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ABSTRACT

The objective was to determine least-cost allocation of fed-beef by regions and export sites, with expanded volumes available for export based on the ability of the industry to supply a larger market. An interregional linear activity programming model that minimized the variable costs of producing, slaughtering, boxing and transporting fed-beef was constructed for the year 1979. Results indicated that the short run least-cost solution to an increase in fed-beef demand would be achieved by expanding production in the North Central region. Allocation of production from several regions would change as export demand rises. Study constraints imposed some limitations on results.

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Since World War II the fed-beef (feedlot finished beef) industry in the United States has been growing and responding to the forces of economic change. Following World War II consumer demand for fed-beef increased as incomes rose and population grew. In response to these factors the cattle feeding sector began to grow rapidly. For example, in 1947, 6.3 million head of fed cattle were marketed; in 1965, 17.9 million head; and in 1979 there were 24.6 million head marketed (Williams and Dietrich; U.S.D.A., 1981a). While the number of fed-cattle marketed has been increasing the number of feedlots producing these cattle has been declining. Between 1965 and 1979 the number of feedlots in the 23 major cattle feeding states has fallen by over 44% (Gee et al.; U.S.D.A., 1981a). The regional location of these feedlots has not changed as their size increased, but the number of cattle produced in each region has changed.

As the cattle feeding sector has changed in response to demand and other factors, the slaughtering and processing sectors have become decentralized and are now located closer to the areas of production. Also, the number of slaughtering plants has declined and large, more specialized plants are slaughtering the majority of the cattle.

Changes in the structure and size of the fed-beef industry affect the cost relationships between various producing regions. Their impacts on volume and allocation of production are revealed through interregional competition analysis which involves the principle of comparative advantage. While regional comparative advantage involves many commodities, interregional competition analysis determines the competitive positions of various regions that produce the same commodity, or closely related commodities (Mighell and Black; Johnson).

Purpose and Objectives

Earlier interregional competition studies of the fed-beef industry (King and Schrader; McCoy et al.; Dietrich) are for the most part outdated by continuous changing of industry supply and demand factors. While there have been more recent studies of the fed-beef industry, for example Byrkett et al. modeled the optimum location of the cattle feeding industry, new processes such as the boxing of beef has been widely adopted since these studies were concluded. Also, none of the previous studies attempted to determine the sources of supply of fed-beef for the export market.

Becuase of rising incomes and changing tastes and preferences world wide, there is interest in developing export markets for U.S. fed-beef. The U.S. fed-beef industry is promoting export programs and trade liberalization. These developments give rise to the question: If U.S. fed-beef exports were to expand, what regions would be in the best economic position to supply the increase in demand?

The purpose of this study was to conduct an interregional competition analysis of the fed-beef industry in the U.S. to determine the existence and sources of competitive advantage by regions. The specific objectives were:

1. to estimate the costs of producing, slaughtering and boxing fed-beef by regions;
2. to determine the least-cost allocation of fed-beef by regions and export sites;
3. to illustrate the least-cost production and allocation of fed-beef with expanded volumes available for export.

The potential export volumes are based on the ability of the U.S. fed-beef industry to supply a larger market. While they do not represent current or projected future export market demands, they are indicative of the magnitude of export expansion to which industry representatives aspire.

Linear Activity Analysis Model

This study used a linear programming model that separated the sources from which a region gains a competitive advantage in the production of fed-beef. This advantage can arise from the cost of feeding cattle in each region which might reflect the availability of low cost feeder cattle and/or feeds, economies of size, superior management, gain efficiencies due to a favorable climate, or several other factors. The regional costs of slaughtering and processing fed-cattle could also result in a competitive advantage. The location of the producing region in relation to regions with a large demand can be an advantage; this is reflected in the cost of transporting beef.

A production and allocation model that incorporates all of the above-mentioned costs was used. This model is a simple form of an inter-regional linear activity analysis model (Takayama and Judge).

The production and allocation model has "n" regions which can produce and process fed-beef within the limits set for each region. Fed-beef is transformed into boxed beef by the slaughtering and processing activities. The final product, boxed beef, is then transported to meet the known demands in each of the "n" regions. In the model export points are treated as demand sites separate from the region in which they are located. The mathematical model which minimizes the costs of producing, slaughtering, boxing and transporting fed beef is shown in the Appendix.

The assumptions for this model are, first, that all boxed beef is homogeneous and, second, that all unit costs remain constant and do not depend upon volume. To simplify the data all quantities of fed-beef and costs associated with fed-beef are on a cwt. of carcass beef basis.

