further limited to industry structures during the period of observation. Mathematical programming permits examination of resource use and normative enterprise adjustments at many levels of aggregation.

Studies directly concerned with industry and national variables have employed econometric as well as mathematical programming techniques. Examples of research problems at the macro level include interregional competition in cattle feeding [4], price-output behavior within the beef and pork sectors [3], and orderly flows within the beef and pork sectors [16]. These studies have provided valuable information concerning the beef and pork industries in the United States. However, the macro approach does not directly confront the matter of enterprise competition, particularly important in the South where crop and livestock enterprises compete for resources.

Farm level studies of supply response and adjustments are generally concerned with competition among alternative enterprises for resources. Detailed enterprise budgets and resource data are often formulated into mathematical programming models, representative of certain sizes and types of farms in specific geographic locations. Results from these models provide information about normative adjustments at the firm level. Actual studies have provided useful farm management information and indications of farmer response to possible changes in market conditions and public policy. However, attempts to assess the aggregate implications of programmed results from representative firm models have not been completely satisfactory [10, 11].

A third approach to supply and adjustments research has been called "micro-macro modeling" [2, 14, 18, 19, 20]. This approach uses mathematical programming procedures with aggregate as well as representative firm constraints and activities. It accounts for farm interdependencies and limits opportunities in the aggregate to something less than the sum of opportunities at the firm level. Equilibrium occurs when the input (output) of any factor (pro-

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[1] In this paper the South includes Virginia, Kentucky, Tennessee and North Carolina (Appalachian States), South Carolina, Georgia, Alabama and Florida (Southern States), and Mississippi, Louisana and Arkansas (Delta States).

duct) has been extended until the marginal value product (marginal cost) of all firms purchasing the factor (producing the product) is equal to the price of the factor (product). Further, any firm not purchasing producing a given factor (product) must have marginal value product (marginal cost) equal to or less (greater) than the factor (product) price. This micro-macro approach was used in this study to appraise changes in enterprise competition and thereby beef industry adjustments in the South.

MODEL STRUCTURE AND ASSUMPTIONS

An empirically based profit maximization linear programming model was developed. This model provided for competition among firms at subregional and regional levels and for competition among enterprises at the firm level. Individual firms were assumed to respond in unison to maximize profit in a static environment with prices, yields and technical coefficients treated as single valued expectations. Highlights of the model structure and assumptions are presented here and in more detail in [9].

The South, a diversified crop and livestock production region, was disaggregated into several more homogeneous areas. Three levels of stratification were made: (1) geographic, (2) farm type and (3) farm size. This procedure resulted in delineation of 17 subregions, two farm types and nine farm sizes (Figure 1 and Table 1). Enterprise alternatives in the model included beef cow-calf, stocker and slaughter production systems, plus hog, cotton, soybean, corn, wheat, oats, barley, grain sorghum and forage production activities. Poultry, dairy and specialty crops and the resources used to produce them were excluded from the model.

