Spatial Price Equilibrium Analyses of the Livestock Economy

2. Application of Spatial Analysis to Quarterly Models and Particular Problems Within the Beef Marketing System

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CONTENTS

Preface

This study is the second of a series reporting the results of research concerning the application of spatial price equilibrium models to the livestock marketing sector of the economy. As such, the research deals primarily with estimating the equilibrium geographical prices, consumption and flows for livestock products under alternative conditions and assumptions. In the first study of this series, the general methodology underlying the application of spatial price equilibrium models was presented and extended to encompass alternative problem situations, annual spatial models for beef were established and the impact of certain disturbances on the equilibrium system was assessed.

Given this base, research was extended in this report to evaluate quarterly spatial models for beef, determine optimum live cattle shipments for slaughter, and to assess the impact of a wide range of disturbances on the basic variables involved.

A complete listing of the studies reported in this series is given below:

SPATIAL PRICE EQUILIBRIUM ANALYSES OF THE LIVESTOCK ECONOMY

1. Methodological Development and Annual Spatial Analyses of the Beef Marketing Sector

2. Application of Spatial Analysis to Quarterly Models and Particular Problems within the Beef Marketing System

3. Spatial Price Equilibrium Models of the Pork Marketing Sector

Spatial Price Equilibrium Analyses of the Livestock Economy

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I Introduction

The purpose of much research in agricultural economics is to provide objective answers to economic questions that arise from potential agricultural policies and firm actions. Operational models embodying questions relating to spatial pricing and interregional commodity movement were largely outside the scope of general equilibrium theory, since the space factor was not considered explicitly in the equilibrium schema. However, developments by Koopmans (3), Samuelson (5) and others led to a theoretical framework wherein space could be introduced explicitly without violating any of the remaining postulates of equilibrium theory. The methodology suggested by the modified theory parallels that of the transportation problem in linear programming, therefore, the mathematical techniques arising in conjunction with attacking a particular problem have been rigorously developed; not only within economics, but in related fields as well.

A. General Problem

The problem of interregional product pricing and movement has been succinctly stated by Samuelson (5), ". . . . We are given at each of two or more localities a domestic demand and supply curve for a given product (e.g., wheat) in terms of its market price at that locality. We are also given constant transport costs (shipping, insurance, duties, etc.) for carrying one unit of the product between any two of the specified localities. What then will be the final competitive equilibrium of prices in all markets, of amounts supplied and demanded at each place, and of exports and imports?"

Given the basic assumptions, the model which reflects the specified conditions for a particular commodity or sector of the economy and the attendant spatial price equilibrium solution, the analysis can be extended to evaluate the consequences of disturbances in the existing structure on

regional supplies, price consumption, flows, etc. The solutions thus generate information which is basic to choice at the various decision making levels.

B. Specific Problem

In a previous bulletin (2) of this series, the spadework of establishing optimum flow patterns and regional equilibrium prices of beef was accomplished for various time periods. Specifically, the former research included annual interregional pricing and shipment models for beef for 1947, 1952, 1955 and for 1963. Also, the impact of changes in transport costs on the basic factors was evaluated, and a hypothetical production-oriented slaughtering program for 1955 was investigated. Given the previous analysis, the present research was initiated to extend the former analysis in two directions: (1) to construct spatial flow and price models that are less aggregative, in the hope that reality will be better served, and (2) to analyze several meaningful questions that either have bearing on current policy and firm actions or may have bearing in the future. A corollary objective was to suggest, by example, the wide range of economic questions that can be handled by spatial analysis, thus stimulating its application to other research.

In particular, the present research includes: (1) estimating optimum product flows and regional equilibrium prices of beef by quarter for 1955, (2) evaluating the effects of market-oriented processing of beef on regional prices and flows, (3) determining optimum flows of live cattle for 1955, (4) assessing the impact of a 90 per cent parity support price on the equilibrium structure, and (5) similarly, examining the effect of a two billion pound beef export program. In accomplishing the primary objectives as stated above, several interesting sub-topics arose, such as investigating the degree of inefficiency inherent in the existing locational matrix of slaughtering plants.

Pure competition postulates underly all analyses. For an explicit account of the prevailing assumptions, along with a description of the methodological processes of spatial analysis, see Judge and Wallace (2).

II The Basic Data

As a first step in the analysis, the United States was divided into 21 contiguous regions. The resulting demarcation was restricted to one or more states for each region since the basic data are not available for smaller areas. A centrally located city was chosen as a market and supply

point for each region. The regional demarcation and basing point cities are given in Table 2.1.

Because of the restrictions on the availability of state or regional consumption data, an aggregate market demand relationship for beef was specified to reflect demand in all regions.[1] This relationship was originally derived as a logarithmic function with price and income elasticity of demand for beef estimated as —0.86 and 0.59, respectively. The logarithmic functional form was transformed to the following linear relationship for 1955 (annual):

$$Y_{1i} = -1.0529Y_{2i} + .0303Z_{1i} + 104.9777 \qquad (2.1)$$

where Y_{1i} is per capita consumption of beef in the i^{th} region; Y_{2i} is equilibrium price in the i^{th} region and Z_{1i} is per capita disposable income in the i^{th} region. Since data relating to regional retail pork prices in 1955 are not available, the average impact of the price of this substitute commodity is included in the constant term. Linear demand relationships for other than the 1955 annual analysis were similarly derived in each instance.

The model further specifies the need for regional data pertaining to beef supplies, population and disposable income. These regional data representing predetermined variables, were obtained from records published by the Departments of Commerce and Agriculture. The data are assumed to accurately reflect the variables involved and are presented for 1955 in Table 2.1. Similar data for all other analyses were obtained from the same sources and are discussed where pertinent in the following sections.

The market and supply sources as formulated in the model are assumed to be designated by a single point in each region. Since the structure of transport rates for beef is basic to the spatial solution, it is necessary to obtain estimates of the costs between the points that represent each pair of regions.

A model to reflect transport rates between market and supply source points was postulated as:

$$C_{ij} = \beta_1 M_{ij} + \beta_2 \sqrt{M_{ij}} + \Sigma \qquad (2.2)$$

where C_{ij} represents the cost in cents of shipping a pound of beef carcass from point i to point j; M_{ij} is the mileage between i and j; β_2 and β_1 are

[1]See T. D. Wallace and G. G. Judge, (6, p. 27).

Table 2.1—The Regional Demarcation and Values of the Predetermined Variables, 1955.

Region	States Included	Basing Cities	Total Beef Supply[1] (1,000 lbs.)	Per Capita Beef Supply (lbs.)	Per Capita Disposable Income ($)[2]	Population[3] (thousands)
1	Vt., N. H., Maine, Mass., Conn., R. I.	Boston	148,710	15.5	1,817	9,619
2	N. Y.	N. Y.	383,783	24.0	1,970	16,021
3	Md., Del., Wash., D. C., Pa., N. J.	Phil.	830,980	41.1	1,785	20,213
4	W. Va., Va., N. C.	Roanoke	198,091	20.0	1,180	9,907
5	Ky., Tenn.	Bowling Green	342,418	53.3	1,087	6,425
6	Mich., Ohio	Toledo	1,066,866	65.6	1,823	16,271
7	Ill., Ind.	Chicago	1,499,690	110.0	1,865	13,630
8	Minn., Wisc.	St. Paul	1,324,079	192.1	1,512	6,892
9	Nebr., Iowa	Omaha	2,109,061	518.8	1,362	4,065
10	Kan., Mo.	K. C.	1,167,530	186.5	1,523	6,261
11	Ala., Ga., S. C.	Atlanta	333,962	36.8	1,066	9,080
12	Fla.	Tampa	166,320	46.5	1,441	3,580
13	Ark., Miss., La.	Vicksburg	211,793	30.8	994	6,869
14	Okla., Tex.	Ft. Worth	947,597	86.5	1,386	10,958
15	N. Dak., S. Dak.	Bismarck	271,697	204.9	1,137	1,326
16	Wash., Ore.	Portland	387,357	90.3	1,677	4,292
17	Mont., Idaho	Butte	120,353	97.0	1,442	1,241
18	Wyo., Colo.	Denver	477,962	257.1	1,534	1,859
19	Utah, Nev.	Ely	108,058	104.7	1,528	1,032
20	Ariz., N. M.	Gallup	81,210	45.1	1,317	1,800
21	Calif.	Fresno	1,318,935	101.8	1,978	12,961
	United States		13,496,632	82.1	1,608	164,302

[1]Agricultural Marketing Service, "The Livestock and Meat Situation," U. S. Department of Agriculture, August 1948 and March 1956; Agricultural Marketing Service, "Livestock Slaughter," U. S. Department of Agriculture, May 1956, p. 4; and Agricultural Marketing Service, "Meat Animal, Farm Production, Disposition and Income, by States," U. S. Department of Agriculture, Bul. 184, 1956, pp. 6-10. For 1955, commercial slaughter in liveweight was added to farm slaughter and the total divided by the appropriate ratio to obtain carcass weight production by states.

[2]U. S. Bureau of Foreign and Domestic Commerce's, "Supplement to Survey of Current Business," U. S. Department of Commerce, 1956, p. 141. Per capita disposable income is not available for 1955 on a state basis, so it was necessary to adjust these data on the basis of state personal income payment to obtain estimates of this series.