The study objectives were achieved by altering constraints and changing assumptions concerning variables in the basic model. These changes are discussed with the results of each specific model.

Production and Consumption Regions, Export Sites

To study interregional competition in the production of fed-beef the U.S. was divided into seven regions, not including Alaska and Hawaii. Six of these regions produce fed-beef while the seventh is only a consumptive region. Cattle feeding regions were delineated by availability of cost data, with states having similar production characteristics grouped together. They basically conform with the U.S.D.A. regional classification for 1970-80.

A single location in each region was specified as the central fed-beef shipping and receiving point. The locations were selected for geographic centrality, not as production or consumption centers. This minimizes the average distance between regions and is standard procedure in interregional models. The states in the seven regions and the central shipping and receiving points are shown in Table 1.

Three export sites (New York, Houston and Los Angeles) were selected on the basis of current beef export volume. A fourth, Portland, was added after the base year linear programming model showed the export volume was supplied by the Pacific Northwest region.[1]

Estimated Regional Feeding Capacities

Among the factors which ultimately may limit a region's cattle feeding capacity are the number of feeder cattle available, the amount of feed available and the number and size of feedlots. In this short run study feeder cattle and feed supplies were not considered limiting factors.[2] Feedlot capacity was assumed to be the only constraint on regional feeding volume. Regional annual feeding capacities were calculated from published U.S.D.A. information on the number and size of feedlots in the U.S., using Dietrich's method for determining capacity by feedlot size groups and a turnover of two. Maximum volume of the under 1000 head capacity feedlots was estimated at 50% over the actual number of head fed.

This method of determining yearly feeding capacities resulted in an estimated 33.2 million head of cattle that could be fed in the U.S. using existing (1979) facilites. Cattle feeding in the 23 major cattle feeding states could increase by approximately 8.5 million head, or 35% over actual 1979 volume.

Regional Feeding Costs

Information for cattle feeding costs was obtained from U.S.D.A. budgets for regions 2, 3, 4 and 5 (U.S.D.A., 1979b). For region 1 a recent Idaho study which employed U.S.D.A methodology was used (Flick and Marousek). Budgets from eastern North Central region were adapted for region 7, since no orginal budgets were available. All inputs were valued at 1979 levels, using actual prices or by indexing (U.S.D.A., 1981b). Costs of producing fed cattle were calculated in each region by multiplying the percentage of cattle marketed by each size group times the cost from the budgets.

The costs of producing live cattle were converted to carcass weight basis. It was assumed that all cattle fed would grade choice and have a conservative dressing percentage of 60 (Romans and Ziegler) (Table 2).

Costs of Expanded Feeding

The variable costs shown in Table 2 were used in the model for producing volumes up to the actual numbers fed in 1979. To calculate variable costs for additional production (to the level of estimated short run feeding capacity), the budgets were adjusted by a weighting procedure incorporating the percentage increase in cattle feeding in the several feedlot size groups (Table 3).

The cost of feeding cattle in the Pacific Northwest region was calculated totally from budgets that did not include potato waste as feed. This was done because estimates of the amount of potato waste available for feed were not large enough to cover the expanded feeding.

Processing Plants

Slaughtering

The plants modeled in this study had hourly kill capacities of 47, 60, 75, 90, 110 and 300 head. These were the capacities used in a 1976 California report by Cothern, Peard, and Weeks (1978b) on economies of size in slaughtering plants. Their report included both fixed and variable costs associated with each model, with each cost apportioned to the various stages of beef slaughter.

For this study all slaughtering plant operating costs reported by Cothern et al. were updated to 1979 levels and regionalized where possible.[3] Depreciation, interest, and installation costs were those calculated in the Cothern et al. study. Slaughtering plants were assumed to operate at full capacity 250 days per year, with a 7.5 hour kill day and .5 hour for cleanup.

Breaking-boxing

Breaking-boxing plant costs were taken from another report by Cothern, Peard, and Weeks (1978a) in which they assumed that a multi-function breaking-boxing plant was attached to the slaughtering plant. Since only breaking and boxing primals was pertinent to this study, operating costs were adjusted to reflect elimination of other processing activities budgeted in the Cothern et al. report. Processing plant sizes (30, 50, 75 and 300 head per hour) were modeled in combination with the appropriate slaughtering plants. Costs were updated to 1979 as with slaughtering plants.

Operating costs

The average variable cost of slaughtering an animal declined in all regions as the size of plant increased, with one exception (Table 4). In going from 47 to 60 head per hour plants, total operating costs increased proportionately more than output. For breaking-boxing, the variable cost per animal also declined as the size of the plant increased except for 300 head per hour plants in regions with lower wage rates (Table 5). Costs were converted from per head to per cwt. of carcass beef for the programming model.