Figure I. GEOGRAPHIC AREA OF STUDY

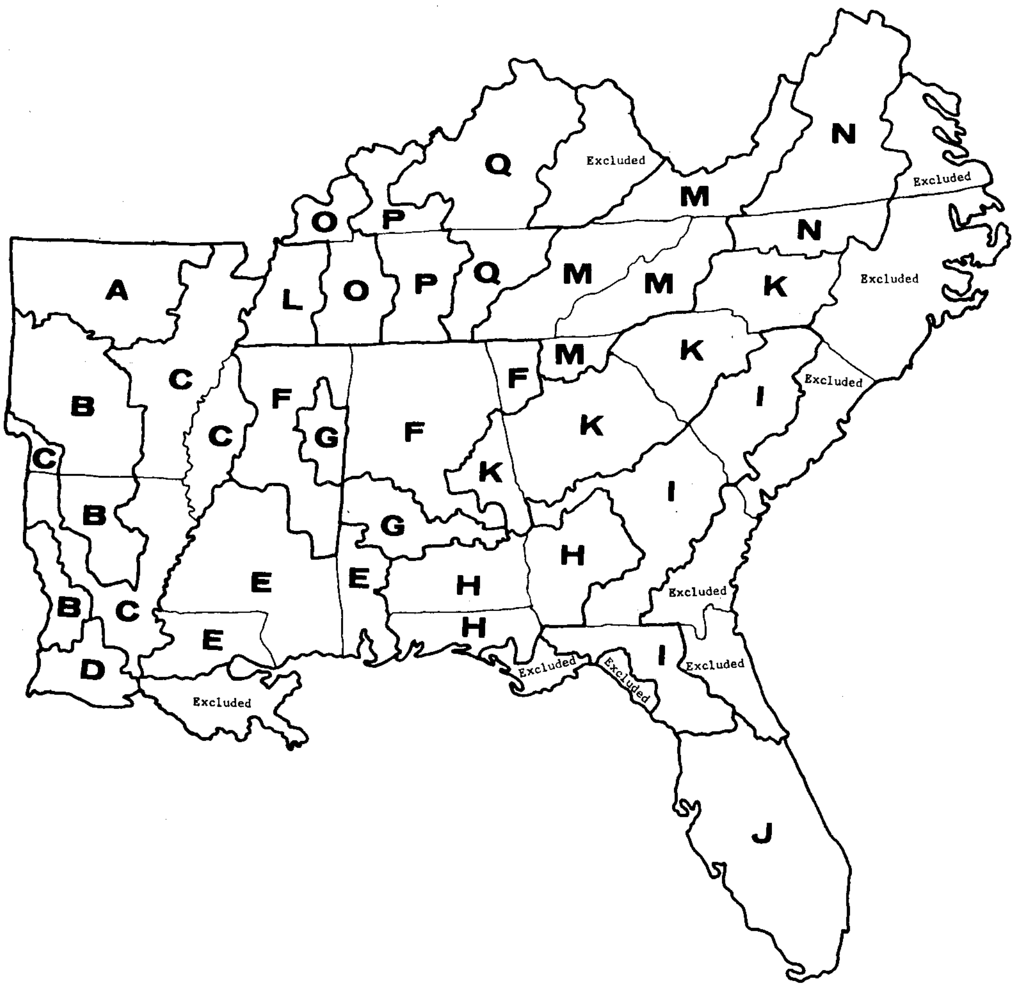

Table 1. REPRESENTATIVE BEEF AND NONBEEF FARM SIZES USED IN STUDY[a]

Subregion	Beef farms: Number of brood cows					Nonbeef farms: Acres of open land					
	<20	20–49	<50	50–499	≥500	<100	≥100	<200	≥200	<300	≥300
A	X	X		X						X	X
B	X	X		X						X	X
C			X	X	X					X	X
D	X	X		X						X	X
E			X	X	X			X	X		
F	X	X		X		X	X				
G			X	X	X					X	X
H			X	X				X	X		
I	X	X		X				X	X		
J					X						
K	X	X		X		X	X				
L	X	X		X						X	X
M	X	X		X		X	X				
N			X	X		X	X				
O	X	X		X				X	X		
P	X	X		X				X	X		
Q	X	X		X		X	X				

[a]Sizes marked with an X represent the farm sizes delineated for each subregion.

The basic level of technology assumed in this study was that which, in 1969, was known, commercially available, and believed likely to be widely adopted by 1975. The level of management was considered advanced in 1969 but likely to be generally found on farms by 1975. Technical and cost coefficients were adapted from unpublished enterprise budgets developed by members of the S-67 regional research project, "Evaluation of Beef Production In The South." Resource requirements and costs varied by size and by geographic area. The type and size of representative farms were fixed, although size and kind of enterprises on representative farms could vary.

Model constraints were included for resources at the representative farm, subregional and regional levels. Constraints forced transfers of intermediate products, sales of final products and use of inputs not to exceed amounts produced plus amounts purchased. Quantities of resident labor, land and livestock facilities on representative farms were those assumed present in 1969. No costs were associated with their use or non-use.