[3]U. S. Bureau of Foreign and Domestic Commerce's, "Supplement to Survey of Current Business," U. S. Department of Commerce, 1956, p. 145. These data apply to population estimates as of July 1.

unknown parameters to be estimated and Σ is an unobservable random error. This functional form was postulated in the belief that transport rates are an increasing function of mileage but should increase at a decreasing rate. For obvious reasons, the function was postulated as having a zero intercept. Since beef carcasses are shipped by both truck and rail, equation (2.2) was specified for each of these types of transportation. Equation (2.2) was also used to reflect live beef shipment costs. Due to the unavailability of an adequate sample of truck rates for shipping live beef, rail rates were assumed to accurately reflect live shipment costs. The symbol, T_{ij}, will be used to denote the live shipment cost for beef between regions i and j.

A sample of data was secured to represent all observable variables and the least squares procedure using moments about zero was used to estimate the unknown parameters. The results were:

$$C_{ij} = .0008M_{ij} + .0464\sqrt{M_{ij}} \qquad \text{(Rail-carcass)} \qquad (2.3)$$
$$R^2 = .970$$

and

$$C^*_{ij} = .0015M^*_{ij} + .0226\sqrt{M^*_{ij}} \qquad \text{(Truck-carcass)} \qquad (2.4)$$
$$R^2 = .969$$

$$T_{ij} = .0005M_{ij} + .0280\sqrt{M_{ij}} \qquad \text{(Rail-live)} \qquad (2.5)$$
$$R^2 = .987$$

Equations (2.3) and (2.4) were used to estimate both rail and truck rates for dressed beef between all pairs of regions. The minimum of these rates in each case was chosen as the relevant transport cost. Equation (2.5) was used to estimate the cost of shipping live beef among regions. Since equation (2.5) tends to overestimate costs of shipping over short distances, highway mileage was used where a large disparity between rail and highway mileage exists. The estimated transport costs for shipping both live cattle and carcass beef among all regions are presented in Appendix A.

III The Empirical Results

The sequential process outlined in the previous bulletin (2) was used for converging to a set of optimum price differentials and a minimum cost shipment pattern was employed. However, in the interests of brevity, only the final or optimum stage for each analysis is presented. Prior to presenting the results of the present study, the optimum ship-

ment program for 1955 is given to establish a comparative base for discussing all other analyses.

A. Price and Spatial Analysis, 1955 (Annual)

The following table (Table 3.1) was presented in a prior bulletin (2, p. 33), along with a discussion of the economic implications of the results. The interested reader is referred to that publication for a more detailed presentation. Only a summary is repeated here.

The numbers appearing in bold faced type in the body of the table represent the amounts of beef shipped interregionally that satisfy regional demands and minimize total transportation costs. The U_i and V_j can be interpreted as price differentials relative to the base region (Region 9). The numbers appearing in light type in the body of Table 3.1 are the result of differencing direct and indirect costs of shipping from one region to another.[2] They are calculated by $C_{ij} + U_i - V_j$, where C_{ij} is the cost of shipping from region i to region j. Note that they are all positive or zero.[3] If one or more were negative, the shipment program would not be optimum since it would be possible to reduce total transport costs by considering another set of activities. The element 0.05 that appears in common to deficit Region 1 and surplus Region 9 indicates that Region 9 would be induced to ship to Region 1 if the shipment cost between Regions 1 and 9 was decreased by 0.05 cents per pound.

The estimates of total beef shipped and total transport costs appearing directly below the table have meaning only for the regional demarcation considered. However, since all subsequent analyses will be accomplished using the same regional breakdown, total cost and shipment estimates should provide interesting comparisons.

To help the reader visualize the optimum movements of carcass beef in 1955, the following figure was derived from Table 3.1.

The shaded regions in Figure 1 were the deficit producing regions as estimated for 1955. Conversely, the unshaded regions were surplus. The lines emanating from the unshaded areas represent the optimum movements of carcass beef, and the numbers appearing in the breaks indi-

[2]Indirect costs are defined as the opportunity cost of *not* having an activity in the basic solution.

[3]A zero indicates an alternative optimum shipment. E.g., Region 8 could ship to Region 3 rather than Region 2 without disturbing total transport costs. Although more than one shipment program may be optimal in the sense of minimum costs, institutional or other factors might limit the alternatives. This may be important in programs where an outside control can be exerted as in the case of government shipping of surpluses, etc.

Table 3.1—Regional Equilibrium Prices, Consumption, Surpluses and Deficit and Optimum Flows (1955)

Region	Equil. Price	Equil. Cons.	Surplus and Deficit	Origins and Quantities of Shipments (1,000 lbs.)											
	cents/ pound	1,000 pounds	1,000 pounds	7	8	9	10	14	15	16	17	18	19	21	Vj
1	69.60	834,188	-685,478	.22	**327,705**	.05	.19	1.03	**179,211**	**10,294**	**21,207**	**147,061**	.20	.58	2.93
2	69.43	1,466,503	-1,082,720	.08	**341,687**	**741,033**	.06	.89	.02	.04	03	.03	.23	.62	2.76
3	69.29	1,739,937	-908,957	.08	0	**908,957**	.06	.91	.04	.07	.10	.05	.25	.65	2.62
4	69.06	673,644	-475,553	.13	.07	**150,025**	**325,528**	.68	.24	.15	.16	.03	.35	.52	2.39
5	68.21	424,531	-82,113	.46	.38	.20	**82,113**	.74	.62	.61	.58	.22	.58	1.03	1.54
6	68.31	1,436,127	-369,261	**269,279**	**99,982**	.03	.23	1.38	.20	.34	.29	.29	.47	.91	1.64
7	67.61	1,230,411	269,279												
8	66.75	554,705	769,374												
9	66.67	309,046	1,800,015												
10	66.87	505,213	662,317												
11	68.79	588,638	-254,676	.50	.38	.17	**254,676**	.33	.43	.31	.35	.12	.46	.32	2.12
12	69.51	270,035	-103,715	.67	.45	.17	.11	.13	.38	.20	.21	**67,629**	.10	**36,086**	2.84
13	68.21	434,518	-222,725	1.19	.88	.38	.19	**111,960**	.96	.63	.84	**110,766**	.60	.16	1.54
14	67.14	835,637	111,960												
15	66.16	92,486	179,211												
16	64.46	377,243	10,294												
17	65.30	99,146	21,207												
18	65.91	152,506	325,456												
19	65.11	85,343	22,715												
20	66.71	134,318	-53,108	3.86	2.92	2.26	2.30	2.19	2.11	.60	.67	.49	**22,715**	**30,393**	.04
21	64.82	1,252,456	66,479												
			U_i	.94	.08	0	.20	.47	-.51	-2.21	-1.37	-.76	-1.56	-1.85	

Total shipments (1,000 lbs.) = 4,238,307.
Total costs = $104,756,372.

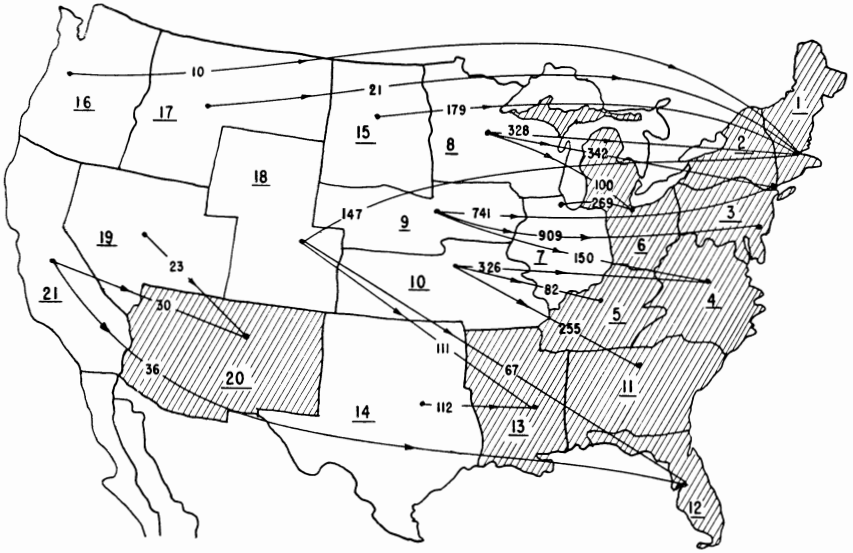

Fig. 1 Optimum Carcass Beef Shipments (Million Pounds) 1955

cate the amount of beef shipped in millions of pounds in each case. As previously indicated, an alternative optimum shipment existed, involving Regions 8 and 3.

B. Quarterly Price and Spatial Analysis: 1955

Due to production conditions, monthly variation occurs in the total output of beef. Also, the relative output position of regions or states may change by month or quarter. In addition, changes in regional incomes and the prices of competing products may cause the level of demand to vary over time. Therefore, in order to consider the effect of seasonal variation on optimum regional prices and flows of beef, a separate analysis was accomplished for each of the four quarters for 1955. This deaggregation by time periods should enable the seasonal characteristics of regions to be more accurately reflected.

Quarterly data to reflect beef production, disposable income and population were constructed from the same sources mentioned in Table 2.1. Since the demand relationship used to estimate consumption was derived from annual data, the quarterly data were adjusted, in each instance, to annual totals. Then, the resulting estimates of consumption were, in each case, divided by four before differencing with quarterly production to obtain estimates of surplus and deficit production in each region by quarters.

1. First Quarter, 1955: The resulting regional equilibrium prices, optimum flows of beef, etc., for the first quarter (January-March), 1955, are presented in Table 3.2.

