OPTIMAL ORGANIZATION OF A STATEWIDE LIVESTOCK AUCTION MARKET SYSTEM: THE CASE OF TENNESSEE

Emily A. McClain and Dan L. McLemore

Abstract

Optimal sizes, number, and locations of Tennessee livestock auction markets were identified as those which minimize the combined costs of assembling and marketing livestock for the state using a separable programming model. The model includes transportation costs, economies of size in market operation, a proxy for reductions in buyers' operating costs attributable to increasing market volumes, and livestock production density, both in and around the state. The model is sufficiently comprehensive and descriptive to be of practical use by policy makers who influence industry change. Results indicate that a reduction in market numbers would lower combined costs.

Key words: livestock auction markets, assembly cost, transportation cost, economies of size, optimal size, location.

Livestock production is a pervasive and important activity in Tennessee. Livestock production takes place in each of the state's 95 counties and, in 1983, comprised 47.8 percent of total cash receipts for all agricultural marketings (Tennessee Department of Agriculture and USDA Statistical Reporting Service, 1984, p. 79). Auction markets are the primary outlets in Tennessee for cattle, calves, and culled breeding hogs. These factors make the efficient organization of the livestock auction market system important to the state.

The auction market industry can be characterized as relatively competitive in terms of homogeneity of services and large number of firms (54 in 1983) (U.S. Department of Agriculture, Packers and Stockyards Administration). Economic theory suggests that competitive pressures should motivate the industry toward efficient operation. The growth and decline in the number of livestock auction markets in Tennessee during the past 50 years is evidence of industry adjustment. However, the realities of asset fixity and spatial separation of markets (which reduces competitive pressure) may combine to slow the adjustment process.

A study by Hicks and Badenhop based on 1968 data labeled the state's livestock marketing system "high-cost" and "inefficient" as a result of too many auction markets. Hicks and Badenhop recommended a reduction of 75 percent in auction market numbers. Between 1968 and 1983 (the date on which this analysis is based) auction market numbers declined 27 percent, while increases in transportation costs, changes in market operation costs and in livestock production have likely altered the optimal number of markets (U.S. Department of Agriculture, 1983).

Since new auctions in the state must be chartered by a regulatory agency, some industry control exists with regard to the number and locations of auctions. This regulation presupposes an understanding of (1) the relationships between segments of the industry, (2) how these relationships combine into industry performance, and (3) how the industry *should* perform. Since 1970, there have been no attempts to empirically describe the relationships between segments of the livestock auction market industry and overall industry

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The authors wish to thank the anonymous *Journal* reviewers for their constructive suggestions for revision of the original manuscript. The authors retain responsibility for any remaining errors.

performance. The purpose of the model developed here is to provide an understanding of these relationships and their interactions. This knowledge can aid regulatory decision-making which could lead to a more efficient organization of the industry. If efficiency is improved, buyers should be able to obtain lower prices and/or producers should receive higher prices for livestock consistent with national market conditions.

It should be noted that the goal of efficient industry organization may differ from the goals of the individual participants in the industry (i.e., producers, auction market owners, and buyers). The definition of efficient organization varies depending upon the optimization criterion. This variation is illustrated by comparison of two different models of Tennessee's livestock auction marketing industry which are described in this paper. The basic model is one of an integrated system which defines efficient organization with respect to all participants—producers, market owners, and buyers. An alternate model follows the tradition of earlier studies of industry organization in that it ignores buyers' costs. The purpose of the alternate model is to generate a solution for comparison with the basic solution to show the effects of different optimization criteria in defining optimal organization and evaluating current performance. The present (1986) livestock marketing system and changes since the 1983 base year are discussed relative to the model results.

MODEL CONCEPTS

The optimal organization of Tennessee's livestock auction market system was defined as the number, sizes, and locations of markets that minimize the sum of total assembly and marketing costs for the state (Cobia and Babb; Hicks and Badenhop; Lindburg and Judge; Stollsteimer). Assembly costs for an auction market are the total transportation costs of moving all animals sold at that auction from their production sites to the market. Thus, each market has its own level of assembly costs related to both the total livestock marketed and the distance each animal is transported. Total assembly cost for the market system is the summation of assembly costs over all markets. Marketing costs refer to auction market operations costs and to buyers' operating costs which are hypothesized to decline with increasing market volumes.[1] Earlier research on optimal auction market industry organization has failed to investigate effects that market volume may have on buyers' operating costs. Auction market operation costs were estimated and reported by Spielman et al., and by McLemore, Whipple, and Spielman. This research confirmed the existence of economies of size in market operation.