Feed grains produced could be sold as final products or could be used for livestock feed. Forages, however, had to be utilized on the farms where they were produced.

Hired labor could be purchased for representative farms on an annual or a seasonal basis. Seasonal labor could not exceed a specified percentage of full-time hired labor in a subregion.

The year 1969 was selected for a benchmark application of the model. Initially, the application was used to identify and resolve numerical and conceptual errors. Later, it was used to compare programmed solutions to the observed 1969 production patterns and as a vantage point for viewing further programming solutions. Subsequently, an intermediate-term formulation of the model was used to study adjustments over a period of five to seven years.

Two assumptions distinguish the benchmark formulation from that used to study intermediate-term formulation of the model was used to study adjustments over a period of five to seven years.

Two assumptions distinguish the benchmark formulation from that used to study intermediate-term adjustments. In the benchmark application, hired labor was restricted to estimated level of use in the base period and wage rates were fixed at estimated base levels. Also, livestock facilities were not allowed to exceed size and type of facilities in the base period. Special assumptions of intermediate-term applications of the model were:

1. Hired labor was mobile among areas.
2. Total labor used in the region could exceed the benchmark level if the wage rate was bid higher.
3. New investments in livestock facilities were permitted.

Although the model remained static, investments in new livestock facilities and labor mobility were viewed as intermediate rather than short-term adjustments. The formulation was distinguished from long-term by reliance on a given level of technology, and by an assumed size and type distribution of farms.

Less than perfectly elastic demand relationships were assumed for products competing with beef. Base quantities for these functions were estimated 1969 study-area production of these products. Base prices were product prices recommended by the S-67 price committee for use in the S-67 study [15] and were near 1969 prices. Price and quantity relationships for non-beef products were approximated by stepped demand functions in the linear programming model.[2] Cross-elasticities of demand for all products were assumed to be zero.

Beef price asumptions used for the benchmark programming stage were consistent with beef price levels observed in the base period. Price relationships reflected historical margins between classes and weights of cattle. Intermediate-term solutions were computed for beef price levels 1, 2, 3 and 4 (Table 2). Level 2 was considered to be the base beef price level. Levels 1, 2 and 3 were suggested by the S-67 Technical Committee [15]. The fourth (and highest) beef price level programmed was selected to determine the supply response at a level higher than that suggested by the S-67 group.

Table 2. BEEF PRICES BY CLASS AND GRADE OF ANIMAL FOR FOUR PRICE LEVELS[a]

Item	Beef price level			
	1	2	3	4
	Dollars per cwt.			
Calves				
Good heifers	23.50	29.00	34.50	45.00
Choice heifers	25.00	31.50	38.00	48.50
Good steers	26.00	31.00	36.00	46.00
Choice steers	29.00	34.00	39.00	49.00
Yearlings				
Good heifers	21.50	25.50	29.50	37.50
Choice heifers	23.00	27.00	31.00	39.00
Good steers	24.00	28.00	32.00	40.00
Choice steers	25.50	29.50	33.50	41.50
Slaughter				
Good heifers	23.50	26.50	29.50	35.50
Choice heifers	25.50	28.50	31.50	37.50
Good steers	25.00	28.00	31.00	37.00
Choice steers	27.00	30.00	33.00	39.00
Cull cows	18.00	22.00	26.00	34.00

[a]For more detail see [8].

BENCHMARK RESULTS

Regional estimates from the benchmark application of the model showed higher levels of crop production than were observed in 1969, and lower livestock production (Table 3). Crop production increases were largest for wheat and double-cropped soybeans. Benchmark solution values for beef cows were about 94 percent of the 1969 estimate, values for hogs being about 90 percent. Thus, benchmark results from this model indicated that normative adjustments in the South would lead to increases in crop

[2]Procedures for including stepped demand and factor supply functions in linear programming models were reviewed by Martin [6].

activities and slight decreases in beef and pork production. There were several reasons why these results did not match 1969 base estimates. All prices, yields and input requirements in the model were treated as single valued expectations. Differences between coefficients assumed in the model and those actually in use accounted for some of the deviations. Other deviations may have been due to a willingness of farmers to accept less than maximum net revenues, whereas the model provides maximizing solutions.