As indicated in Table 3.2, regional beef prices are estimated to be about 2 cents per pound higher for the first quarter of 1955 than for the entire year (see Table 3.1). This results since total production for the first quarter (annually adjusted) is less than for the complete year of 1955. For example, Oklahoma and Texas show a surplus of only about 9 million pounds of beef for the period January through March, 1955, compared to an estimated surplus of about 112 million pounds of beef for the entire year. Annual production for 1955 was approximately 82.1 pounds per capita while production for the first quarter (adjusted to an annual base) was estimated to be 77.2 pounds per capita. This difference offset the relatively low per capita income of 1,568 dollars (adjusted to annual) compared with 1,608 dollars for the full year. Because of the low seasonal production, total shipments for the first quarter were only 23 per cent of annual total shipments. Approximately, the same proportion held in comparing total shipment costs for the first quarter with total annual shipment costs. The optimum flow pattern and equilibrium price differentials were the same as for the annual analysis.

2. Second Quarter, 1955: The results of carrying out a spatial analysis for the second quarter (April-June), 1955, are presented in Table 3.3.

The second quarter of 1955 showed an increase in the amount of beef shipped and a decrease in regional prices, in comparison with the first quarter. Per capita disposable income for the second quarter was estimated at 1,598 dollars (adjusted to annual totals) which is 10 dollars less than for the whole year, but is 30 dollars higher than for the first quarter. Prices were less for the second quarter than for the first, however, since per capita production increased from 77 pounds (adjusted to annual) for the first quarter to 80 pounds (adjusted) for the second quarter.

The optimum flow pattern changed for the second quarter in that Region 8 (Minnesota and Wisconsin) shipped to Region 3 (Maryland, Delaware, Pennsylvania and New Jersey) rather than Region 2 (New York), Region 14 (Oklahoma and Texas) shipped to Region 12 (Florida) and Region 18 (Wyoming and Colorado) did not ship to Region 13 (Arkansas, Mississippi and Louisiana). The resulting program was due to the changes in the magnitudes of surpluses and deficits rather than

Table 3.2—Regional Equilibrium Prices, Consumption, Surpluses and Deficits and Optimum Flows, First Quarter (January-March), 1955.

Region	Equil. Price	Equil. Cons.	Surplus and Deficit	Origins and Quantities of Shipments (1,000 lbs.)											
	cents/ pound	1,000 pounds	1,000 pounds	7	8	9	10	14	15	16	17	18	19	21	Vj
1	71.25	194,760	-156,504	.22	**68,259**	.05	.19	1.03	**40,575**	3,515	**9,337**	**34,818**	.20	.58	2.93
2	71.08	342,378	-250,846	.08	**99,080**	**151,766**	.06	.89	.02	.04	.03	.03	.23	.62	2.76
3	70.94	406,213	-212,595	.08	0	**212,595**	.06	.91	.04	.07	.10	.05	.25	.65	2.62
4	70.71	157,400	-113,275	.13	.07	**50,709**	**62,566**	.68	.24	.15	.16	.03	.35	.52	2.39
5	69.86	99,203	-24,984	.46	.38	.20	**24,984**	.74	.62	.61	.58	.22	.58	1.03	1.54
6	69.96	335,144	-82,297	**67,251**	**15,046**	.03	.23	1.36	.20	.34	.29	.29	.47	.91	1.64
7	69.26	287,051	67,251												
8	68.40	129,435	182,385												
9	68.32	72,123	415,070												
10	68.52	117,901	151,215												
11	70.44	137,554	-64,665	.50	.38	.17	**63,665**	.33	.43	.31	.35	.12	.46	.32	2.12
12	71.16	63,083	-17,678	**.67**	.45	.17	.11	.13	.38	.20	.21	**3,508**	.10	**14,170**	2.84
13	69.86	101,539	-55,368	1.19	.88	.38	.19	**9,415**	.96	.63	.84	**45,953**	.60	.16	1.54
14	68.79	195,029	9,415												
15	67.81	21,576	40,575												
16	66.11	87,944	3,515												
17	66.95	23,128	9,337												
18	67.56	35,570	84,279												
19	66.76	19,899	7,440												
20	68.36	31,346	-11,348	3.86	2.92	2.26	2.30	2.19	2.11	.60	.67	.49	**7,440**	**3,903**	.04
21	66.47	291,873	18,077												
			U_i	.94	.08	0	.20	.47	-.51	-2.21	-1.37	-.76	-1.56	-1.85	

Total shipments (1,000 lbs.) = 988,560.
Total costs = $24,608,373.

Table 3.3—Regional Equilibrium Prices, Consumption, Surpluses and Deficits and Optimum Flows of Beef, 2nd Quarter (April-June), 1955.

Region	Equil. Price	Equil. Cons.	Surplus and Deficit	Origins and Quantities of Shipments (1,000 lbs.)											
	cents/ pound	1,000 pounds	1,000 pounds	7	8	9	10	14	15	16	17	18	19	21	Vj
1	69.39	202,254	-167,344	.22	**41,851**	.05	.19	.90	**39,316**	**1,844**	**3,244**	**81,090**	.20	.58	2.93
2	69.22	355,520	-261,301	.08	0	**261,301**	.06	.76	.02	.04	.03	.03	.23	.62	2.76
3	69.08	421,829	-225,302	.08	**115,163**	**110,139**	.06	.78	.04	.07	.10	.05	.25	.65	2.62
4	68.85	163,435	-117,629	.13	.07	**51,339**	**66,290**	.55	.24	.15	.16	.03	.35	.52	2.39
5	68.00	102,986	-23,202	.46	.38	.20	**23,202**	.61	.62	.61	.58	.22	.58	1.03	1.54
6	68.10	348,186	-88,938	**67,982**	**20,956**	.03	.23	1.23	.20	.34	.29	.29	.47	.91	1.64
7	67.40	298,317	67,982												
8	66.54	134,513	177,970												
9	66.46	74,959	422,779												
10	66.66	122,519	148,932												
11	68.58	142,847	-59,440	.50	.38	.17	**59,440**	.20	.43	.31	.35	.12	.46	.32	2.12
12	69.30	65,481	-22,030	.67	.45	.17	.11	**8,695**	.38	.20	.21	**1,775**	.10	**11,569**	2.84
13	67.87	105,658	-48,844	1.32	1.01	.51	.32	**48,844**	1.09	.76	.97	.13	.73	.29	1.41
14	66.80	203,050	57,539												
15	65.95	22,427	39,316												
16	64.25	91,456	1,844												
17	65.09	24,046	3,244												
18	65.70	36,984	82,865												
19	64.90	20,691	4,757												
20	66.50	32,574	-12,089	3.86	2.92	2.26	2.30	2.06	2.11	.60	.67	.49	**4,757**	**7,332**	.04
21	64.61	303,588	18,892												
			U_i	.94	.08	0	.20	.34	-.51	-2.21	-1.37	-.76	-1.56	-1.85	

Total shipments (1,000 lbs.) = **1,026,120.**
Total costs = **$25,288,860.**

any regions being reclassified as to surplus or deficit. As a result, the price differential for Region 14 (Oklahoma and Texas) changed from 0.47 to 0.34 cents per pound and the price differential for Region 13 (Arkansas, Mississippi and Louisiana) changed from 1.54 to 1.41 cents per pound. Oklahoma and Texas are indicated as having a much larger surplus for the second quarter than for the first. In fact, the second quarter represents a larger surplus production for Region 14 (Oklahoma and Texas) than for any other quarter. Total shipments and total transport costs for the second quarter were larger than for the period January-March, 1955, but still below 25 per cent of annual estimates.

3. **Third Quarter, 1955:** The results of the spatial analysis for the third quarter (July-September), 1955, appear in Table 3.4.

For the country as a whole, there was more production of beef relative to demand during July-September than for either of the first two quarters of 1955. This is reflected in the lower regional prices and in the increase in total shipments. Contrary to the country taken in total, Oklahoma and Texas showed a decrease in surplus production over the second quarter. Per capita disposable income for the third quarter was estimated as 1,621 dollars (adjusted) and this figure is larger than for any other except the fourth quarter. Total shipments for the third quarter were 25.9 per cent of total annual shipments while total costs were 26.1 per cent of annual. Although the pattern of shipments was the same for both analyses, this result indicates that more beef was shipped over the longer hauls in the third-quarter program.

4. **Fourth Quarter, 1955:** A presentation of the results for the final quarter (October-December) appears in Table 3.5.

Regional prices were lower and surpluses were larger for the fourth quarter than for any of the first three quarters for 1955 due to the large seasonal production for the fourth quarter. Equilibrium price in the base region (Region 9) was estimated to be about 66 cents per pound for the fourth quarter compared with about 67 cents for the annual analysis. Prices would have been even lower, except that incomes were higher for the fourth quarter than for the first three quarters.

About 86 per cent of total shipments for the fourth quarter originated with Regions 7 (Illinois and Indiana), 8 (Minnesota and Wisconsin), 9 (Nebraska and Iowa) and 10 (Kansas and Missouri) compared with 83 per cent for the annual program. Region 16 (Washington

Table 3.4—Regional Equilibrium Price, Consumption, Surpluses and Deficits and Optimum Flows of Beef, 3rd Quarter (July-September), 1955.