Given economies of size in market operation and a fixed amount of livestock to be marketed, if auction numbers decline, average market volume will increase and total market operation costs will decline. Increases in average volume imply that the production areas supplying individual markets must expand, increasing transportation costs to assemble livestock at auctions. The trade-off between market operation and livestock assembly costs as market volume changes is unique for each potential market location because the density of livestock production varies over space. This fact makes the representation of the geographic concentration of livestock production a crucial model feature for accurate inclusion of assembly costs.

The operating costs of livestock buyers were hypothesized to be related to market volume (size) and therefore to impact the optimal sizes and number of auction markets. A negative relationship is expected to exist between size of the market and buyer operating cost per head purchased. The rationale for this hypothesis is that buyers attending larger volume markets are more likely to find the exact numbers and types of animals needed to fill their orders as more animals are offered for sale. When buyers attend a relatively small sale, they may risk either the ability to fill their orders or to fill them with the desired quality animals. If more than one small market must be visited to get the same quantity of livestock that could have been acquired at a single large market, additional costs accrue in the forms of time, mileage, food, lodging, and intermediate assembly to get a full, uniform quantity for shipment.

If the hypothesized relationship between buyer cost and market volume holds, one implication is that a given animal will bring a higher price at a large market when compared to a small market, *ceteris paribus*. This price difference reflects a difference in marginal cost (Clarkson and Miller, p. 240). Whether or not higher prices would actually be bid at

[1]Operating costs of buyers include all costs to buyers except the price paid for livestock.

larger auctions would depend upon competitive pressure among buyers. Therefore, a necessary assumption is that the efficiency gains of attending large sales attract more buyers to these larger markets, other things equal. If this assumption is true, then a positive correlation should be observable between price levels and sales volume levels among livestock markets. Information on Tennessee markets was used to support and quantify this relationship.

To be complete, a least-cost model of industry organization should also include distribution costs from auction market to the next level of use. However, these costs were not included for this study. This omission should not seriously limit the usefulness of the results for two reasons. A majority of animals sold through the state's auction markets are feeder cattle destined for grazing or feedlots in the Midwest or Great Plains. Because the general movement of these animals is westward and northwestward for relatively long distances, the location of assembly points within the state should have little effect on total transportation costs from auction to next use for these animals. The remainder of the animals marketed are bought by small local livestock producers or by buyers for local slaughter houses. The transportation costs to these destinations would probably not be greatly affected by market location. The increases in computational complexity and data collection costs that would be generated by their inclusion were felt to outweigh added analytical benefits.

MODEL COMPONENTS

The realism with which a spatial equilibrium model identifies an optimal solution is greatly affected by the level of input aggregation in the model. For this analysis, the greater the number of origins and alternative market sites from which the model has to choose, the more likely that choice is to be optimal. Since the county level is the lowest level of aggregation at which livestock inventory data are available, each county was considered to be a supply origin and potential market location for purposes of this study. This should provide a good representation of nonuniform livestock production density within the supply area considered.

The supply area and potential market locations encompassed Tennessee and all counties outside the state whose geographic centers lie within 50 air-miles of Tennessee's border. The inclusion of areas surrounding the state should reduce the bias against border market locations within Tennessee in the optimal solution. For simplicity, the geographic center of each county was assumed to be a distinct production point and potential auction site to serve as a reference for estimating transportation costs as a function of distance along shipment routes. The supply area for each potential auction site was limited to those counties whose geographic centers lie within 50 air-miles of that site. The 50 air-mile limit reduces the number of potential transportation routes without seriously limiting realistic routes. In almost all cases, the model's upper limit on auction market volume (90,000 animal marketing units) could be reached within this radius. Air-mile distances were chosen to represent road distances and were estimated using a formula for calculation of air-miles (Tramel and Seale).[2] A total of 3,524 potential assembly routes were identified for the 238 counties in the supply area (including 143 counties surrounding the state). These potential assembly routes include an arbitrary 10 mile route assigned from each county to itself to reflect intra-county shipment costs.