Table 3. REGIONAL SUMMARY OF 1969 ESTIMATES AND PROGRAMMED ACTIVITY LEVELS IN THE BENCHMARK AND INTERMEDIATE TERM SOLUTIONS

Item	Unit	1969 estimate	Benchmark solution	Intermediate term solution at beef price:[a] 1	2	3	4
		1,000 units					
Breeding stock							
Brood cows	Head	7,102	6,710	7,820	11,580	18,601	25,708
Brood sows	do.	678	614	732	716	615	266
Livestock sold							
Cull cows	do.	b	896	1,009	1,536	2,431	3,364
Weaned calves	do.	b	3,711	246	1,611	11,060	16,454
Yearlings (500-800 lbs.)	do.	b	348	c	3	238	997
Slaughter cattle (<800 lbs.)	do.	b	704	5,425	6,715	2,102	1,058
Cull sows	do.	b	241	304	290	244	108
Market hogs	do.	9,974	8,907	10,208	9,967	9,325	4,062
Feeder pigs	do.	b	361	987	937	0	0
Crops produced							
Cotton	Acre	3,779	4,623	4,584	4,439	4,298	3,864
Soybeans:							
Single crop	do.	10,938	11,303	11,156	11,359	11,422	10,892
Double cropped	do.	305	1,938	1,968	1,444	839	711
Corn	do.	5,000	5,515	5,501	3,474	1,560	641
Wheat	do.	982	3,357	3,444	2,869	2,360	1,822
Oats & barley	do.	668	556	922	580	353	345
Grain sorghum	do.	237	194	177	96	69	0

[a]See Table 2 for beef price variables used at each price level.

[b]Data not available for making these estimates.

[c]Less than 1,000.

Estimates at subregion and representative farm levels showed larger deviations from observed 1969 levels than the regional level estimates.[3] Increases and decreases at the subregional and representative farm levels were partly offsetting and, therefore, resulted in regional estimates being nearer observed levels.

The inherent assumptions of linear programming partially explain some of these larger subregional and representative farm deviations. A linear programming model fully exploits any available comparative advantages. This can lead

[3]Space does not permit presentation of subregional and representative farm solution values, but these values are included in Nix [8].

to larger units of production than occur under actual conditions, if comparative advantage is not fully recognized or exploited by producers. The ability of a linear programming model to select the most profitable combination of these values also may lead to deviations from the observed production patterns. Due to the offsetting effects at subregional and representative farm levels, and to the tight controls placed on the model at the region level, the linear programming analysis leads to larger deviations at these lower levels of aggregation than at the regional level.

BEEF SUPPLY RESPONSE

To examine beef supply response in the South, the intermediate-term model was applied for four levels of beef prices. All coefficients, other than those affected by changes in beef prices, were constant for the four applications.

Given the predominance of the cow-calf system, beef supply response in the South is largely determined by how well the cow-calf enterprise competes with other enterprises. Model solutions at beef price levels 1, 2, 3 and 4 included regional herds of 7.8, 11.6, 18.6 and 25.7 million beef cows, respectively, all of which were above the 1969 estimate and the benchmark solution level (Table 3). This indicated a potential for expansion of brood cows at base prices (price level 2) and a limited potential at lower prices. Greater expansion of brood cow numbers was indicated at beef price levels 3 and 4. Cow herds (of the size included in price level 3 and 4 solutions) would require major shifts in uses of area resources.

Production of weaned calves above those kept for replacement was 4.8 million head in the benchmark solution. It ranged from 5.7 million head at the lowest price level to 18.5 million at the highest, in the intermediate-term application. The model provided for alternative disposition of these calves, i.e., to sell weaned calves or to retain them on rations of forage and/or grain and sell them as stocker or slaughter animals. A noticeable shift — from retaining a high percentage of the calves and later selling them as slaughter animals, to selling a high percentage without further feeding — occurred as beef prices were increased. Only small percentages were sold as stockers at any price level.