Region	Equil. Price	Equil. Cons.	Surplus and Deficit	Origins and Quantities of Shipments (1,000 lbs.)											
	cents/ pound	1,000 pounds	1,000 pounds	7	8	9	10	14	15	16	17	18	19	21	Vj
1	68.66	219,205	-184,072	.22	**87,028**	.05	.19	1.03	**46,042**	**6,609**	**3,558**	**40,835**	.20	.58	2.93
2	68.49	385,301	-285,613	.08	**65,582**	**220,031**	.06	.89	.02	.04	.03	.03	.23	.62	2.76
3	68.35	457,295	-235,839	.08	0	**235,839**	.06	.91	.04	.07	.10	.05	.25	.65	2.62
4	68.12	177,189	-121,921	.13	.07	**15,965**	**105,956**	.68	.24	.15	.16	.03	.35	.52	2.39
5	67.27	111,685	-11,870	.46	.38	.20	**11,870**	.74	.62	.61	.58	.22	.58	1.03	1.54
6	67.37	377,423	-97,637	**64,717**	**32,920**	.03	.23	1.36	.20	.34	.29	.29	.47	.91	1.64
7	66.67	323,328	64,717												
8	65.81	145,821	185,530												
9	65.73	81,266	471,835												
10	65.93	132,801	178,346												
11	67.85	154,863	-60,519	.50	.38	.17	**60,519**	.33	.43	.31	.35	.12	.46	.32	2.12
12	68.57	70,985	-29,945	.67	.45	.17	.11	.13	.38	.20	.21	**19,432**	.10	**10,513**	2.84
13	67.27	114,306	-57,863	1.19	.88	.38	.19	**39,229**	.96	.63	.84	**18,634**	.60	.16	1.54
14	66.20	219,702	39,229												
15	65.22	24,328	46,042												
16	63.52	99,189	6,609												
17	64.36	26,079	3,558												
18	64.97	40,111	78,901												
19	64.17	22,456	5,585												
20	65.77	35,334	-14,098	3.86	2.92	2.26	2.30	2.19	2.11	.60	.67	.49	**5,585**	**8,513**	.04
21	63.88	329,173													
			U_i	.94	.08	0	.20	.47	-.51	-2.21	-1.37	-.76	-1.56	-1.85	

Total shipments (1,000 lbs.) = 1,099,378.
Total costs = $27,353,879.

Table 3.5—Regional Equilibrium Prices, Consumption, Surpluses and Deficits and Optimum Flows of Beef, 4th Quarter (October-December), 1955.

Region	Equil. Price	Equil. Cons.	Surplus and Deficit	Origins and Quantities of Shipments (1,000 lbs.)										
	cents/ pound	1,000 pounds	1,000 pounds	7	8	9	10	14	15	17	18	19	21	Vj
1	67.37	217,966	-177,554	.22	**119,627**	.05	.19	1.14	**53,223**	**4,704**	.11	.31	.69	2.93
2	67.20	383,058	-284,810	.08	0	**284,810**	.06	1.00	.02	.03	.14	.34	.73	2.76
3	67.06	454,624	-235,038	.08	**72,631**	**162,407**	.06	1.02	.04	.10	.16	.36	.76	2.62
4	66.83	176,167	-123,227	.13	.07	**42,955**	**80,272**	.79	.24	.16	.14	.46	.63	2.39
5	65.98	111,091	-22,490	.46	.38	.20	**22,490**	.85	.62	.58	.33	.69	1.14	1.54
6	66.08	375,364	-100,379	**69,011**	**31,368**	.03	.23	1.47	.20	.29	.40	.58	1.02	1.61
7	65.38	321,658	69,011											
8	64.52	145,130	223,626											
9	64.44	80,856	490,172											
10	64.64	132,161	183,948											
11	66.56	153,962	-71,640	.50	.38	.17	**71,640**	.44	.43	.35	.23	.57	.43	2.12
12	67.39	70,465	-33,999	.56	.34	.06	**9,546**	.13	.27	.10	**23,934**	.10	**519**	2.95
13	66.09	113,526	-61,160	1.08	.77	.27	.08	**5,576**	.85	.73	**55,584**	.60	.16	1.65
14	65.02	218,294	5,576											
15	63.93	24,211	53,223											
16	63.75	96,981	0											
17	63.07	25,956	4,704											
18	63.79	39,854	79,517											
19	62.99	22,295	4,935											
20	64.59	35,087	-15,576	3.75	2.81	2.15	2.19	2.19	2.00	.56	.49	**4,935**	**10,641**	.15
21	62.70	327,147	11,160											
			U_i	.94	.08	0	.20	.58	-.51	-1.37	-.65	-1.45	-1.74	

Total shipments (1,000 lbs.) = 1,125,872.
Total costs = $27,603,663.

and Oregon) was left out of the shipment matrix as a self-sufficient area for the fourth quarter.[4]

5. Summary of Quarterly Shipments: A summation of shipments for the four quarters of 1955 is presented in Table 3.6. These estimates provide a basis for determining the degree of distortion present in the more aggregative annual analysis for 1955.

In the aggregate, the four quarterly shipment programs differ from the annual shipment program in that Regions 10 (Kansas and Missouri) and 14 (Oklahoma and Texas) are indicated as shipping to Region 12 (Florida) and Region 9 (Iowa and Nebraska) ships to Region 4 (West Virginia, Virginia, and North Carolina). None of these three activities were included in the annual shipment program. Seasonal variation accounted for a slight increase (1,623 thousand pounds) of beef shipped under the regional breakdown considered. Aggregate transport costs for the quarterly programs are about 98 thousand dollars higher than estimated in the annual analysis. Relative to the magnitudes of total shipments and costs, there is a surprising consistency in the alternative estimates, which indicates that for the beef sector of the economy, the aggregative annual analysis for 1955 offers a good approximation.

Under no conditions could the annual analysis have yielded the shipment pattern presented in Table 3.6. This is due to the restriction that only $n + m - 1$ or, in this case, 20 activities may enter in a minimum shipment program. Thus, the larger transport cost estimate for the four quarterly programs taken jointly is logically consistent since 23 activities occur in the summation of quarterly shipments.

C. Models With Supply Unequal to Demand

Many problems amenable to spatial analysis require that the assumption of total supplies being equal to total demands be modified. Two such problems were posed in this research. The first was to assess the impact of a 90 per cent of parity farm support price on regional consumption, retail prices and flows of beef. The second involved a hypothetical 2 billion pound export program for beef.

1. Effect of a 90 per cent of parity support price — 1955: In 1955 the effective parity price for beef at the farm in 1955 was 21.20 cents.[5] If beef had been supported at ninety per cent of parity, the resulting farm price of beef would have been 19.08 cents per pound. The

[4]See Judge and Wallace (2, p. 38) for a discussion of omitting a self-sufficient region from the analysis.

[5]See reference (4).

Table 3.6—Summation of Optimum Quarterly Shipment Programs, (1955)

Origins / Dest.	7	8	9	10	14	15	16	17	18	19	21
1		316,765				179,156	11,968	20,843	156,743		
2		164,662	917,908								
3		187,794	720,980								
4			160,968	315,084							
5				82,546							
6	268,961	100,290									
11				255,264							
12				9,546	8,695				48,649		36,762
13					103,064				120,171		
20										22,717	30,394

Total shipments (1,000 lbs.) = 4,239,930.
Total costs = $104,854,775.

actual average price paid to farmers for beef in 1955 was 15.70 cents per pound. Thus, a 90 per cent of parity price support program would have raised farm price by 3.38 cents per pound and would have raised retail price by 7.30 cents per pound, using the dressing ratio of 1:2.16 pounds and assuming that marketing margins would have been unchanged. Under these assumptions and employing the price elasticity estimate of —.86, it was estimated that the U.S. average retail price of beef would have been 75.0 cents per pound for 1955 under a price support program of 90 per cent of parity. Using the same estimated price elasticity of demand for beef, it was then calculated that 74.4 pounds of beef per capita, would have been consumed in 1955 at this price. These estimates represented an increase in 1955 in price from 67.7 cents per pound and a decrease in consumption from 82.1 pounds per capita. Under the hypothetical parity farm prices, a surplus of 1,273 million pounds of carcass beef obtained. In order to handle government purchases in the equilibrium analysis, a slack vector or dummy destination was introduced in the spatial model to take up this surplus. Storage costs were taken as zero for all activities in the slack vector. An introduction of non-zero storage cost estimates would have made the analysis more realistic and could have changed the entire program. However, such estimates were not available.

Under the assumed conditions, equilibrium regional consumption and prices and optimum flows of beef are presented in the following table.

Assuming that a government purchasing system would have taken up the surpluses, farm receipts for mature beef under a 90 per cent of parity program for 1955 would have been approximately 4,738 million dollars. Actual farm receipts for mature beef in 1955 were about 3,899 million dollars. The government would have been required to purchase a surplus of 2,342 million pounds at an estimated expenditure of 447 million dollars if the surplus cattle had been purchased before slaughter. Additionally, there would have been processing, storage and distribution costs for the excess supply. Retail receipts were approximately 7,783 million dollars in 1955 and would have been approximately 7,810 million dollars under a 90 per cent of parity farm support program, provided that the surplus production was disposed of outside the retail marketing system.[6]

[6] It takes approximately 1.84 pounds of live mature beef to yield one pound of carcass beef. Similarly, it is estimated that one pound of retail cuts requires, on the average, 2.16 pounds of live cattle. Therefore, to obtain estimates of total receipts, the ratio of 1.84/2.16 is multiplied times carcass weight production and the resulting quantity multiplied times the U. S. average price. The average price estimates used are for choice beef, therefore, total receipt estimates may be somewhat high, but are useful in a comparative sense.

Table 3.7—Regional Equilibrium Prices, Consumption and Surpluses and Deficits and Optimum Flows of Beef, Assuming a 90 Per Cent Parity Support Price for 1955.

