INTERREGIONAL AND INTERSEASONAL COMPETITION IN THE U.S. BEEF INDUSTRY: AN APPLICATION OF REACTIVE PROGRAMMING*

Dilip Pendse and James Youde

Interregional and interseasonal competition in the U.S. beef industry have been studied extensively during the past decade. Linear programming, quadratic programming, simulation, and various other econometric models have formed the analytical frameworks in these studies.[1]

Reactive programming was first introduced as a useful tool in analyzing interregional competition problems by Tramel and Seale in 1959 [12]. Since that time, it has been utilized on a limited basis in spatial analyses in general, and the beef sector in particular.[2] Goodwin used reactive programming in analyzing feeder cattle distribution patterns in the Southwest [6]. In 1972, King and Ho reported a revised reactive programming algorithm and three illustrations of its applicability [8].

This article considers interregional and interseasonal competition in the fed beef and nonfed beef markets, utilizing a reactive programming framework. The article is divided into three sections. the first section briefly states the assumptions and constraints and describes a general equilibrium solution of interregional, interseasonal, and interproduct competition in the U.S. beef industry. The equilibrium solution is, of course, within the bounds of reactive programming formulation. The second section deals with input estimation. The last section presents and discusses empirical findings.

ANALYTICAL FRAMEWORK

The following assumptions, constraints, and general model provide the framework of the analysis.

Assumptions

1. A highly competitive market exists in the beef industry.
2. Total supplies of different categories of beef cattle that can be converted into different beef products are known and fixed. Also, the unit costs of conversion are known.
3. Demand and supply regions, represented by single geographical points are separated by unit costs of transportation. The unit transportation costs are known and remain unchanged regardless of seasons.
4. A specific time period is divisible into any number of seasons.
5. Demand for different beef products exists at the feed lot and packer levels.
6. In aggregate, total supplies of and total demands for each of the beef products are equal.

Constraints

1. When beef cattle are marketed from one

Dilip Pendse is research associate of agricultural economics at Oregon State University, and James Youde is professor of agricultural economics at the University of California, Davis.

*Oregon State Experiment Station Technical Paper No. 3649.

[1] For examples of these studies see [2, 7, 9].

[2] For a comprehensive bibliography on the technique and its application, see [8, pp. 22-23].

region to another, the quantity (number) shipped must be greater than or equal to zero.

2. "Net price" must be nonnegative and equal among the markets where beef cattle are shipped. At the same time, these net prices must not be less than those corresponding to markets where beef cattle are not shipped. Net price is the difference between the market price and the sum of transportation costs and costs of converting beef cattle into different products.
3. All available supplies are allocated if net prices are nonnegative, but not necessarily so if they are zero.

Given the above assumptions and constraints, an equilibrium solution is reached when net prices are equal among all markets to which beef cattle are marketed and no incentive is left for further trade. The equilibrium pattern thus established implies that although total net returns for the entire system are maximum, regional differences in net returns may exist.

INPUT ESTIMATES

Twenty production (supply) and slaughter (demand) regions, and two seasons of 1968 are considered for two products: fed and nonfed beef.[3] Inputs for both fed and nonfed beef include: (1) predetermined regional and seasonal supplies; (2) regional and seasonal demand functions; and (3) transfer costs.[4]

Supply Estimates

Beef cattle supply was divided into fed and nonfed beef for several reasons. First, prices of fed and nonfed beef cattle are significantly different. Second, seasonal production and marketing patterns are dissimilar for fed and nonfed beef. Finally, fed and nonfed beef provide different types and quantities of products for final consumption.

The basic supply of beef cattle for slaughter during the year 1968 was assumed to have come from cattle and calves on hand at the beginning of the year, and from that year's net calf crop.[5] The total number of fed cattle supplied for slaughter by the 48 states was estimated to be 23,407,000 head.[6] Regional and seasonal supply estimates were based on the reported quarterly data on cattle marketings, except for regions 19 and 20.[7] Nonfed cattle supplied for slaughter were estimated to be 11,614,400 head.

The estimated nonfed cattle supply was roughly 33 percent of the total commercial cattle slaughter.[8] However, the percentages were different in each season. Thus, the estimated total nonfed cattle supplies were approximately 30.53 and 35.67 percent of the total commercial cattle slaughter in seasons I and II, respectively. Regional nonfed cattle estimates were estimated on the assumption that the above percentages held true for all regions, for the respective season.