The response of the cow-calf enterprise to changes in beef prices varied by representative farms [8]. In general, same size farms located in different subregions responded similarly. At the lower beef price levels, programmed solutions for smaller beef farms had fewer brood cows than in 1969, and the larger beef farms had more. The number of brood cows on smaller beef farms increased above the 1969 number at higher beef price levels. The larger beef farms had more brood cows at all price levels than in 1969.

Almost all large beef farms fully utilized their land at all beef price levels. Their potential for expansion at the higher beef price levels was limited. At higher price levels, smaller farms expanded production and produced a higher percentage of beef than at the lower prices. Even at the highest beef price level, small farms had idle land and potential for further expansion.

As beef production increased, the production of competing commodities — pork, cotton, feed grains, soybean and wheat — decreased. Equilibrium prices for non-beef products generally increased as beef prices were increased [8]. Pork production in intermediate term solutions was above the estimated 1969 level at beef price levels 1 and 2, and only slightly below this at level 3. When beef prices were increased from level 3 to level 4, pork production declined to about 40 percent of the 1969 estimate.

Feed grain acreage, which decreased from about 112 percent of the 1969 estimate at beef price level 1 to about 17 percent at beef price level 4, showed the largest adjustment. Cotton, soybean and wheat acreages declined as beef prices were increased, but remained above the 1969 level in all programmed solutions. Most soybean acreage adjustment was caused by the decline in double-cropped soybeans.[4]

Additional labor was hired as beef prices were increased. The pattern of labor hiring varied by size of farm. Most labor hired by the smaller beef farms was seasonal, and these farms accounted for a very small percentage of full-time labor hired in the region. Almost all of the full-time hired labor was utilized by larger beef farms, which also hired large quantities of seasonal labor.

SHIFTS IN BEEF SUPPLY

The model reported here centered on 1969,

[4]While these results more substitutability between beef and feed grains in the South, they do not reflect adjustment possibilities in other regions or in the Nation as a whole. A similar study in the Midwest indicated a higher level of substitutability between beef and soybeans than between beef and feed grains [7].

and the input and product prices used were intended to be representative of prices during that period. However, input costs have increased considerably since 1969 and several adjustments also have occurred in product prices.

Because of the large number of input and cost calculations involved in such a model, updating each individual cost item would be expensive and time consuming. Thus, an updating procedure was chosen which permitted increases in cost variables in the objective function by stated percentages. Two levels of costs, 145 and 160 percent of base, were selected and programmed with beef price levels 3 and 4. Even though this procedure for updating the model is not precise, it is believed to provide insight into changes that have occurred in the recent past. Information on the direction and magnitude of the shifts in beef supply is provided by this application of the model.

At beef price level 3, about 18.6, 5.1 and 4.1 million brood cows were included in model solutions for base costs, 145 and 160 percent of base costs, respectively (Table 4). The represented decreases from base costs of about 73 and 78 percent in brood cow numbers for costs 145 and 160 percent of base, as well as substantial reductions in the cow herd from the 1969 base (7.1 million).

Table 4. REGIONAL SUMMARY OF 1969 ESTIMATES AND PROGRAMMED ACTIVITY LEVELS IN THE INTERMEDIATE TERM SOLUTIONS FOR TWO BEEF PRICE LEVELS AND THREE COST LEVELS