Region	Equil. Price	Equil. Cons.	Surplus and Deficit	Origins and Quantities of Shipments (1,000 lbs.)											
	cents/ pound	1,000 pounds	1,000 pounds	7	8	9	10	14	15	16	17	18	19	21	Vj
1	76.43	758,849	-610,139	.14	**610,139**	.05	.19	1.01	.51	2.21	1.37	.76	1.76	2.43	2.93
2	76.26	1,333,284	-949,501	**143,742**	**210,861**	**594,898**	.06	.87	.53	2.25	1.40	.79	1.79	2.47	2.76
3	76.12	1,582,303	-751,323	0	0	**751,323**	.06	.89	.55	2.28	1.47	.81	1.81	2.50	2.62
4	75.89	613,561	-415,470	.05	.07	**26,286**	**389,184**	.66	.75	2.36	1.53	.79	1.91	2.37	2.39
5	75.04	386,258	-43,840	.38	.38	.20	**43,840**	.72	1.13	2.82	1.95	.98	2.14	2.88	1.54
6	75.06	1,305,429	-238,563	**238,563**	.08	.11	.31	1.42	.79	2.63	1.74	1.13	2.11	2.84	1.56
7	74.37	1,117,385	382,305												
8	73.58	503,079	821,000												
9	73.50	280,326	1,828,735												
10	73.70	458,259	709,271												
11	75.62	536,137	-202,175	.42	.38	.17	**202,175**	.31	.94	2.52	1.72	.88	2.02	2.17	2.12
12	76.45	245,552	-79,232	.48	.34	.06	**74,072**	**5,160**	.78	2.30	1.47	.65	1.55	1.74	2.95
13	75.02	395,597	-183,804	1.13	.90	.40	.21	**183,804**	1.49	2.86	2.23	.78	2.18	2.03	1.52
14	73.95	758,633	188,964												
15	73.50	83,282	188,415												
16	73.50	332,956	54,581												
17	73.50	88,295	32,058												
18	73.50	136,944	341,018												
19	73.50	75,853	32,205												
20	74.79	119,922	-38,712	2.53	1.67	1.01	1.05	.92	1.37	1.56	.79	**38,712**	.31	.60	1.29
21	73.50	1,112,163	206,772												
		Surplus	1,272,617	.86	.08	**456,228**	.20	.45	**188,415**	**54,581**	**32,058**	**332,306**	**32,205**	**206,772**	0
			U_i	.86	.08	0	.20	.45	0	0	0	0	0	0	

Total shipments (1,000 lbs.) = 3,512,707.
Total costs = $81,306,890.

Results of the spatial analysis under the postulated conditions indicated that Regions 9, 15, 16, 17, 18, 19 and 20 "shipped" to the dummy destination. This indicates that surpluses in the amounts estimated would have accrued in these regions had a 90 per cent parity support price existed in 1955 and government purchases of the surplus cattle had taken place at slaughtering facilities. All of these except Region 9 (Nebraska and Iowa) retain their entire surplus of regional production over regional consumption. Although total receipts would be increased by an increased price, providing the demand for beef is inelastic, this analysis makes explicit the regions that would be at a relative disadvantage, and therefore, indicates the location and level regarding a corollary beef purchasing program that must or would be instituted. In this analysis, it is assumed that government purchases would occur at the place of slaughter. Alternatively, the purchase could take place before live cattle are shipped for slaughter. For example, if beef were purchased prior to movement for slaughter, Region 20 (Arizona and New Mexico) rather than Region 21 (California) probably would have provided the surplus beef for government purchase on the West Coast.

Note that the price differentials are zero for all regions that retain surpluses. This is due to the choice of the base region. If the base region had not retained a surplus, this would not have obtained. All regions that "shipped" to the surplus vector consequently have the same price (73.5 cents per pound).

Total flows of carcass beef throughout the free market would have been reduced under the initial 1955 program from 4,238 to 3,513 million pounds, subject to the regional demarcation considered. However, it should be noted that the surplus beef would have had to be slaughtered, and stored or distributed, through some government program.

This analysis provides an example of how decisions could be reached concerning the optimum location and level of government storage facilities under price-setting government purchase programs.[7] Given the level and location of government buying activities and certain designated geographical demands for the product, the transportation model could also be used to determine an optimum pattern of distributing the surplus beef.

2. The effect of a 2 billion pound beef export program, 1955: This

[7]For example, spatial models similar to the one used for the hypothetical parity price situation for beef could be employed under current price policy programs for corn and wheat in order to estimate the location and level of demand for storage facilities.

analysis began with the supposition that for political or other reasons the government had decided to export 2 billion pounds of beef in 1955. It was further assumed that government purchasing and exporting depots were established in Region 21 (California) and Region 1 (New England) for the purpose of buying and exporting 750 million and 1,250 million pounds of beef, respectively, at the two depots. Suppose further that no rationing programs or other such devices were employed but that prices were to be offered that would insure that the appropriate amounts would be forthcoming at each of the two export points. Subject to the underlying assumptions and the above suppositions, the spatial and price equilibrium model was used to determine the levels of the regional factors that would obtain, the prices that would have to be offered at each of the export depots and the optimum flows of beef among regions.

As indicated in Table 3.8, a price of about 87 cents per pound would have had to be offered at the West Coast depot while the price at the New England depot would have been required to be about 88 cents per pound to meet the requirements. The U. S. average price was estimated to be 86.7 cents per pound due to the restriction of average domestic per capita consumption to 70 pounds. These estimates are based on the assumption that production was pre-determined at the 1955 level.

Under the hypothetical program, the California export depot received shipments from Regions 16, 17, 18, 19 and 21 in the optimum flow solution. The New England depot received its quota from Regions 8, 9, 15 and 18. Note that the price differentials and, consequently, the prices are the same for Region 21 and the California export depot and also are equal for Region 1 and the New England export depot. This is due to the assumption that demands are concentrated at a point within each region. The reader may be interested to note the large number of alternative optima for this program indicated by the appearance of zeros in Table 3.8.

The transportation costs for this hypothetical program are estimated to be about 16 million dollars more than for the initial 1955 program. Total shipments are greater by about 860 million pounds.

Under the hypothetical program, retail receipts would have been about 9,962 million dollars. This is about 2 billion dollars more than actual retail receipts in 1955. Using the price estimates of 87.06 cents per pound at the West Coast export depot and 88.03 cents per pound at the New England export depot, government expenditures for the 2

Table 3.8—Regional Equilibrium Prices, Consumption, Surpluses and Deficits and Optimum Flows of Beef, 1955, Assuming a Two Billion Pound Beef Export Program

Region	Equil. Price	Equil. Cons.	Surplus and Deficit	Origins and Quantities of Shipments (1,000 lbs.)											
	cents/ pound	1,000 pounds	1,000 pounds	7	8	9	10	14	15	16	17	18	19	21	Vj
1	88.03	715,471	-566,761	.09	**66,761**	0	.08	.59	0	2.36	.85	0	2.25	4.39	2.98
2	87.81	1,257,190	-873,407	**286,819**	.05	**421,003**	**165,585**	.50	.07	2.45	.93	.08	2.33	4.48	2.76
3	87.67	1,491,903	-660,923	0	.05	**660,923**	0	.52	.09	2.48	1.00	.10	2.35	4.51	2.62
4	87.38	579,015	-380,924	.11	.18	.06	**380,924**	.35	.35	2.62	1.12	.14	2.51	4.44	2.33
5	86.53	363,950	-21,532	.44	.49	.26	**21,532**	.41	.73	3.08	1.54	.33	2.74	4.95	1.48
6	86.61	1,228,905	-162,039	**162,039**	.13	.11	.25	1.05	.33	2.83	1.27	.42	2.65	4.85	1.56
7	85.91	1,050,832	448,858												
8	85.18	472,269	851,810												
9	85.05	263,231	1,845,830												
10	85.19	430,759	736,771												
11	87.11	505,760	-171,798	.48	.49	.23	**168,730**	**3,068**	.54	2.78	1.31	.23	2.62	4.24	2.06
12	87.63	232,649	-66,329	.85	.76	.43	.31	**66,329**	.69	2.87	1.37	.31	2.46	4.12	2.58
13	86.20	374,248	-162,455	1.50	1.32	.77	.52	**162,455**	1.40	3.43	2.13	.44	3.09	4.41	1.15
14	85.13	715,745	231,852												
15	84.59	78,615	193,082												
16	85.25	312,117	75,420												
17	84.58	83,323	37,030												
18	84.34	129,530	348,432												
19	85.59	70,846	37,212												
20	85.63	113,747	-32,537	3.24	2.43	1.72	1.70	1.26	1.62	2.47	1.03	**32,537**	1.56	3.32	.58
21	87.06	1,026,526	292,409												
California Export Depot		87.06	-750,000	2.97	2.07	1.49	1.46	1.22	1.07	**75,420**	**37,030**	**307,929**	**37,212**	**292,409**	2.01
New England Export Depot		88.03	-1,250,000	.09	**285,049**	**763,904**	.08	.59	**193,082**	2.36	.85	**7,966**	2.25	4.39	**2.98**
			U_i	.86	.13	0	.14	.08	-.46	.20	-.47	-.71	.54	2.01	

Total shipments = 5,098,706.
Total costs = $120,788,396.

billion pounds of slaughtered beef would have been about 1,494 million dollars. By deducting expected receipts from foreign sales from this estimate, net expenditures for the program could be estimated. Analyses such as this could be used to estimate the domestic economic consequences of government purchase programs which then move products through international channels by such devices as export subsidies or dumping. Given foreign demands for a product, the transportation model could also be used to estimate the optimum location of export depots as well as the amount of product each depot should optimally handle.