The supply estimates for fed and nonfed beef cattle were converted to liveweight figures.[9] The average liveweight of nonfed beef cattle supplied for slaughter was estimated to be 874 pounds and was obtained as follows:

$$\text{ALWNFBCS} = \frac{\text{TDWNFBCS}^{10}}{\text{SNFC}} \div \text{dressing percentage}^{11}$$

[3] See the appendix for demand and supply points considered for each region. The months included in each season are: January-June for season I, and July-December for season II. Fed beef includes fattened cattle (mostly steers and heifers) that are available for immediate slaughter. Nonfed beef includes cows culled from beef and dairy herds, bulls and stags, and commercial steers and heifers. These cattle are assumed available for immediate slaughter without being fattened in a beef feedlot.

[4] Transfer costs include truck transportation costs plus cost of converting beef cattle into fed and nonfed beef products.

[5] Cattle imports are likely to enhance the actual and the potential supply of beef cattle for some regions. However, due to negligible volume of total imports of live cattle weighing 700 pounds or above, no attempt was made to separate imported cattle from the domestic supply.

[6] This is approximately 68 percent of the total commercial cattle slaughtered in 1968 [13 and 14].

[7] In the case of regions 19 and 20, the estimated number of fed beef cattle marketed from 16 nonreporting states was obtained on the basis of fed cattle marketings from five reporting states in the two regions.

[8] Since in aggregate the reported number of commercial cattle slaughtered in the U. S. equaled the sum of fed and nonfed beef cattle, total nonfed cattle estimates were obtained simply by deducting fed beef estimates from the reported commercial cattle slaughter estimates.

[9] This conversion was necessary for two reasons: first, to facilitate the incorporation of transportation rates and intermediate costs that are generally expressed in relation to carcass weight and/or liveweight; second, to facilitate the formation and comparison of different demand functions.

[10] The TDWNFBCS was estimated to be 5,586,303,400 pounds.

[11] The dressing percentage of calves and vealers slaughtered under Federal inspection in 1968 was 58.0 percent [13, Table 148]. Generally cows, bulls, and stags yield less carcass weight relative to liveweight hence, dressing percentage of nonfed beef cattle was assumed to be 55.0 percent.

where:

ALWNFBCS = Average liveweight of nonfed beef cattle supplied for slaughter;

TDWNFBCS = Total dressed weight of nonfed beef cattle supplied for slaughter ; and

SNFBC = Estimated number of nonfed beef cattle supplied for slaughter.

The total liveweight of nonfed cattle supplied for slaughter was estimated to be 10,157,278,000 pounds. Regional and seasonal nonfed beef estimates were obtained simply by multiplying the estimated number of nonfed cattle by the average liveweight.

The total liveweight of nonfed cattle constituted 28.60 percent of the total commercial cattle slaughter in 1968, implying that the remaining 71.40 percent constituted fed beef supply. The total liveweight of fed beef supplied was thus estimated to be 25,357,718,000 pounds. The average liveweight of fed beef cattle was estimated to be 1,083 pounds, and was assumed to be constant for all regions during both seasons.

Demand Relationships

Relationships between the quantity demanded and the price of both fed and nonfed beef were estimated using the log linear form:

$$(1)\quad \ln Q_F = \ln A_F - b_F \ln P_F$$

$$(2)\quad \ln Q_{NF} = \ln A_{NF} - b_{NF} \ln P_{NF}$$

where:

Q_F = estimated quantity of fed beef demanded,

Q_{NF} = estimated quantity of nonfed beef demanded,

A_F = a constant term pertinent to equation (1),

A_{NF} = a constant term pertinent to equation (2),

b_F = price elasticity of demand with respect to fed beef at farm level,

b_{NF} = price elasticity of demand with respect to nonfed beef at farm level,

P_F = price of fed beef, and

P_{NF} = price of nonfed beef.

For computational purposes and practi al considerations, equations (1) and (2) were expressed in terms of P = f(Q), and the following procedure was used in quantitying demand relations for fed and nonfed beef:

1. *Elasticity coefficients:* Langemeier and Thompson's farm-level demand elasticity estimates of –0.893 and –1.011 for b_F and b_{NF}, respectively, are used in the analysis [9]. These price elasticity estimates are assumed to hold for all regions and both seasons, and for the entire range of each demand relationship.[12] Langemeier and Thompson's coefficients were considered reliable, relatively recent, and within the range of elasticity estimates derived in other studies.
2. *Prices:* Choice steer (800 to 1,100 pounds) prices and commercial cow prices represented P_F and P_{NF}, respectively, for each region and season. U.S.D.A.-reported prices for a major livestock market in each region were utilized.
3. *Quantities:* Quantities of fed and nonfed beef demanded for slaughter were estimated at the farm level. Approximately 72 percent of the total commercial cattle slaughtered in each region during each season represented the demand for fed beef. Regional and seasonal nonfed beef cattle demand estimates were obtained simply by deducting the fed beef demand estimates from the reported commercial cattle slaughter estimates.