Item	Unit	1969 Estimate	Beef price level[a] 3: 100% of Base Cost	3: 145% of Base Cost	3: 160% of Base Cost	4: 100% of Base Cost	4: 145% of Base Cost	4: 160% of Base Cost
		1,000 units						
Breeding stock								
Brood cows	Head	7,102	18,601	5,061	4,132	25,708	11,357	9,132
Brood sows	do.	678	615	746	730	266	650	652
Livestock sold								
Cull cows	do.	b	2,431	651	545	3,364	1,468	1,188
Weaned calves	do.	b	11,060	3,464	2,821	16,454	7,973	6,353
Yearlings (500-800 lbs.)	do.	b	238	186	172	997	258	258
Slaughter Cattle (<800 lbs.)	do.	b	2,102	0	0	1,058	0	0
Cull sows	do.	b	244	294	303	108	268	270
Market hogs	do.	9,974	9,325	10,434	10,215	4,062	9,962	9,966
Feeder pigs	do	b	0	953	953	0	0	0
Crops produced								
Cotton	Acre	3,779	4,298	6,295	6,169	3,864	5,740	5,636
Soybeans:								
Single crop	do.	10,938	11,422	13,081	12,989	10,892	11,712	12,134
Double cropped	do.	305	839	4,390	3,969	711	4,593	3,969
Corn	do.	5,000	1,560	4,823	5,082	641	4,412	4,690
Wheat	do.	982	2,360	4,816	4,598	1,822	4,490	4,492
Oats & barley	do.	668	353	2,620	1,973	345	2,470	2,127
Grain sorghum	do.	237	69	177	177	0	177	177

[a]See Table 2 for beef price variables used at each price level.

[b]Data not available for making these estimates.

Decreases in beef production at higher cost levels were not as large at beef price level 4 as at level 3. The number of brood cows included in the model solutions for price level 4 was 25.7, 11.4 and 9.1 million at base costs, 145 percent of the base and 160 percent of base costs, respectively (Table 4). This represented a 56 percent decrease in brood cows, as costs were increased from base to 145 percent of base, and a 64 percent decrease between base costs and 160 percent of base. For price level 4, the cow herd was larger when costs were increased than it was in 1969.

The 11.4 million beef cows in the model solution, with beef prices at level 4 and costs at 145 percent of base, were about the same as the January 1, 1975, inventory of beef cows in the 11 states included in this study. This also was about the same size as the herd included in the model solution with beef prices at level 2 and costs at the 1969 level.

Sizable decreases in beef production occurred when input costs were increased. At these higher cost levels, all calves produced were sold as weaned calves or as yearlings. No cattle were fed to slaughter weights as they were at base costs (Table 4).

Quantities of beef produced in all situations programmed are shown in Table 5. These figures show that quantities of beef produced with beef prices at level 3, and costs at the higher levels, were substantially below those produced when costs were at base level. They also show that the amount of beef produced at this level of prices and costs was less than that produced in benchmark and beef price levels 1 and 2 solutions. Quantities of beef produced under higher costs with beef prices at level 4 were substantially below that produced with costs at the base level. However, beef production at these higher cost levels was above the production in the benchmark solution, and only slightly below that for beef price level one.

Table 5. PROGRAMMED QUANTITIES OF BEEF SOLD IN BENCHMARK AND INTERMEDIATE TERM SOLUTIONS BY CLASS OF ANIMAL, AND PRICE AND COST LEVELS

Item	Benchmark solution	Intermediate term solution at beef price:[a]							
		1	2	3			4		
		100% of Base Cost	100% of Base Cost	100% of Base Cost	145% of Base Cost	160% of Base Cost	100% of Base Cost	145% of Base Cost	160% of Base Cost
		1,000 cwt.							
Cull cows	8,974	10,124	15,375	24,351	6,698	5,466	34,249	14,729	11,933
Weaned calves	17,361	1,198	7,761	52,966	16,368	13,380	79,178	37,900	30,185
Yearlings	2,152	b	24	1,474	1,170	910	6,721	1,715	1,575
Slaughter	6,790	51,971	64,533	20,393	0	0	10,264	0	0
Total	35,277	63,293	87,693	99,184	24,236	19,756	130,412	54,344	43,693

[a]See Table 2 for beef price variables used at each price level.

[b]Less than 1,000.

When beef production decreased under conditions programmed for this application of the model, production of other products increased. Pork production increased above base cost levels for each beef price level considered. The numbers of hogs included in model solutions — with the higher cost levels and beef prices at level 3 — were above the 1969 base estimate. They were only slightly below the 1969 base estimate at beef price level 4 (Table 4).