Farm-to-market transportation costs per mile per animal transportation unit (A.T.U.) were estimated to be $0.226.[3] This amount is multiplied by route distance to get transportation costs per A.T.U. from origin to potential market location. The transportation cost estimate was based on representative loads of livestock being hauled to Tennessee auctions. These typical loads were identified from the results of personal surveys of 275 individuals hauling livestock to eight auction markets in the state (McLemore, McClain, and Whipple). The surveys were taken during winter 1984 and were designed to collect data on types of equipment, distances traveled, and number, types, and sizes of livestock transported. An economic-engineering approach was used to develop transport cost budgets for 1983 based on these data (McClain).

[2]Air-mile distances have been shown to closely approximate actual highway mileages (Tramel and Seale, p. 176). However it is likely that distances may be underestimated for routes in the hilly eastern regions of the state, which might bias the model towards larger volumes in that area.

[3]An animal transportation unit (A.T.U.) is a measure used to allow aggregation across livestock types. In this study, an animal transportation unit is defined to be one cow, two calves, or three hogs.

Spielman et al. estimated a long-run average total cost (LRATC) function for auction market operation using ordinary least squares to regress average costs on market volumes. Annual (1978 and 1980) cross-sectional data were used in the regression with market volumes that ranged from 3,500 to 88,000 animal marketing units (A.M.U.'s) (Spielman et al., p. 14).[4] For the current study, Spielman's cost function was inflated to 1983 values using the USDA's Index of Prices Paid by Farmers (USDA, Agricultural Statistics Board). This function was multiplied by volume to obtain the following nonlinear total cost function (TC):

$$(1)\ TC = 27{,}555 + 4.872834V - \frac{33{,}686{,}926}{V},$$

where TC = annual total cost of auction market operation (dollars), and V = annual market volume in animal marketing units (A.M.U.). A graph of this function is shown in Figure 1.

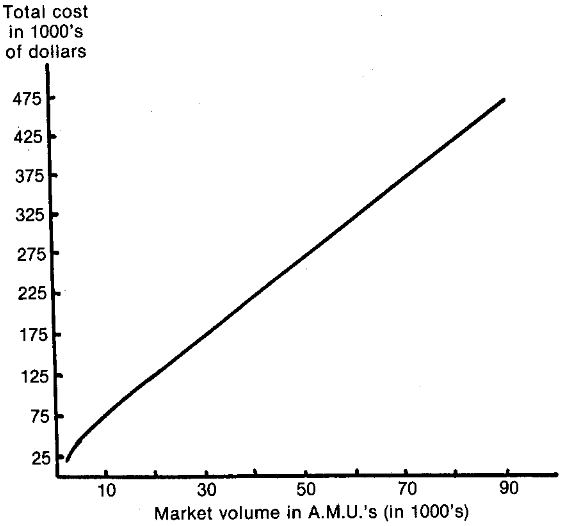


FIGURE 1. TOTAL COSTS OF AUCTION MARKET OPERATIONS.

Production densities were included in the model as expected annual marketings of livestock for each origin (county) in the supply area. This should give a reasonably accurate geographic representation of quantities of livestock to be marketed through auctions. County livestock inventory data from agricultural statistical bulletins served as a base for estimating expected marketings for Tennessee (Tennessee Department of Agriculture and USDA Statistical Reporting Service, 1984) and surrounding states. Expected annual marketings were estimated as a percentage of 1983 inventory numbers. This percentage was based on average percentages of total state inventory numbers marketed through auctions during the previous 11 years. Average marketings over several years should smooth the effects of cattle and hog cycles on expected marketings.

The hypothesized negative relationship between buyers' operating costs per head and market volume was added to the model as an adjustment to equation (1). This adjustment was made using, as a proxy for buyer operating cost, an estimated relationship between market volume and livestock price. If buyers realize cost savings by attending auctions with large volumes, then these cost savings should affect the price a buyer is willing to pay for livestock. Keen competition among buyers would force prices up to the limit of the cost savings. Thus, larger markets would exhibit higher prices. To quantify and test this relationship, regression analysis was applied to unpublished Tennessee Department of Agriculture data on livestock prices originating at 16 auction markets in Tennessee during 1982 and 1983.