Transfer Costs

Beef cattle are transported both by truck and by rail. However, in recent years, the importance of railroads in transporting cattle has dwindled significantly [4]. Flexibility in schedules and hauling rates, better pickup and delivery service, improved highways, and improved equipment have been major causal factors leading to increased truck shipments of cattle [3]. Hence, truck transport rates bear a significant influence on interregional and intraregional beef cattle movements.

In the analysis reported in the next section, truck costs were obtained from the following equation:

$$Y = 0.1961 + 0.0019\ X_{ij} + 0.00455\ \sqrt{X_{ij}},$$

where:

Y = truck transportation cost in dollars per hundredweight, and

[12] In reality these estimates may differ among regions and between seasons, but the variation is not likely to be substantial. Also, it is unlikely that spatial movements will be affected by these estimates alone since interregional shipments are more seriously affected by demand, supply, and transfer costs.

X_{ij} = mileage between shipping point i to receiving point j.

This relationship, estimated from a sample of truck waybill data, has been utilized in recent studies by Dietrich [5] and Bhagia [1]. While transport-cost equations that include weight per shipment, time required for shipment, and average speed of haul may have more intuitive appeal, analyses incorporating these variables did not yield significantly different directions or volumes of interregional beef trade.[13]

Intermediate Costs

Those expenditures incurred in converting the basic supply of cattle into fed or nonfed qualities and weights of live beef are termed "intermediate costs." They include both the feed costs and nonfeed costs involved in this process. Feed costs vary between and within regions depending on rations fed, costs of ration components (grain, supplements, and roughage), length of feeding period, and feed conversion efficiency of cattle. Nonfeed costs – including labor, taxes, interest on borrowed capital, utilities, veterinary services, death loss, and depreciation – also vary among regions and in relation to size of livestock enterprise.

Regional costs of producing fed beef estimated by Bhagia in a recently-completed study were utilized as a reference point in this analysis [1]. Appropriate adjustments were made to include 20 geographical regions and a gain of 383 pounds per head in the feedlot. The costs of feeder cattle were also included to derive regional estimates of fed beef production costs.

Nonfed beef is produced from heterogeneous types of cattle, including calves, cull cows, bulls, and grass-fed heifers and steers. Some of these classes are by-products of the producer's beef enterprise, making it difficult to allocate production costs to them. To circumvent this problem, regional prices of commercial, utility, and canner and cutter cows were used as proxies for the intermediate costs of producing nonfed (live) beef.

These intermediate costs of producing fed and nonfed beef were combined with truck transport costs to estimate total costs of one region supplying each type of beef to another region. Thus, supply costs from a given region increase (by the additional transport costs) as the distance to a recipient region increases.

EMPIRICAL RESULTS

The estimates of regional and seasonal demands, supplies, and transfer costs discussed above were analyzed using the reactive programming algorithm. The iterative process of the model allowed fed and nonfed beef processors (demanders) to "react" to prices resulting from shipments made (received) by competitors in different regions. The equilibrium solution thus obtained is termed "optimum" in the discussion to follow. Empirical results without considering the effect of backhauls are discussed first, followed by a discussion of the impact of backhauls on the optimum distribution pattern.[14] In these discussions shipments (movements) of cattle refer to the optimum results and not to actual interregional shipments that occurred in 1968.

Fed Beef

Figure 1 portrays the optimum movements of fed cattle for slaughter among 20 production and demand regions during two seasons in 1968. Of the total estimated fed beef supply of 23.4 million head, about 3 million head (13 percent of the total) were shipped between regions, with the remainder slaughtered in the region where they were produced. Eight regions outshipped fed cattle to other regions during both seasons; five regions shipped fed cattle either in season I or in season II. Four regions made 73 percent of the net shipments; by descending numbers they were, Nebraska, Texas, Arizona, and Illinois. Major recipients of fed beef shipments were the Northeast, Southeast, Kentucky-Tennessee, and Michigan-Indiana-Ohio regions. The largest percentage of fed beef production shipped out for slaughter was Arizona's 59 percent. Texas has the unique situation of inshipping fed cattle from Arizona and Oklahoma and outshipping fed cattle to the Southeast region.[15] Average distance of interregional fed beef shipments was 824 miles, with the longest optimum shipments from the Dakota region to the Northeast region.

---

[13] For detailed comparisons of analytical results with alternative transfer cost relations, see [11, pp. 143-169].