Production of cash and feed grain crops also increased above base cost levels for each beef price. Acreages of cotton, soybeans and wheat were larger at higher cost levels than at the base, and above the 1969 base acreage. Feed grain acreage also was larger than at the base cost level. Corn acreage, however, exceeded the 1969 level in only one of the higher cost situations.

This analysis has significant implications for persons attempting to project changes in the supply of beef during periods such as have existed in recent years. It indicates that if the price of beef increases relative to other product and input prices, potential for expansion of beef production in the South in considerable. The analysis also indicates that, under rising costs and higher competing product prices, potential for beef production in the South is noticeably less.

IMPLICATIONS AND SUGGESTIONS FOR FURTHER STUDY

Several implications can be drawn from this study. Under conditions in 1969, the potential for expansion of beef production in the South was good. Prospects for expansion were even better when the relative price of beef was increased, and some expansion in beef production was indicated with lower relative beef prices. Thus, farmers in the South would likely increase production of beef if prices increased relative to other prices and costs.

Differences by size of farm in response to changes in beef prices provide another important implication. It was found that operators of larger farms made their greatest expansion in beef production at the lower beef price level. It also was found that these producers used higher percentages of their land at the lower beef price levels than did smaller beef producers. As beef prices were increased, production of other products on the larger beef farms had to be decreased to release land for beef production. There was relatively more idle land on smaller farms, which had higher percentages of the cows in the region at higher beef prices than at lower ones. This indicates that a shift from smaller to larger beef farms would increase the potential for expansion of beef production at lower beef prices.

Analysis of the influence of increased costs on beef production also supported the conslusion that beef production declined noticeably under increased costs. The magnitude of the decrease in beef production was such that with prices at levels near model level 3, and with costs near current levels, a sharp decline in southern beef production is indicated. If current cost and price conditions continue, some reduction in beef production in the South can be expected, then.

This study indicated an increase in the beef cow herd to about 11.6 million head with base beef prices and costs, and to about 11.4 million head with beef prices at level 4 and costs at 145 percent of the 1969 base. Although these programmed solutions indicated sizable increases in the beef cow herd, these increases already have been achieved. The USDA estimate of beef cows on farms January 1, 1975, in the 11 states in this study was 11.5 million head [17].

Expansion of the beef cow herd to just over 11 million head required several adjustments in the use of production resources. Expansion of the cow herd to levels indicated by programmed solutions for beef price levels 3 and 4, with base costs, would probably require greater adjustments than could reasonably be expected to occur. The inability of the model to limit such adjustments is one of its major limitations.

A static model such as this necessarily treats all prices and technical coefficients as permanent, and adjustments as instantaneous. In reality, beef adjustments occur more slowly than those for many other farm enterprises. Beef cow inventory changes lead and partially predetermine adjustments in beef supply by 2 to 4 years. The conditions of the well-known cattle cycle cannot be represented accurately in a static model. Neither can the seasonal flows of animal inventories be handled adequately in the present model. Further research is needed to formulate the beef and related enterprises into a model capable of producing a time path of adjustments.

Input data requirements of these and similar efforts are sizable. Technical and cost coefficients for enterprise alternatives in the model should ensure comparability accross study areas and representative farms. Likewise, resource endowments to representative farms should reflect the resource mix facing individual decision makers. Limitations of this study are signaled by discrepancies between benchmark results and base data. These limitations are regarded in part as indications of needed improvement in input data. Furthermore, these benchmark results serve as guides for further work toward improved input data.

This model and procedure enable one to examine a complex agricultural production area, such as the South, where a number of farm enterprises compete for resources. It is useful in evaluating structural changes and estimating aggregate price and quantity adjustments that might result from the adoption of new beef production systems. It also has the capability of providing answers about pork and crop production in the South. Although it is not likely that formal models will replace experience and judgement, working models for making timely analyses of effects market conditions and/or public policy on enterprise adjustments would be valuable complements to other decision processes.

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