The data consisted of daily prices for 400–500 pound medium number 1 feeder steers, utility slaughter cows, and sows under 500 pounds. The total numbers of observations for the three livestock types were 1,436, 1,443, and 351, respectively. Market volumes ranged from 7,493 to 63,732 animals, with a mean of approximately 30,600 head. To eliminate the effects of seasonal or cyclical price patterns, the dependent variable was expressed in the form of a price index consisting of daily market-specific price divided by the average weekly price over all markets. The dependent variable was regressed against annual volume at each of the markets. Separate regressions were used for each of the three animal types. Dummy variables were included to account for differences in livestock weighing practice and for the day of the week on which the sale was held, since these factors could also contribute to

[4]An animal marketing unit, A.M.U., is a standard livestock unit defined by the USDA to be one cow, one calf, or three hogs. This study used two different livestock equivalence units because the costs per animal vary among animal type and between transportation and marketing activities. While both the animal transportation unit (A.T.U.) and A. M.U. consider space requirements, the distinction between these equivalency measures is that the A.M.U. is based on handling requirements, while the A.T.U. gives more consideration to weight and space required in shipment.

price variation among markets.[5] The regression equations were expressed as:

$$(2)\ \frac{P_{ij}}{\sum_{i=1}^{n} P_{ij/n}} = a + b_1V_i + b_2D_1 + b_3D_2 + b_4D_3 + b_5D_4 + b_6W,$$

where:

P_{ij} = daily price at the ith market during the jth week;

n = the number of markets;

V_i = annual sales volume for the ith market;

D_1–D_4 = 0, 1, −1 dummy variables for day of the week on which the sale was held (Monday through Friday, with Friday omitted); and

W = 1, −1 dummy variable representing weighing practice (in-weight or out-weight, respectively).

Overall regression results were statistically significant at the 1 percent level. Table 1 shows the intercept and volume coefficients and their standard errors for each of the three regressions. Since the 1, −1 configuration of the dummy variables separates the effects of sale day and weighing practice from the intercept term, a, the coefficients on all classes of the dummy variables could be ignored when converting the estimated relationship (price-volume) to a buyers' cost savings-volume relationship. This conversion was accomplished as follows.

The separate regression results for each animal type can be represented as:

$$(3)\ \frac{MP}{AMP} = a + bV,$$

where:

MP = market price per hundredweight (cwt.);

AMP = average market price per cwt., calculated from the regression data set;

a = the estimated intercept coefficient;

b = the estimated volume coefficient; and

V = annual market volume.

Multiplying equation (3) by AMP expresses the relationship in terms of market price:

$$(4)\ MP = aAMP + bVAMP.$$

Subtracting AMP from both sides of equation (4) gives the difference between the market price and the average market price, ΔP:

$$(5)\ \Delta P = MP - AMP = AMP(a - 1 + bV).$$

Because a positive price differential is hypothesized to represent decreases in buyers' costs (ΔC) with volume increases, equation (5) is multiplied by −1 to convert ΔP per cwt. to ΔC per cwt.:

$$(6)\ \Delta C = -AMP(a - 1 + bV).$$

ΔC per cwt. was converted to ΔC per A.M.U. using average animal weights from the data set. Once in A.M.U.'s, the ΔC equations were weighted by the percentages of feeder cattle, slaughter cows, and sows in the state's annual marketings of livestock to combine the three equations into one. The percentages were based on average marketings for 1973 through 1983 (the same data used to estimate expected annual marketings). The resulting composite ΔC equation is:

$$(7)\ \Delta C = 7.35788 - 0.000254V.$$

This equation represents the average change in buyer costs per A.M.U. as volume (in A.M.U.'s) changes. Before this equation could be used to adjust equation (1), it was multiplied by V to get total change in buyers' costs (TBC):

$$(8)\ TBC = 7.35788V - 0.000254V^2.$$

Adding equations (8) and (1) yields the total net marketing cost function (TNC) used in the separable programming model:

$$(9)\ TNC = 27{,}555 + 12.2307V - \frac{33{,}686{,}926}{V} - 0.000254V^2.$$

TNC is highly nonlinear as shown in Figure 2, rising at a decreasing rate, leveling off, then declining and becoming negative at volumes larger than 51,000 A.M.U.'s. This negativity

[5]The dummy variable for weighing practice at the market was 1 if animals were weighed upon arrival and −1 if animals were weighed at the time of the sale. This reflects the buyer's discount for shrinkage that occurs between arrival and sale times. Sales are held on Monday through Friday. Dummy variables representing day of the week on which the sale was held were given a 0, 1, −1 configuration, with a 1 assigned to the day on which the sale occurred and 0 to the other days. Friday was omitted to avoid singularity. A −1 was assigned to all days if the sale occurred on the omitted day (Pindyck and Rubinfeld, pp. 135-137).

results when the reduction in buyers' operating cost is greater than marginal auction market operating cost at large volumes. Since the function is a combination of the *level* of market operation costs and the *change* in buyer costs, its absolute level has specific meaning only when compared to other levels generated by the same type of function. That is, the TNC function does not measure the level of total marketing cost.