[14] For discussion purposes, the optimum shipments obtained in liveweights are converted into number of head using estimated average liveweights for fed and nonfed beef.

[15] This should not be a surprise for two reasons: (1) although one of the conditions for optimum distribution implies no shipments from demand region to supply region(s), positive shipments (i.e., shipments among supply regions) are not ruled out; and (2) the regional supply estimates considered in the analysis are not "net" figures. In other words, regions were not predefined in terms of net surplus or net deficit.

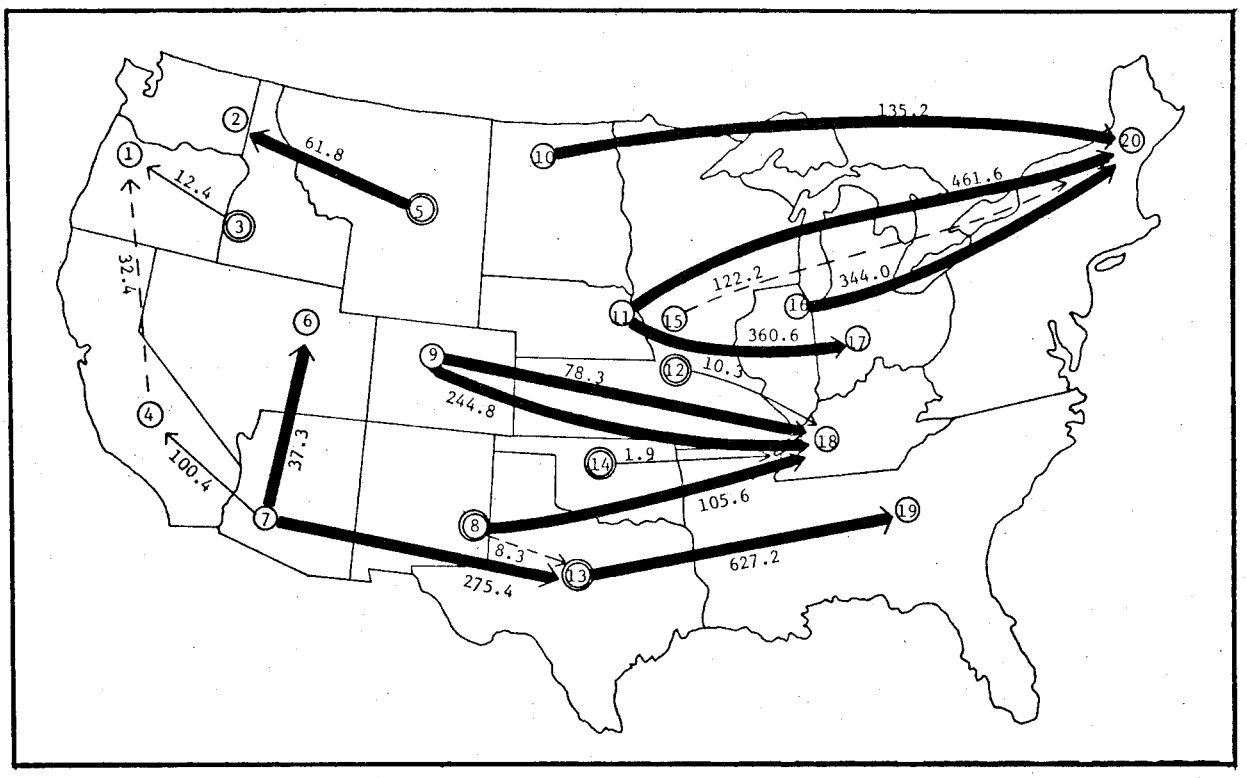
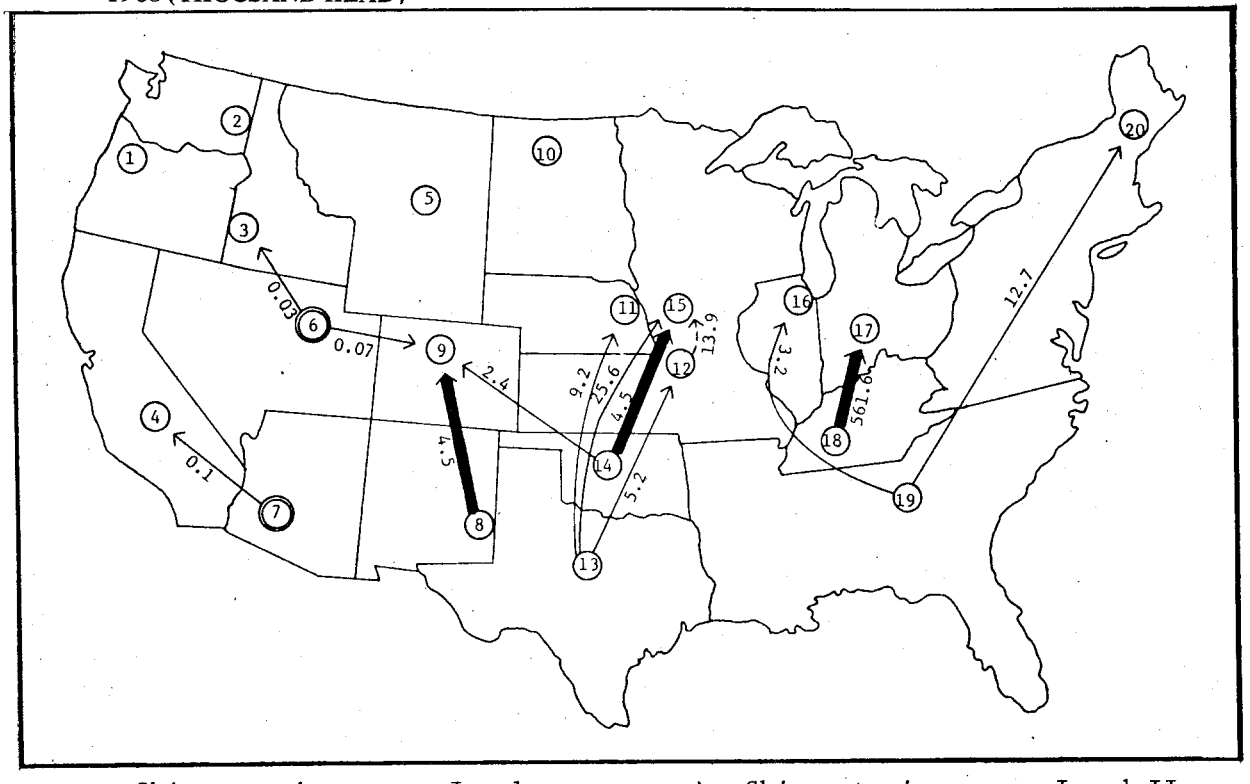