D. Optimum Live Shipment Flows, 1955

The initial 1955 program dealt with optimum flows of carcass beef. A considerable amount of movement of slaughter cattle occurs prior to actual slaughter. Therefore, the following analysis was accomplished to establish optimum flows of live cattle for slaughter given regional levels of production and slaughter in 1955, and to estimate the associated transport costs involved. Excess supplies and demands for slaughter cattle in each region were determined by differencing regional slaughter and regional farm production for slaughter. The latter data were estimated by multiplying regional farm production of beef by the ratio of total farm production to total slaughter. The conversion ratio of 1.84 pounds was used to convert carcass weight to live weight estimates. If subtracting slaughter from farm production for slaughter resulted in a negative quantity for some region, the region was classified as deficit in live cattle for slaughter and designated as a demander. Conversely, positive differences indicated surplus regions in live cattle. Live weight transport costs among regions were determined from equation (2.5), Section II.[8]

Optimum flows of live cattle for slaughter, 1955, are presented in Figure 2. The table from which the figure was taken is presented in Appendix B. These results make explicit the importance of Regions 3, 6, 7 and 21 as slaughtering centers of beef produced in other areas. The results further indicate that Regions 6, 7, 8, 9, 16 and 21 are deficit in live cattle for slaughter, but surplus in carcass beef (see the initial 1955 solution, Table 3.1). Conversely, Regions 4, 5, 11, 13 and 20 were surplus in live cattle for slaughter but were deficit in processed beef. However, the only direct cross-hauling of live cattle and finished beef that was discerned in the analysis involved Regions 20 and 21. According to the optimum live cattle shipment program, cattle were

[8]See Table A-2, Appendix A for estimated live cattle transport costs among all 21 regions.

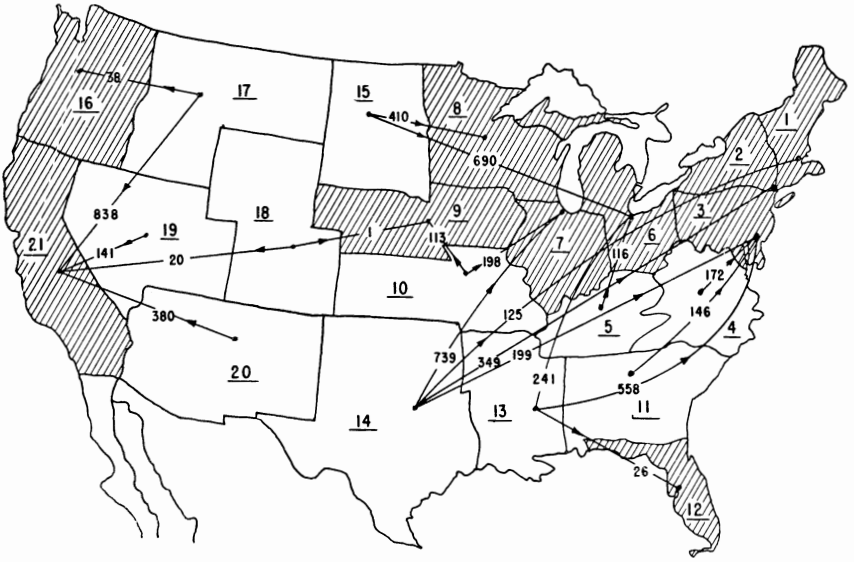

Fig. 2 Optimum Live Cattle for Slaughter Shipments (Million Pounds) 1955

shipped from Arizona and New Mexico into California and the initial 1955 beef shipment program (Table 3.1) indicates that carcass beef was shipped from California to New Mexico and Arizona.

Total live shipments are estimated at about 5.5 billion pounds for 1955. This is equivalent to about 3 billion pounds, carcass weight. This amount, added to the estimate of total carcass shipments (Table 3.1) yields an estimate of 7.2 billion pounds total shipment for 1955, under the regional demarcation considered. Total costs for shipping this 7.2 billion pounds of beef were estimated to be approximately 183 million dollars ($105 millions for carcass beef and $78 millions for live cattle).

Total retail receipts were approximately 7.8 billion dollars in 1955. Therefore, the per cent of transportation costs of total receipts was 2.35 per cent, based on the above estimates. As a percentage of total receipts, live and carcass beef transport costs are 1.00 and 1.35 per cent, respectively. These estimates are probably too small due to the aggregative nature of the regional demarcation. Also, they are based on optimum rather than actual shipments. As a basis of comparison, the reader may find alternative estimates of the per cent of transport costs of the retail price of beef for 1955 in a U. S. Department of Agriculture publication (1). However, the estimates available in this publication were derived by making case studies of the stages of production and marketing of steers, rather than from a normative model.

E. Spatial and Price Equilibrium Model, Assuming Slaughter Is Market Oriented

In the previous bulletin (2, pp. 35-36), a spatial equilibrium solution was obtained based on the assumption that slaughter was production oriented; therefore, all interregional beef movements were of carcass form. Alternatively, beef could be shipped live and slaughtered at the consuming center. To assess the effect of market-oriented slaughter on regional prices, consumption and optimum flows, as well as total shipment costs, the following analysis was accomplished.

The U_i and V_j in Table 3.10 are, in this case, live animal price differentials relative to Region 9. For example, in equilibrium, the cost of live animals would have been 23 cents per hundred pounds less in Oklahoma and Texas than in Iowa and Nebraska if slaughter had been market oriented in 1955. To obtain the equilibrium retail price differentials, the U_i and V_j must be multiplied by the live weight to carcass ratio of 1.84 pounds before adding to the base price. Thus, the retail price differential between, say, Region 1 and Region 9 is (1.89) $\times$ (1.84) or 3.48 cents per pound. The retail price differential between these two regions as given by the initial 1955 analysis was 2.93 cents per pound. The difference in the retail price differentials derived from the alternative programs is due to the relatively higher cost of shipping live cattle rather than carcass meat. Due to the differences in regional price differentials, the pattern of shipment is somewhat different between the market-oriented and production-oriented programs. For example, one region (Washington and Oregon) changed from surplus, assuming production-oriented slaughter, to deficit, assuming market-oriented slaughter.

The total costs of shipment for this program were about 183 million dollars and a total of 11 million pounds of live cattle was shipped. This represents an average cost of 1.61 cents per pound shipped. Converting from live weight to carcass weight, an estimate of 6,044 million pounds of total shipment was obtained. The production-oriented program yielded a total shipment estimate of 6,059 million pounds. The smaller total shipments for the market-oriented program are due to the relatively higher transport costs for shipping live cattle. The next section (F) is devoted to comparing shipment costs among the alternative programs.

Shipment costs for live cattle (adjusted to carcass weight equivalence) and for carcass beef, and the activities appearing in the market-oriented equilibrium analysis, provide a basis for assessing necessary

Table 3.9—Regional Equilibrium Prices, Consumption, Surpluses and Deficits and Optimum Flows, 1955, Assuming that Slaughter Is Market Oriented

Region	Equil. Price	Equil. Cons.	Surplus and Deficit	Origins and Quantities of Shipments (1,000 lbs.)											
	cents/ pound	1,000 pounds	1,000 pounds	8	9	10	13	14	15	17	18	19	20	V_j	(1.84) V_j
1	69.67	1,533,688	-1,384,841	.01	**575,276**	.04	.25	.10	0	**191,442**	**618,123**	.94	.45	1.89	3.48
2	69.48	2,696,960	-2,339,682	.01	**454,424**	.01	.14	**456,832**	**1,428,426**	.01	.01	.95	.43	1.79	3.29
3	69.34	3,199,709	-2,745,457	**999,894**	0	**874,649**	.14	**870,914**	.01	.05	.01	.96	.44	1.71	3.15
4	68.89	1,242,859	-706,685	.12	.04	**647,712**	**58,973**	.04	.23	.17	.09	1.11	.44	1.47	2.70
5	67.97	784,183	-38,495	.34	.19	.04	.12	**38,495**	43	.39	.20	1.20	.61	.97	1.78
6	68.25	2,644,512	-1,727,565	.03	**1,727,565**	.07	.41	.28	.06	.12	.26	1.05	.55	1.12	2.08
7	67.79	2,259,325	-436,858	.02	**436,858**	.10	.53	.32	.12	.17	.11	1.12	.61	.87	1.60
8	66.36	1,025,928	999,894												
9	66.19	572,462	3,194,123												
10	66.32	936,321	1,522,361												
11	68.14	1,094,611	-334,590	.57	.38	.27	**334,590**	.35	1.02	.53	.39	1.14	.61	1.06	1.95
12	68.64	502,929	-222,686	.80	.58	.51	.04	**222,686**	.29	.64	.50	1.38	.70	1.33	2.45
13	66.58	821,269	393,563												
14	65.77	1,566,756	1,588,927												
15	65.64	171,522	1,428,426												
16	66.69	675,623	-472	1.97	1.85	2.09	2.74	2.00	1.23	**472**	1.04	.84	1.38	.27	.50
17	64.61	184,099	912,041												
18	65.34	282,680	618,123												
19	65.88	155,501	184,560												
20	65.45	251,555	277,883												
21	67.74	2,231,314	-1,182,571	1.77	1.39	1.35	1.77	.98	1.16	**720,128**	.58	**184,560**	**277,883**	.84	1.55
			U_i	.09	0	.07	.21	-.23	-.30	-.86	-.46	-.17	-.40		
			(1.84) U_i	.16	0	.13	.39	-.42	-.55	-1.58	-.85	-.31	-.74		

Total shipments= 11,121,126.
Total costs = $182,615,411.

differences in processing costs between regions, if slaughter is to be consumer oriented. For example, if a deficit region imports cattle for slaughter, rather than importing carcass beef, the processing costs in the deficit region must be at least k cents per pound less than in the surplus region, where

$$T_{ij} - C_{ij} = k > 0.$$

The symbol C_{ij} represents the unit cost of shipping carcass meat from region i to region j and T_{ij} is the unit cost of shipping live cattle (adjusted by the dressing ratio). Therefore, minimum processing cost differentials can be established that would be necessary to a market-oriented system of slaughter, by differencing the adjusted live cattle shipment costs and the carcass beef shipment costs for those activities that occur in the market-oriented shipment program. The estimates of minimum processing cost differentials that were obtained in this manner are presented in Table 3.10.