Supply and Demand Estimates

Production and consumption

Production of fed-beef by regions was estimated by multiplying average carcass weight in each region times the number of fed-cattle marketed during 1979. Total production was 152.86 million cwt., carcass weight.

Domestic fed-beef consumption was determined by subtracting fed-beef exports from total fed-beef production. Total consumption divided by the 1979 population of the 48 states in the study (U.S. Bureau of the Census, 1981) gave a per capita annual consumption of 68.03 pounds of fed-beef. This per capita consumption was used in conjunction with regional population to compute regional consumption.

The results of this estimating method are comparable with published statistics. For example, in 1979 fed-cattle marketings accounted for 73.12% of commercial cattle slaughter (U.S.D.A., 1981d). Using the estimated production of fed-beef and the reported total beef production, 71.90% of the beef produced in 1979 was fed-beef. Since total fed-beef production in this study included only the 23 major feeding states the slightly lower estimate appears very reasonable.

Reported per capita beef consumption in 1979 was 105.5 lb (U.S.D.A., 1981d). Fed beef then accounted for 64.48% of total beef consumption, including imports.

Exports

The U.S. exported 167.6 million lb of beef and veal in 1979, which equals 222 million lb carcass weight equivalent (U.S.D.A., 1981d). It was assumed that fed-beef was exported fresh or frozen and not as prepared beef. The amount of beef, not including veal, exported fresh and frozen in 1979 was approximately 97,778,000 lb, of which 83,270,000 lb was boneless (U.S.D.A., 1981c). To convert the boneless exports to a carcass equivalent it was assumed that a carcass yields 69.8% of its weight in trimmed boneless meat (U.S.D.A., 1979a). The boned exports equaled approximately 119,298,000 lb carcass weight equivalent. Total carcass weight equivalent of exported beef that could have been fed-beef was 133,806,000 lb. It was further assumed that 75% of the total carcass weight equivalent exported was fed-beef, or approximately 100,000,000 lb. This figure (75%) was chosen arbitrarily and is probably conservative since the U.S. is deficient in non-fed beef and would thus not be exporting non-fed beef products.

Transportation Costs

The cost of transporting beef from surplus regions to deficit regions and to export sites was estimated from equations developed by Webb et al. The equations are:

(1) 200 miles to 920 miles

$$¢/100\text{ lb} = 63.8563 + 0.21017\text{ miles} - 0.00004359\ (\text{miles})^2$$

(2) 920 to 3000 miles

$$¢/100\text{ lb} = 0.750743 + 0.241357\text{ miles}$$

Mileages between regional shipping and receiving points (Table 1) were used in calculating transportation costs.

Programming Models and Results

Four specific models used various assumed levels of export demand for fed-beef. All models used the variable costs of producing fed-beef. The variable costs of processing fed-beef were calculated by assigning each region one size slaughtering plant and the associated breaking-boxing plant size. The assignment of slaughtering plant sizes was on a relative basis, using the average number of cattle slaughtered by each plant in the region.[4]

Model 1, base year (1979)

Model 1 used 1979 production and consumption levels. Exports of fed-beef in the model were at the estimated level of one million cwt. Any of the six production regions could supply part or all of this export demand which could be satisfied at any of the four export points: New York, Houston, Los Angeles or Portland.

The optimal shipments of fed-beef in 1979 are shown in Table 6 which indicates the region in which the beef was produced, slaughtered and boxed, and the region(s) to which it was shipped. In this model the Pacific Northwest region supplied its own needs, the export demand at Portland and part of the fed-beef requirements of the Southwest and Intermountain region.[5] The Central and Northern Plains region, which is the largest producer of fed-beef, supplied beef to itself and four other regions. The Southern Plains region was the only other region that had a surplus of fed-beef beyond its own needs.

The other numbers in the table are the opportunity costs for the activities that did not enter the solution. These costs represent the penalty of forcing in one unit of that activity. They can also be considered the transportation cost reduction necessary before these shipments will occur. For example, the Southwest and Intermountain region would need to reduce transportation costs to Los Angeles by $1.53 per cwt. before it could compete with the Pacific Northwest for the export market, with all other costs held constant.

Table 7 shows the shadow prices (opportunity costs) for boxed fed-beef in each region. These figures indicate how much costs could increase (+) or decrease (-) before interregional allocation, including export sites, of fed-beef would change. The North Central region showed the largest cost advantage ($5.10 per cwt., carcass basis) while the Pacific Northwest was second ($4.72). The Southwest and Intermountain region had the greatest cost disadvantage, -$0.82.