Figure 1. OPTIMUM MOVEMENT PATTERN OF FED BEEF (NO BACKHAUL): 20 REGIONS, 2 SEASONS, 1968 (THOUSAND HEAD)



⟶ Shipments in season I only

⟶ Shipments in season I and II

- - - → Shipments in season II only

◎ Carry over from season I to season II

Figure 2. OPTIMUM MOVEMENT PATTERN OF NONFED BEEF (NO BACKHAUL): 20 REGIONS, 2 SEASONS, 1968 (THOUSAND HEAD)

Nonfed Beef

The 1968 optimal shipments of nonfed beef cattle between regions are illustrated in Figure 2. Of the 11.6 million head of nonfed cattle slaughtered that year, about 600,000 head (5 percent) were shipped to other regions for slaughter, with the rest being slaughtered in the region where they were produced. Five of the 20 regions shipped nonfed cattle to other regions in season I, and only three regions (Oklahoma, New Mexico, Kentucky-Tennessee) shipped out nonfed beef cattle during both seasons. This limited interregional trade in nonfed beef cattle indicates a tendency for regions to meet their own nonfed beef demands from their own production, rather than shipping large volumes of cattle and calves interregionally. An exception is the Kentucky-Tennessee region, which shipped two-thirds of its nonfed beef supply to the Michigan-Indiana-Ohio area. Texas shipped nonfed cattle to three regions during season I. Very little nonfed beef was shipped into or among the western regions under the model's optimum solution. The lower market value of nonfed beef (relative to fed beef) probably accounts for the limited shipments of nonfed beef cattle for slaughter.

Impact of Backhauls on Interregional Shipments

A factor not considered in most interregional competition studies is the impact of transportation service, demands, and supplies on commodity movements. The probability of locating a product to "haulback" toward their home base is one important variable considered by truckers in establishing livestock trucking rates. If a backhaul is assured from one area, truckers are willing to charge less to haul livestock to that area than they would require in trucking to a region with limited backhaul possibilities. One study found that "truck carriers interviewed indicated that backhauls were available for about one-third of the cases" [6, p. 17].

To assess the impact of backhaul probabilities on interregional beef cattle movements, it is assumed that regions shipping fed or nonfed beef cattle to Washington, Oregon, or California would be able to locate feeder cattle, sheep and lambs, or other products to haul back to their originating region. Thus, truck transport rates from other regions to the three West Coast regions were reduced by 50 percent.[16] The following changes occurred in optimum interregional flows.