TABLE 1. REGRESSION ESTIMATES FOR THE PRICE-MARKET VOLUME RELATIONSHIP, TENNESSEE, 1982-1983[a]

Animal Type	Intercept	Volume
Feeder Cattle	0.9751 (0.0035)	$7.1868(10)^{-7}$ $(1.0000(10)^{-7})$
Cows	0.9633 (0.0027)	$8.7901(10)^{-7}$ $(8.0000(10)^{-7})$
Sows	0.9957 (0.0006)	$15.5440(10)^{-7}$ $(4.0000(10)^{-7})$

[a]Standard errors are shown in parentheses below the estimated parameters.

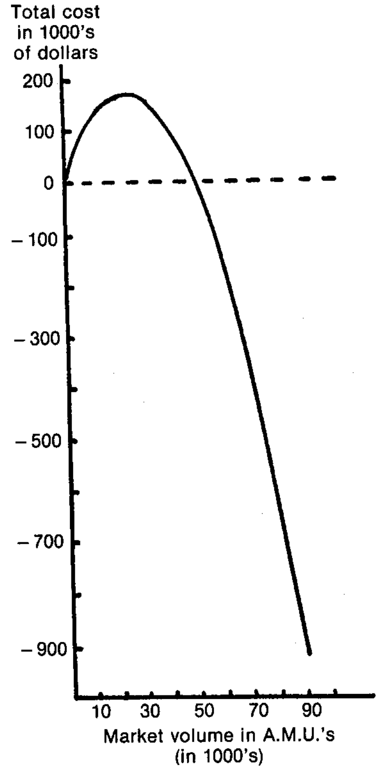


FIGURE 2. TOTAL NET COST FUNCTION.

SOLUTION METHOD

Because of the nonlinear TNC curve, separable programming was chosen as the optimization technique (Baritelle and Holland). The TNC function was approximated by seven piecewise linear segments as shown in Figure 3. Besides the ability to handle approximated nonlinear functions, separable programming has the capacity to solve large problems. One difficulty with this choice of technique is that, since the objective function is not strictly convex, there may be more than one local optimum solution, and there is no guarantee that the best one will be chosen (Baritelle and Holland; Miller). For some problems, the objective function at local optima may be quite close to the global optimum (Hadley, p. 110).

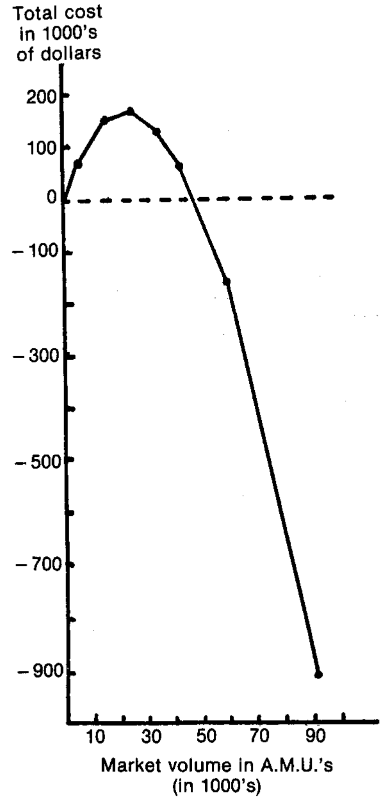


FIGURE 3. PIECEWISE LINEAR APPROXIMATION OF THE TOTAL NET COST FUNCTION.

The general mathematical optimization model was stated as:

$$(10)\ \text{Minimize: } TCC = \sum_{i=1}^{m}\sum_{j=1}^{m} t_{ij}a_{ij} + \sum_{i=1}^{m}\sum_{j=1}^{m} c_{nj}a_{ij},$$

(11) subject to: $\sum_{j=1}^{m} a_{ij} \leq a_i, \quad i = 1, 2, \ldots m,$

(12) $\sum_{i=1}^{m} \sum_{j=1}^{m} a_{ij} \geq A$, and

(13) $\sum_{i=1}^{m} a_i = A,$

where:

TCC = total annual combined costs of assembly and marketing;

t_{ij} = cost of moving one A.T.U. from origin i to destination j;

a_{ij} = number of A.T.U.'s moved from origin i to destination j or number of A.M.U.'s marketed at destination j;

c_{nj} = marketing cost per A.M.U. along segment n of the linearized cost function for market j;

A = the total quantity of livestock available in the supply area consisting of all origins;

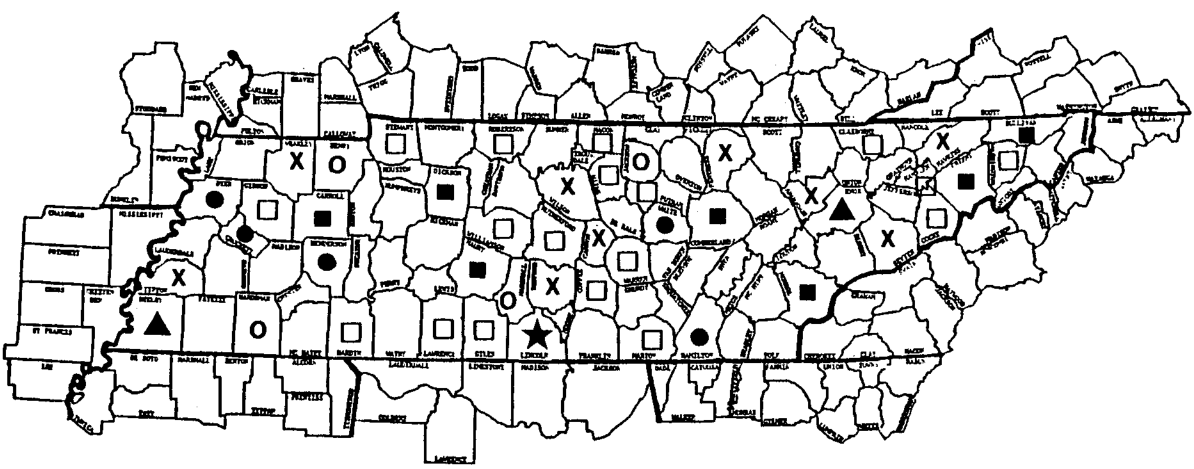
a_i = number of A.T.U.'s available at origin i;

m = the number of origins which equals the number of destinations (m = 238); and

n = the number of piecewise linear segments into which TNC was separated (n = 7).

The first part of the objective function is the summation of assembly costs at all markets. The second part is the summation of the net costs of marketing all livestock units. The constraint equations combine to ensure that all available supplies of livestock are shipped and marketed and also to eliminate the possibility of negative shipments.

The model used in this study was solved by constraining the initial feasible solution to 1983 actual locations and volumes of auction markets in Tennessee. This 1983 situation is represented on the map of the model's supply area in Figure 4. Parametric procedures were used to remove the current location/volume constraints after an initial solution was found. This freed the algorithm to optimize location and market volumes. The current industry constraints helped to ensure that a local optimum in the area near the existing market situation would be found, making the results more useful in targeting policy measures to improve the current auction market configuration.



Legend

Volume of Market (A.M.U.'s)

X 1 to 7000 — □ 10001 to 20000 — ■ 30001 to 50000 — ★ 80001 to 90000

0 7001 to 10000 — ● 20001 to 30000 — ▲ 50001 to 80000

FIGURE 4. MAP OF THE SUPPLY AREA WITH LOCATIONS AND VOLUME CATEGORIES OF LIVESTOCK AUCTION MARKETS IN TENNESSEE, 1983 (SOURCE: TENNESSEE DEPARTMENT OF AGRICULTURE, 1983).

ALTERNATE MODEL

Previous research has focused solely on the existence and utilization of size or scale economies in auction market operation and has ignored economies that may exist in livestock buying. To see how the optimal solution would change if buyers' cost savings were omitted, an alternate model was specified to minimize only combined transportation and market operations costs. The base for this model was equation (1) rather than (9). Thus, the alternate model defines optimal industry organization considering only producers and auction market owners in its objective function. Equation (1) was linearized into three segments for this model. This model was solved, as was the basic model, by first constraining the initial feasible solution to current market locations, and then freeing the model to optimize from the constrained solution.