Model 2, two million cwt. export demand

In model 2, the export demand for fed-beef was assumed to double from the 1979 level, to two million cwt. Also each region's feeding capacity was increased to the estimated maximum level. This increased feeding capacity was achieved by adding a second production activity that used the estimated increased variable costs (Table 3). The costs for the original (1979) feeding level in the model were the same, as were all costs (for both original and expanded volumes) for processing and transportation. Consumption in each region was also held constant at the 1979 level. Each region was assumed to produce at least as much fed-beef as in 1979. The model then determined which region(s) would produce the fed-beef needed to meet the expanded export market.

The optimal solution to this model is shown in Table 8. The Pacific Northwest region supplied 87% of the export volume but did not increase feeding beyond the 1979 level. The Pacific Northwest region no longer shipped beef to the Southwest and Intermountain region as it did in model 1. Instead, that fed-beef was shifted into the export market at Portland and the Central and Northern Plains region supplied more beef to the Southwest and Intermountain region. The remaining 13% of export volume was supplied by the Southern Plains region at Houston. The North Central region produced the additional one million cwt. of fed-beef, but this beef was allocated to domestic use allowing other regions to shift their shipments in a least-cost way to meet the increased export volume.

Table 9 shows the changes in the costs of producing fed-beef beyond the 1979 level of production that would need to take place before the solution to the model would change. These cost changes are only for the increased production, since the 1979 production level was maintained in each region. For example, the cost of feeding additional cattle in the Pacific Northwest must fall by $1.49 per cwt. to $105.34 per cwt. (carcass basis) before that region would become competitive with the North Central region in the production of additional beef, with all other costs in the model constant. The North Central region had the greatest cost advantage for supplying the increased fed-beef demand while the Southwest and Intermountain region had the greatest cost disadvantage. These relationships exist only within the constraints of the model, including the stipulation that each region continues to produce no less than in 1979. The additional output is produced from least-cost sources, to the limit of a region's feedlot capacity.

This model was also run excluding processing costs. This did not change the optimal shipments and levels of production, indicating that processing costs are not as important as the costs of producing and transporting fed-beef in determining a region's ability to compete for a market.

Model 3, five milliion cwt. export demand

Model 3 was the same as model 2 except export demand for fed-beef was assumed to be five million cwt. The increased demand was satisfied by the North Central region. This additional fed-beef was again allocated to the domestic market, thus allowing the Southern Plains to supply part of the export market at Houston and the Pacific Northwest to supply the remainder at Portland. The Pacific Northwest supplied only 35% of the export market, with 65% supplied by the Southern Plains. The opportunity costs for the transportation activities that did not enter into the solution are the same as in Table 8 for model 2, since no new activities entered the solution. The cost changes shown in Table 9 for the increased feeding activities are also the same as in Model 2 because the solution did not change. Here again the optimal solution did not change when the model was run omitting processing costs.

Model 4, ten million cwt. export demand

The only modification in model 4 was to increase assumed export demand to ten million cwt. In this model, as in the previous two, the additional fed-beef was produced in the North Central region. This production supplied domestic demand, allowing the Southern Plains to supply more fed-beef to Houston for export. The Pacific Northwest region still supplied the same amount of beef to Portland for export as in the previous two models.[6] The cost changes shown in Table 9 also hold for this model. Finally, the optimal solution again remained the same when processing costs were assumed to be zero.

Conclusions and Implications

The overall results of these short run analyses indicate that the least-cost solution to an increase in fed-beef demand would be achieved by expanding production in the North Central region. Other regions would maintain their 1979 levels of production, with only the allocation of their fed-beef changing as export demand rises.

In the short run the North Central region had the greatest competitive advantage in the production of fed-beef in 1979. The Pacific

Northwest region was the second most competitive and the Southwest and Intermountain region the least competitive, based on the results of the base year model. When export demand was assumed to increase and fed-beef production in each region allowed to expand, the North Central region also held the greatest competitive advantage for expanded production in the short run. But because of the increased variable cost of feeding cattle without additional byproduct feeds, the Pacific Northwest was less competitive in supplying a larger market. The Southwest and Intermountain region had the highest cost for expanded production.

While the North Central region expanded its production of fed cattle when export demand was assumed to increase, the additional beef was not allocated to export sites. Instead this fed-beef was used to meet domestic demand, allowing other regions to ship beef to ports. The excess of production over consumption requirements in the Pacific Northwest was allocated for export from Portland, but the region did not expand production beyond the 1979 level. When total export volume exceeded the the short run feeding capacity of the Pacific Northwest, the Southern Plains region began to ship beef to Houston for export. These conclusions are based on cost minimization to the port of embarkation only, with no regard to the final destination (country) of the fed-beef.