Fed Beef. Total shipments of fed beef cattle into and between the three West Coast states increased by 18 percent to 245,000 head (Figure 3). All West Coast inshipments originated in Arizona. Montana-Wyoming and Idaho no longer shipped to Washington and Oregon, respectively. The directions of other optimum interregional shipments were not significantly altered, though the volumes did change in most instances. The same number of fed cattle moved interregionally, however, Arizona became the largest outshipping region under the backhaul conditions imposed. Average distances of fed beef movements increased to 900 miles with certain backhauls in effect.

Nonfed Beef. Total nonfed beef cattle shipments increased slightly when West Coast backhauls were included (Figure 4). Nonfed cattle moved from Utah-Nevada to Oregon and from California to New Mexico (a surprising result). Seven regions shipped nonfed beef to ten other regions, with an average shipping distance of 594 miles, an increase of 109 miles over the average distance when backhauls were not included.

CONCLUDING COMMENTS

Many additional empirical results of the analysis could be discussed. One could also compare actual and optimum shipment patterns of fed and nonfed beef. Such a comparison would undoubtedly help in evaluating the reliability and adequacy of the reactive programming framework.[17] However, the major purpose of this article is to illustrate the use of reactive programming in analyzing industries with complex space, time, and form interrelations. The incorporation of seasonal demand and supply functions for both fed and nonfed beef, and the consideration of backhaul impacts on interregional shipments provide a significant improvement over spatial studies of the beef industry conducted by

[16] A 50 percent reduction implies a 100 percent probability of backhaul, and no changes in costs or returns for the trucker with the backhaul. While this is the extreme situation that could be expected, it illustrates the maximum effect of backhauls on interregional beef cattle movements.

[17] The lack of data on actual shipments of beef cattle for slaughter, within and among different states of the Union, precluded us from such a comparison. In any case, some discrepancy is bound to exist between the actual and optimum shipment patterns. See the dissertation on which this article is partially based for possible reasons for discrepancies [11].