SENSITIVITY ANALYSIS

Sensitivity analysis was performed on both the basic and alternate models by arbitrarily and systematically varying livestock numbers, transportation costs, and marketing costs. The results of the variations were used as a validity test to see whether the models responded in a logical fashion to altered conditions. The variations are also useful to indicate how the optimal organization would change if the specified changes in conditions did actually occur.

RESULTS, CONCLUSIONS, AND IMPLICATIONS

Two different models of Tennessee's livestock auction market industry are described in this paper—a basic model and an alternate model. The basic model is one which simultaneously determines the optimal sizes, number, and locations of auction markets of an integrated system by minimizing the combined costs of farm-to-market transportation, auction market operation, and buyers' operation. That is, optimal industry organization is defined considering the interests of producers, auction market owners, and buyers. The alternate model follows the tradition of previous studies and ignores buyers' costs. The purpose of the alternate model is for comparison with the basic model to show the effects of a different optimization criterion in defining efficient industry organization. Since the basic model is more comprehensive, results from its solution are more appropriate than those from the alternate model for use in policy direction.

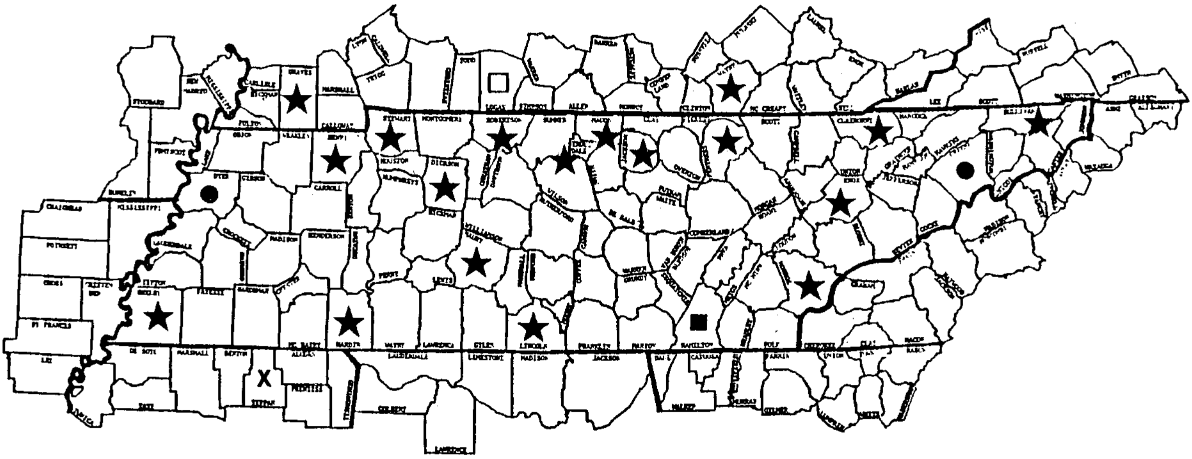
The basic model identified a system of 19 markets with an average annual volume of 80,562 A.M.U.'s as optimal. This represents a substantial change from the 1983 system of 54 markets averaging 21,959 A.M.U.'s per year (Tennessee Department of Agriculture, 1983). The optimal solution is depicted in Figure 5 for the state and detailed in Table 2. The drastic reduction in market number should lower total costs of assembly and marketing and increase industry efficiency. This result implies that the licensing of new auctions in the state should be discouraged.

The validity of the basic model is supported by the theoretically predictable changes in the optimal solution which resulted from parametric changes in livestock numbers, transportation costs, and marketing costs. For example, when livestock numbers decreased, the optimal number of markets decreased. Increases in transport costs up to 25 percent had no effect on the number of Tennessee auctions although out-of-state auction numbers increased slightly. Changes in the optimal solution for the state that resulted from the sensitivity analysis are given in Table 3.

The solution to the alternate model describes the optimal auction market system for Tennessee as one consisting of 47 markets with average annual volume of 26,859 A.M.U.'s. Results are presented in Table 2. This solution differs less from the actual 1983 market system than the basic model's solution. However, even though buyers' costs are ignored, the optimal solution still indicates that a reduction in market numbers could lead to a more efficient system.

The trade-off between market operation cost and assembly cost is more delicate in the alternate model because buyers' costs are omitted. Thus, the solution is more sensitive to variations in model components than the basic model's solution. The results of the sensitivity analysis (Table 3) clearly validate the alternate model in their conformity to theoretical expectations regarding changes that should be observed in the optimal solution in response to variations in model components. Ten percent changes in livestock numbers or costs elicit relatively small responses in the model solution while 25 percent changes cause somewhat larger movements. Overall, the optimal solution seems relatively stable.