Processing costs were not as important as feeding and transportation costs in determining a region's ability to compete for a market for its fed-beef. Processing costs would have an effect on a region's competitive position if feeding costs were equal or very close in all regions. But with divergent feeding costs regional differences in processing costs did not affect the location or allocation of production.

The conclusions of this study must be tempered by the constraints and assumptions which it was necessary to impose. Actual market conditions were compromised (1) by assuming that each region satisfied its own demand before shipping to other regions or for export (no cross hauls), (2) by the inability to regionalize some slaughtering and boxing plant costs, (3) by adopting a transportation rate structure based on distance only and (4) in the case of export volume, by allocating shipments to the least-cost port of embarkation only. Destination and routing of fed-beef exports requires knowledge of ocean shipping costs and importing countrys' demands.

These conclusions are based on a short run analysis. In a longer time frame factors not considered in this study become important. These include construction of new feedlots and processing facilities, new developments in transportation and shifts in areas of production due to changing cost structures for feeds.

In a longer run analysis production costs which are fixed in the short run become important in determining a region's ability to compete in a market for its fed-beef. Fixed costs declined sharply with economies of size in feeding cattle. While the difference in variable costs of feeding between the regions with the highest and lowest cost was $4.12 per cwt. (live animal basis), the difference became $13.94 per cwt. when the fixed costs of feeding were included. The west and plains regions have more large feedlots and lower fixed costs of feeding while the North Central and Northeast regions have smaller feedlots and higher fixed costs.

The long run westward shift of fed-beef production may be lessened to the extent that the North Central region achieves feedlot size economies and utilizes its feed grain production efficiency. The Pacific Northwest region provides an example of combining size economies and the most economical feeds. The cost of producing fed cattle in this region is inversely related both to feedlot size and feeding food processing industry byproducts.

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APPENDIX

The mathematical model which minimizes the variable costs of producing, slaughtering, boxing and transporting fed-beef is:

$$\text{Minimize} \quad \sum_{i=1}^{n} F_i K_i + \sum_{i=1}^{n} S_i X_i + \sum_{i=1}^{n} B_i X_i + \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} X_{ij}$$

Subject to

(1) $X_i - \sum_{j=1}^{n} X_{ij} \geq 0$ — The amount of fed-beef region i ships to itself and other regions is less than or equal to the amount of beef produced and processed in region i

(2) $X_i + \sum_{i=1}^{n} X_{ji} \geq Y_i$ — Consumption or demand for fed-beef in region i is less than or equal to the production of fed-beef in region i plus the inshipments of fed-beef from region j.

(3) $K_i - T_i \leq 0$ — A region cannot produce fed-beef beyond its feedlot capacity.

(4) $K_i, X_i, X_{ij} \geq 0$ — There can be no negative production or shipments of fed-beef.

In the equations let:

i,j denote the regions, $i = 1,2,3,...,n$, $j = 1,2,3,. . .,n$

C_{ij} denote the cost of transporting boxed beef from region i to region j

X_{ij} denote the quantity (cwt.) of boxed beef shipped between region i and region j

X_i denote the total quantity (cwt., carcass basis) of boxed beef produced in region i

F_i denote the cost of feeding cattle in region i, on a cwt., carcass basis

K_i denote the total cwt. of carcass beef produced in region i

S_i denote the cost per cwt. (carcass weight basis) to slaughter cattle in region i

B_i denote the cost of boxing a cwt. of carcass beef in region i

T_i denote the regional fed-beef production capacity, in cwt. of carcass beef

Y_i denote the cwt. of fixed demand for boxed carcass beef in region i

FOOTNOTES

1. These include all major year around potential export sites and are not unduly restrictive since ocean freight rates are much lower than overland rates.

2. Given sufficient price incentives feeders will bid for existing feeder cattle and feed supples to fill their lots. An exception is the availability of potato waste for expanded feeding in the Pacific Northwest; this is discussed in the section on costs of expanded feeding.

3. Regionalized costs and sources were: production worker labor (U.S. Department of Labor); office worker labor (U.S. Bureau of the Census, 1980); electricity (U.S. Department of Energy); property taxes (U.S. Advisory Commission on Intergovernmental Relations).

4. Since processing costs had no impact on regional production and interregional shipments (see below) a more refined regional size-cost processing plant model was not developed.

5. Export demand was filled at Los Angeles when Portland was not included in the model.

6. In all the models Pacific Northwest shipments to export sites were allocated to Los Angeles when Portland was not included in the model.