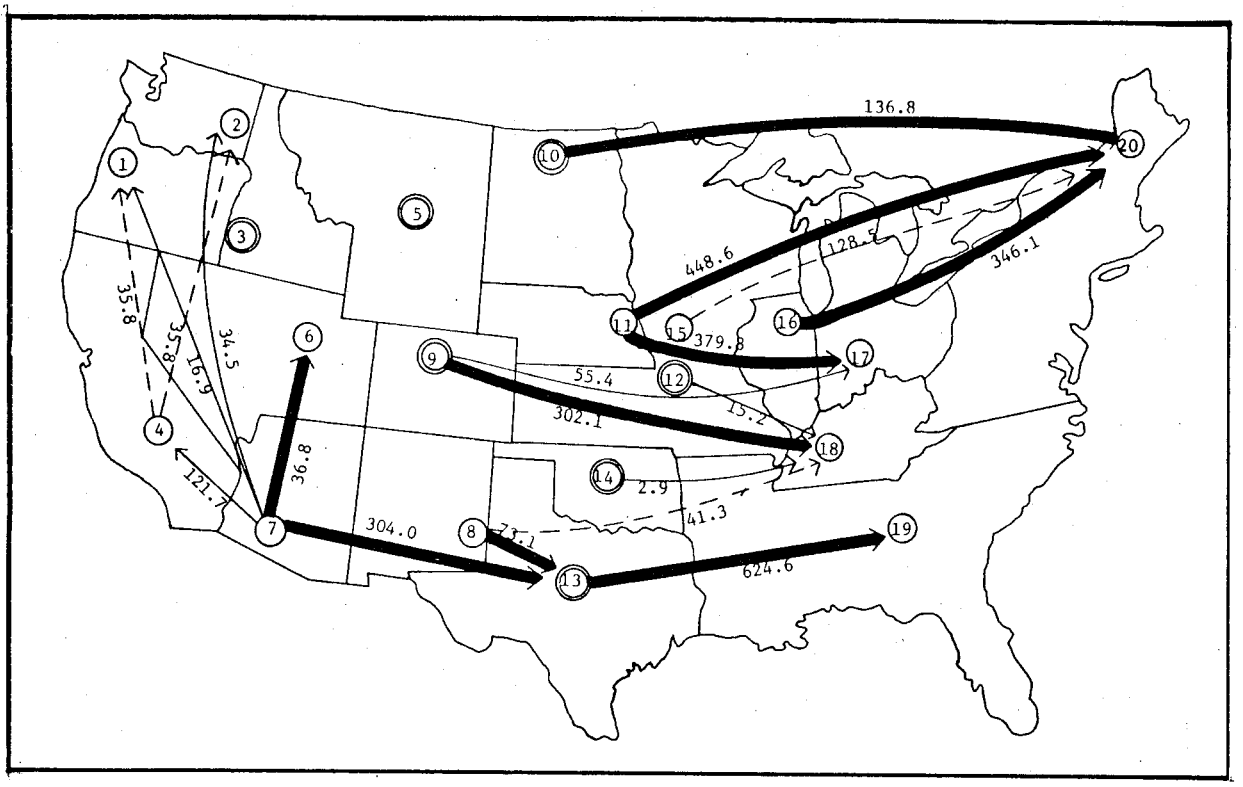
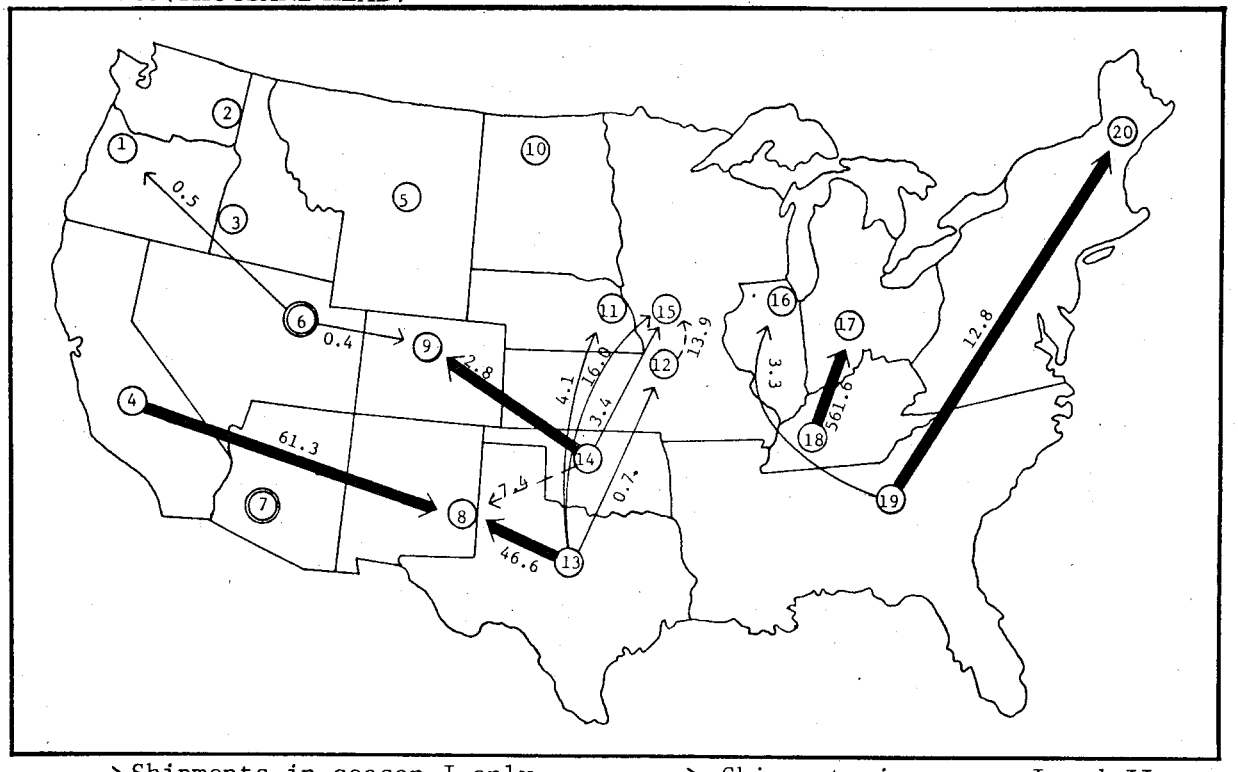


Figure 3. OPTIMUM MOVEMENT PATTERN OF FED BEEF (WITH BACKHAUL): 20 REGIONS, 2 SEASONS, 1968 (THOUSAND HEAD)



→ Shipments in season I only

⟶ Shipments in season I and II

- - - → Shipments in season II only

◎ Carry over from season I to season II

Figure 4. OPTIMUM MOVEMENT PATTERN OF NONFED BEEF (WITH BACKHAUL): 20 REGIONS, 2 SEASONS, 1968 (THOUSAND HEAD)