For comparison purposes, data on 1986 auction numbers and volumes were obtained. Auction market numbers declined slightly to 52, but average volume rose to 26,663



Legend

Volume of Market (A.M.U.'s)

X 1 to 7000
0 7001 to 10000
□ 10001 to 20000
● 20001 to 30000
■ 30001 to 50000
▲ 50001 to 80000
★ 80001 to 90000

FIGURE 5. OPTIMUM LIVESTOCK AUCTION MARKET LOCATIONS AND SIZE CATEGORIES FOR THE BASIC MODEL.

TABLE 2. OPTIMAL SOLUTIONS TO THE BASIC AND ALTERNATE MODELS FOR TENNESSEE

Location (County)	Annual Volume (A.M.U.'s) Basic Model	Annual Volume (A.M.U.'s) Alternate Model
Anderson	—	18,221
Carroll	—	15,937
Claiborne	90,000	21,000
Cocke	—	16,773
Coffee	—	42,552
Crockett	—	37,092
Cumberland	—	29,802
Dickson	90,000	51,810
Dyer	23,584	11,921
Fentress	90,000	36,412
Gibson	—	20,513
Giles	—	31,719
Greene	29,055	40,436
Hamblen	—	44,090
Hamilton	38,034	29,029
Hardeman	—	36,950
Hardin	90,000	8,977
Hawkins	—	35,900
Henderson	—	25,730
Henry	90,000	22,751
Jackson	90,000	13,482
Johnson	—	6,069
Knox	90,000	29,351
Lawrence	—	32,077
Lincoln	90,000	25,010
Macon	90,000	11,757
Marion	—	7,085
Marshall	—	49,093
Maury	90,000	50,027
Monroe	90,000	68,010
Obion	—	21,606
Perry	—	4,781
Putnam	—	15,618
Rhea	—	5,630
Robertson	90,000	26,074
Rutherford	—	32,421
Shelby	90,000	14,619
Smith	—	16,013
Stewart	90,000	22,310
Sullivan	90,000	21,014
Trousdale	90,000	35,126
Warren	—	46,662
Washington	—	26,378
Weakley	—	19,952
White	—	26,249
Williamson	—	40,757
Wilson	—	27,566

A.M.U.'s during 1986 (Tennessee Department of Agriculture, 1986). The increase in market volume can be partially attributed to the net liquidation of livestock inventory in the state during 1986 (Tennessee Department of Agriculture and USDA Statistical Reporting Service, 1986). However, these figures suggest that the industry is moving in the direction indicated by the optimal solutions in this study.

Results of this research imply that change in the operating costs of livestock buyers as market volumes changes is an important consideration in industry efficiency. This importance is emphasized by the difference in optimal market numbers between the basic and alternate models in this study. Future research concerning optimal size and number of auction markets should account for buyer operating costs and, perhaps, develop a more direct method for measuring them.

The divergence between the optimal number of markets under the two models leads to questions about whether buyer costs are having significant impact on organization of the industry. The alternate model (ignoring buyer costs) seems to more closely mimic actual market numbers. If the industry in Tennessee were better integrated perhaps these costs would be reflected and there would be fewer auctions in the system.

The livestock industry is classically known for harboring participants with widely diverging perspectives (Purcell). These conflicting perspectives often contribute to decreasing the efficiency of the total marketing system. This study demonstrates how results pertaining to the organization of an "efficient" marketing system can be radically different due to the deletion of one of the main participant's perspectives.

TABLE 3. CHANGES IN THE BASIC AND ALTERNATE MODELS' SOLUTIONS IN RESPONSE TO VARIATIONS IN MODEL COMPONENTS

Variation in the Model	Changes in the Number of Tennessee Markets	
	Basic Model	Alternate Model
Livestock Numbers Decreased 10%	−4	−2
Livestock Numbers Decreased 25%	−5	−3
Livestock Numbers Increased 10%	0[a]	0[a]
Livestock Numbers Increased 25%	4	2
Transportation Cost Increased 10%	0[a]	1
Transportation Cost Increased 25%	0[a]	9
Marketing Cost Increased 10%	−1	0[a]
Marketing Cost Increased 25%	0[a]	−4

[a]Changes in market number for the total supply area were consistent with prior expectations, though changes for the state alone might not have exhibited this same consistency.

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