Table 3.10—Minimum Regional Processing Cost Differentials Necessary to Market-Oriented Slaughter (Cents per Hundred Pounds)

Origins / Distribution	8	9	10	13	14	15	17	18	19	20
1		50					76	63		
2		53			54	56				
3	44		54		51					
4			39	40						
5					40					
6		39								
7		38								
11				37						
12					37					
16							41			
21							65		39	39

Each number appearing in the Table 3.10 represents the processing cost advantage that must obtain in the deficit region (destination) requisite to a shipment of live cattle rather than processed beef, assuming pure competition. For example, the processing cost in Region 1 (New England) would have to be at least 50 cents per hundred pounds less than in Region 9 (Iowa and Nebraska) in order that the cattle be shipped live rather than as carcass beef. Likewise, the slaughtering costs in New York would have to be at least 54 cents per pound less than in Oklahoma and Texas. Figure 3, appearing in the following section, indicates how the results of the optimum live cattle and carcass beef shipment programs may be used to obtain a rough idea of how

slaughtering costs must differ in order that the existing complex of slaughtering plants be perpetuated, assuming no shifts in regional production.

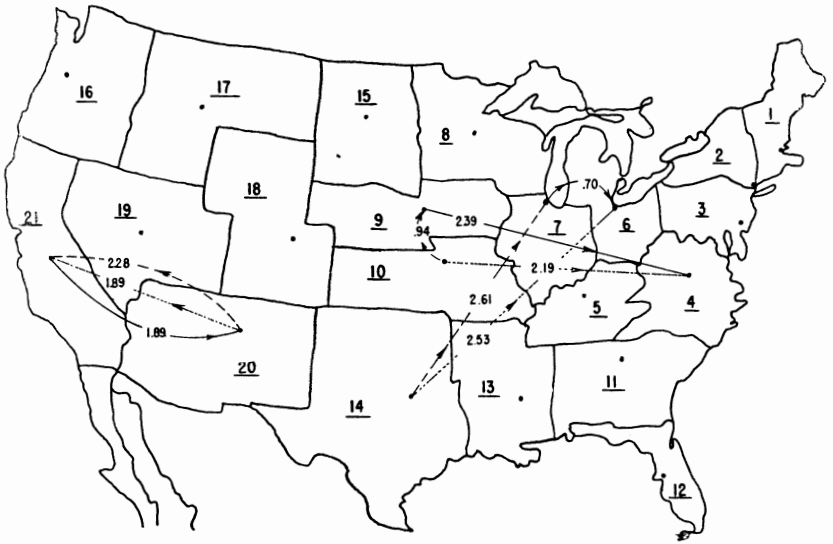

Fig. 3 Examples of the Inefficiency of Live Cattle and Carcass Beef Movements, 1955

F. Comparison of Shipment Costs Among Alternative Programs

Thus far, shipment programs have been presented for live cattle and carcass meat in 1955, and for live cattle, assuming that slaughter was market oriented. In the previous bulletin (2), an optimum shipment program for carcass beef was derived, assuming that slaughter was production oriented. Total shipments and total costs that resulted from each of these analyses are presented in Table 3.11.

Table 3.11—Total Costs and Shipments, Alternative Programs, 1955

Optimum Programs	Total Costs (Dollars)	Total Shipments (1,000 lbs.)
Actual 1955 carcass beef	104,756,372	4,238,307
Actual 1955 live cattle	77,984,801	2,987,954[1]
Total Actual, 1955	182,741,173	7,226,261
Market-Oriented Slaughter	182,615,411	6,044,090[1]
Production-Oriented Slaughter	152,348,777	6,058,622

[1]Converted to carcass weight equivalent

As evidenced by the tables, transport costs for production-oriented slaughter are some 30 million dollars less than either of the other programs. Also, costs for the market-oriented slaughter program are slightly less than total shipment costs estimated from the 1955 carcass and live cattle optimum shipment programs. This is rather surprising, since live cattle shipment costs are relatively larger than carcass costs. However, the average transportation cost for the 1955 programs that recognize existing processing plant location was 2.53 cents per pound while average cost for the market-oriented program was 3.02 cents per pound. This points up the indirect movements that must occur within the existing matrix of processing plants, production and consumption, even employing an optimum shipment program at the two stages of production. Three examples of the indirect movements inherent in the system are illustrated in Figure 3.

The dashed lines in Figure 3 represent movements of live cattle as indicated by the optimum shipment program for live cattle (Figure 2). The solid lines were derived from the optimum shipment program for carcass beef, while the dotted lines represent alternative direct shipments of carcass beef from the producing to the consuming regions, provided that beef was slaughtered in the region where produced. The numbers appearing in the breaks in the lines are unit carcass shipment costs in cents per pound in the case of carcass beef shipments and represent live shipment costs adjusted by the dressing ratio (1:1.84) as they appear in conjunction with the dashed lines.

As indicated in the figure, cattle could have been slaughtered in Region 14 (Oklahoma and Texas) and shipped directly to Region 6 (Ohio and Michigan) at a cost of 2.53 cents per pound. The optimum two-stage shipment of live beef from Region 14 to Region 7 (Illinois and Indiana) and carcass beef from Region 7 to Region 6 incurs a cost of 3.31 cents per pound. Also, if cattle had been slaughtered in Region 10 (Kansas and Missouri) and shipped directly to Region 4 (West Virginia, Virginia and North Carolina), a per unit saving of approximately (3.33 — 2.19), or 1.14 cents could have been realized for that amount of beef involved in the two-stage shipment.

The only case of direct cross-hauling of live cattle and carcass beef discerned in the analyses involved Region 21 (California) and Region 20 (New Mexico and Arizona), (see Figure 3). This cross-hauling involved a total per unit cost of 4.17 cents, whereas the beef could have been slaughtered in Region 20 and shipped directly at a per unit cost of 1.89. Table 3.1 indicates that Region 21 should have shipped 30,393

thousand pounds of carcass beef to Region 20, and Table 3.10 shows a shipment of 380,012 pounds of live beef from Region 20 to 21. This involves a total of 5.3 million dollars in transport costs. Had Region 20 slaughtered all of its production and shipped the surplus to California, a transport cost of only 2.9 million dollars would have resulted in a saving of 2.4 million dollars.

Obviously, a great amount of feeding and finishing goes on that requires such indirect movements, but these analyses were restricted to slaughter cattle. Also, regional production varies from year to year and a production-oriented slaughtering system from year to year might not be feasible. Another explanation could be that scale effects of centrally located processing may be enough to offset the associated larger transport costs. The tendency over time, however, should be toward production-oriented slaughter, to the extent that the tenets of equilibrium theory are true for the beef slaughtering industry.

IV Summary and General Implications

Since specific implications of the results were discussed in conjunction with each appropriate analysis in the preceding chapter, this section will be devoted to briefly summarizing the research and to pointing up general implications for the particular problem areas and for future research.

This research was directed toward (1) a description of the spatial aspects of the beef marketing sector of the economy and (2) spatial price-equilibrium analyses relating to economic consequences of particular situations and disturbances. In a previous bulletin (2), annual spatial and price equilibrium models for beef were established for the years 1947, 1952, and 1955 and the effect of disturbances such as increases and decreases in transportation costs on the basic factors was assessed. With this groundwork laid, this research was extended to evaluate quarterly models for 1955, determine optimum live cattle shipments for slaughter, and to assess the impact of a wider range of disturbances on the basic factors involved. The particular problems investigated within the latter classification included analyses of (1) a 90 per cent parity support price for beef, (2) a hypothetical 2 billion pound export program, and (3) a market-oriented slaughtering system. In each case, the estimated models provide an indication of both the direction and magnitude of the changes involved.

Although beef output and demand varies by quarters, disaggregation

in the time dimension yielded a limited amount of information regarding prices, consumption and flows over and above that contained in the annual 1955 spatial model. The model depicting a postulated 90 per cent parity price support program for beef yielded information relative to the levels of regional beef consumption and the location and level of government purchases. Additional returns to producers under the postulated program were also estimated and suggestions were made as to how spatial equilibrium models might be used in order to estimate level and location of demand for storage services for such crops as corn and wheat.

The analysis of live beef shipments made explicit the present inefficient locational matrix of slaughtering plants. Evidence was presented relative to the indirect movement of live cattle for slaughter and, in the case of California, Arizona and New Mexico, the results indicated that direct cross-hauling of live and carcass beef obtained between these points. The transportation cost advantage of production-oriented slaughter was estimated and this saving indicates that, in all probability, the trend toward slaughter being oriented toward production will continue. This should lead to an expansion of slaughtering activities in the south and west. The expansion in these areas will, of course, be conditioned by the geographical volume of supplies and the economies of scale associated with the processing of meat.