APPENDIX

Table 1. REGIONAL DEMARCATION, AND REPRESENTATIVE DEMAND AND SUPPLY POINTS, U. S., 1968

Region Number	State(s)	Representative Demand or Supply Point
1	Oregon	Portland
2	Washington	Spokane
3	Idaho	Boise
4	California	Fresno
5	Montana, Wyoming	Billings
6	Utah, Nevada	Salt Lake City
7	Arizona	Phoenix
8	New Mexico	Clovis
9	Colorado	Denver
10	North Dakota, South Dakota	Bismark
11	Nebraska	Omaha
12	Kansas, Missouri	Kansas City, Mo.
13	Texas	Fort Worth
14	Oklahoma	Oklahoma City
15	Minnesota, Iowa, Wisconsin	Des Moines
16	Illinois	Chicago
17	Michigan, Indiana, Ohio	Indianapolis
18	Kentucky, Tennessee	Nashville
19	Arkansas, Louisiana Mississippi, Alabama, Georgia Florida, South Carolina, North Carolina	Atlanta
20	Virginia, West Virginia Pennsylvania, Delaware, New Jersey, New York, Vermont, New Hampshire, Rhode Island, Connecticut, Massachusetts, Maryland, Maine	Albany

others.[18] Some limitations of this analysis cannot be ignored. The reasonableness of the empirical results is limited by the assumptions of the analytical model and the accuracy of the data used. More precise information on regional feed and nonfeed costs, demand and supply functions, and transportation rates would undoubtedly yield more realistic results. With a given level of data precision, however, reactive programming should yield more realistic empirical results than some of the more normative models that have been used to study industry space, form, and time dimensions.

[18] In this context, spatial analysis of the cattle feeding industry made by Langemeier and Finley needs to be mentioned [10]. They considered simultaneously slaughter capacity and demand functions for fed and nonfed cattle.

REFERENCES

[1] Bhagia, G. S., "An Economic Analysis of Cattle Feeding and Interregional Flows of Live and Carcass Beef." Ph.D. thesis dissertation, Oregon State University, 1971. 164 numbered leaves.

[2] Bhagia, G. S. and J. G. Youde, *An Economic Analysis of the United States Fed Beef Industry,* Oregon State Agr. Exp. Stat. Special Report 342, Oct. 1972.

[3] Boles, P. P., "The Role of Railroads in Handling Farm Products," U. S. Dept. of Agriculture, Economic Research Service. *Marketing and Transportation Situation* 180, Washington, 1971. p. 16-24.

[4] Capener, W. N., et. al., *Transportation of Cattle in the West,* Wyoming Agricultural Experiment Station Research Journal 25, 1969.

[5] Dietrich, R. A., *Market Structure Changes in the Livestock and Meat Industry, With Special Reference to Texas and Oklahoma,* Texas Agricultural Experiment Station, Department of Agricultural Economics and Sociology, Departmental Information Report No. 66-10, College Station, 1966.

[6] Goodwin, J. D., *Optimum Distribution Patterns of Feeder Cattle from the Southeast,* Southern Cooperative Series, Bulletin No. 101, 1965.

[7] Havlicek, J., R. L. Rizek, and G. G. Judge, *Spatial Structure of the Livestock Economy. II. Spatial Analyses of the Flows of Slaughter Livestock in 1955 and 1960.* South Dakota Agricultural Experiment Station, North Central Regional Research Bulletin No. 159, Brookings, 1964.

[8] King, Richard A. and Foo-Shiung Ho, *Reactive Programming: A Market Simulating Spatial Equilibrium Algorithm,* Economics Research Report No. 21, Department of Agricultural Economics, North Carolina State University, April 1972.

[9] Langemeier, L. and R. G. Thompson, "Demand, Supply, and Price Relationships for the Beef Sector, Post World War II Period," *Journal of Farm Economics* 49(1): 169-183. Feb. 1967.

[10] Langemeier, L. and R. M. Finley, "Effects of Split-Demand and Slaughter-Capacity Assumptions on Optimal Locations of Cattle Feeding," *American Journal of Agricultural Economics,* 53(2): 228-234. May 1971.

[11] Pendse, D. C., "Interregional and Interseasonal Competition in the U.S. Beef Industry, 1967–An Integrated Analysis." Ph.D. thesis, Oregon State University, 1972. 186 numbered leaves.

[12] Tramel, Thomas E. and A. D. Seale, Jr., "Reactive Programming of Supply and Demand Relations–Application to Fresh Vegetables," *Journal of Farm Economics,* Vol. 41, No. 5, Dec. 1959, pp. 1012-1022.

[13] United States Department of Agriculture, Economic Research Service, *Livestock and Meat Statistics,* Supplement for 1968 to Statistical Bulletin No. 333. Washington, D.C., July 1969.

[14] United States Department of Agriculture, *Marketing and Transportation Situation* - 167. Washington, D.C., 1967. 35 p.