In regard to potential areas of research, it should be noted that this study was limited in that production of beef was taken as pre-determined; therefore, the effect of changes could be traced back only to the shipment of live cattle for slaughter. Given the locational matrix of the resources of production of feedstuffs, cattle and of the slaughtering operation and the spatial array of demands for beef, a more thorough research job could be done by establishing models that include all activities of production.

Also, many pertinent questions would fail to be answered satisfactorily by the models considered due to the level of aggregation involved. Some problems would require that individual states or perhaps even smaller geographic entities be treated as regions. Also, the assumption that price and income elasticities of demand for beef were equal for all regions fails to permit regional diversity regarding response relationships. Until less aggregative data become available, these restrictions and others will be unsurmountable.

Despite the restrictions involved, this study provides indication (1) of the wide range of problems that can be attacked through the use of

alternative variations of spatial price equilibrium models and (2) makes explicit the economic consequences of alternative situations, thus providing a basis for decision making or action on the government and firm levels.

References*

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(2) Judge, G. G. and Wallace, T. D., "A Spatial Price Equilibrium Analysis of the Beef Marketing System," Oklahoma Agricultural Expt. Sta. Tech. Bul. T-78 Oklahoma State University, Stillwater, Oklahoma June 1959.

(3) Koopmans, T. C. (Ed.), **Activity Analysis of Production and Allocation,** Cowles Commission Monograph No. 13, New York: John Wiley and Sons, 1951. Pp. 33-97.

(4) "The Livestock and Meat Situation," Agricultural Marketing Service, U. S. D. A., Washington, D. C., May, 1957. P. 20.

(5) Samuelson, P. A., "Spatial Price Equilibrium and Linear Programming," **The American Economic Review,** Vol. 42. Pp. 283-303, 1952.

(6) Wallace, T. D. and Judge, G. G., "Econometric Analysis of the Beef and Pork Sectors of the Economy," Oklahoma Agr. Expt. Sta. Tech. Bul. T-75, Oklahoma State University, Stillwater, Oklahoma, August 1958.

*For a more complete bibliography on spatial price equilibrium analysis and its application, see reference (2, pp. 47-48).

APPENDIX A–Estimated Transport Rates for Fresh Beef and Live Cattle

The estimates of transport rates used in this study are presented for the interested reader in the following tables. Estimated rates for fresh carcass beef are given in Table A.1, and rates for live cattle are presented in Table A.2. For a description of the derivation of the estimates, see Chapter II.

Table A.1—Estimates of Transport Rates for Fresh Beef between Specified Points, By Regions, United States[1]

Region 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Cents per Pound or Dollars per 100 lbs.																				
1 0	.67	.87	1.63	2.41	1.77	2.21	2.85	2.98	2.92	2.38	2.86	3.04	3.49	3.44	5.14	4.30	3.69	4.69	4.29	5.36
2	0	.35	1.19	2.00	1.46	1.90	2.68	2.76	2.62	2.00	2.53	2.72	3.18	3.29	5.01	4.16	3.55	4.55	4.11	5.23
3		0	1.00	1.85	1.31	1.76	2.54	2.62	2.48	1.83	2.40	2.59	3.06	3.17	4.90	4.09	3.43	4.43	4.00	5.12
4			0	1.21	1.24	1.58	2.38	2.39	2.19	1.16	1.81	1.92	2.60	3.14	4.75	3.92	3.18	4.30	3.62	4.76
5				0	1.13	1.06	1.84	1.74	1.34	.89	1.83	1.23	1.81	2.67	4.36	3.49	2.52	3.68	3.04	4.42
6					0	.70	1.56	1.67	1.67	1.61	2.50	2.03	2.53	2.35	4.19	3.30	2.69	3.67	3.26	4.40
7						0	1.10	1.22	1.27	1.68	2.57	1.79	2.22	1.98	3.89	2.99	2.28	3.40	2.96	4.12
8							0	1.00	1.18	2.42	3.21	2.34	2.22	1.16	3.38	2.39	1.97	3.16	2.88	3.95
9								0	.63	2.29	3.01	1.92	1.65	1.44	3.33	2.44	1.35	2.62	2.30	3.50
10									0	1.92	2.75	1.53	1.34	1.83	3.59	2.67	1.50	2.90	2.14	3.33
11										0	1.20	1.19	1.98	3.06	4.64	3.84	3.00	4.14	3.26	4.29
12											0	1.73	2.50	3.73	5.25	4.42	3.60	4.50	3.82	4.69
13												0	1.07	3.01	4.38	3.75	2.30	3.70	2.52	3.55
14													0	2.56	3.92	3.24	1.78	3.00	1.76	3.15
15														0	2.84	1.61	1.70	2.63	2.66	3.54
16															0	1.67	2.79	1.96	2.85	1.81
17																0	1.88	1.53	2.08	2.48
18																	0	1.76	1.29	2.72
19																		0	1.60	1.47
20																			0	1.89
21																				0

[1]These rates were estimated by using equations (2.3) and (2.4) in the text.

Table A.2—Estimates of Transport Rates for Live Beef between Specified Points, By Regions, United States[1]

Region	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
									Cents per Pound or Dollars per 100 lbs.												
1	0	.54	.66	1.10	1.58	1.18	1.41	1.81	1.89	1.86	1.51	1.81	1.93	2.22	2.19	3.30	2.75	2.35	3.00	2.74	3.44
2		0	.31	.85	1.30	1.01	1.25	1.71	1.79	1.73	1.30	1.60	1.72	2.02	2.09	3.21	2.66	2.26	2.91	2.62	3.36
3			0	.74	1.22	.92	1.17	1.62	1.71	1.64	1.21	1.52	1.64	1.94	2.02	3.14	2.62	2.18	2.84	2.55	3.29
4				0	.87	.88	1.08	1.50	1.51	1.40	.84	1.20	1.26	1.74	2.00	3.05	2.50	2.02	2.75	2.31	3.05
5					0	.82	.78	1.22	1.16	.94	.68	1.21	.88	1.20	1.70	2.79	2.22	1.63	2.34	1.98	2.83
6						0	.55	1.06	1.12	1.12	1.09	1.66	1.32	1.63	1.48	2.68	2.10	1.84	2.34	2.07	2.82
7							0	.80	.87	.90	1.13	1.70	1.19	1.42	1.29	2.48	1.90	1.44	2.16	1.88	2.64
8								0	.74	.85	1.54	2.04	1.52	1.42	.84	2.15	1.53	1.29	2.04	1.90	2.52
9									0	.51	1.44	1.91	1.26	1.11	1.00	2.12	1.55	.95	1.73	1.46	2.23
10										0	1.26	1.77	1.05	.94	1.94	2.29	1.69	1.03	1.93	1.38	2.12
11											0	.86	.85	1.64	2.38	2.97	2.45	1.91	2.64	2.07	2.74
12												0	1.16	1.56	1.92	3.37	2.83	2.29	2.88	2.43	3.01
13													0	.78	1.73	2.80	2.39	1.61	2.36	1.66	2.40
14														0	1.59	2.50	2.06	1.18	2.02	1.17	2.05
15															0	1.80	1.09	1.14	1.80	1.95	2.30
16																0	1.13	1.77	1.28	2.05	1.20
17																	0	1.24	1.05	1.34	1.70
18																		0	1.17	.91	1.88
19																			0	1.08	1.01
20																				0	1.24
21																					0

[1]These rates were estimated by using equation (2.5) in the text.

Appendix B—Optimum Flows of Live Beef for Slaughter, 1955

Appendix Table B.1—Optimum Flows of Live Beef for Slaughter, 1955

Deficit Regions	Surplus Regions											Total Demand (1,000 pounds)	V_j
	4	5	10	11	13	14	15	17	18	19	20		
1	.08	.16	.16	.02	.01	**124,780**	.11	.79	.21	1.73	1.24	124,780	1.19
2	.03	.08	.23	.01	0	**348,882**	.21	.90	.32	1.84	1.32	348,882	.99
3	**171,687**	.08	.22	**145,531**	**558,441**	**199,094**	.22	.94	.32	1.85	1.33	1,074,751	.91
6	.46	**115,638**	.02	.20	**240,906**	.01	**689,542**	.74	.30	1.67	1.17	1,046,086	.59
7	.86	.16	**197,615**	.44	.07	**739,348**	.01	.74	.10	1.69	1.18	936,963	.39
8	1.72	1.04	.39	1.29	.84	.44	**410,484**	.81	.39	2.01	1.64	410,484	-.05
9	1.68	.93	**112,811**	1.14	.53	.08	.11	.78	**1,276**	1.65	1.15	114,087	0
12	.94	.55	.83	.13	**25,786**	.10	.60	1.63	.91	2.37	1.69	25,786	.43
16	2.86	2.20	1.42	2.31	1.71	1.11	.55	**37,917**	.46	.84	1.38	37,917	.36
21	2.29	1.67	.68	1.51	.74	.09	.48	**836,773**	**20,077**	**141,235**	**380,012**	1,378,097	.93
Total Supplies (1,000 lbs.)	171,687	115,638	310,426	145,531	825,133	1,412,104	1,100,026	874,690	21,353	141,235	380,012	5,497,835	
U_i	.17	-.23	-.51	-.30	-.73	-1.03	-.89	-.77	-.95	-.08	-.31		

Total costs = $77,984,801.

12-59/1¾M