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Joint Spatial Analysis of Regional Slaughter and the Flows and Pricing of Livestock and Meat

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NORTH CENTRAL REGIONAL
RESEARCH BULLETIN NO. 163

SPATIAL STRUCTURE of the LIVESTOCK ECONOMY

III. Joint Spatial Analysis of Regional Slaughter and the Flows and Pricing of Livestock and Meat



Agricultural Experiment Stations of
Illinois Minnesota
Indiana Missouri
Iowa Nebraska
Kansas North Dakota
Kentucky Ohio
Michigan South Dakota
 Wisconsin
and the United States Department of
Agriculture, cooperating

Agricultural Experiment Station
South Dakota State University
Brookings, South Dakota

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FOREWORD

Thirteen Agricultural Experiment Stations in the Midwest joined in a research project entitled "Adjustments in Livestock Marketing in the North Central States to Changing Patterns of Production and Consumption." Agricultural economists, whose names appear in the previous listing of state committee members, have made extensive analyses of data on the geographical movement of livestock and meat in the United States in 1955 and 1960 and have made projections for future years. This publication is one of a series emanating from these studies.

Because of the large number of farms and businesses engaged in providing the Nation's meat supply and the importance of meat in the American diet, this study should have widespread significance. In a dynamic society in which the human population is migrating from rural to metropolitan areas and in which some metropolitan areas grow more rapidly than others, there must be a continuous change in the ultimate destination of the meat supply. Likewise, as farm technology and production patterns change, there is a continuous change in the sources of supply. Businesses and industries engaged in the marketing, processing and distribution of livestock and meat must continuously adjust to these changing conditions. Studies that throw light on these changes can provide valuable information to those who must make decisions in these business operations. It is those farmers and ranchers, marketing and transportation agencies, processors, wholesalers and retailers who are engaged in the complex livestock and meat industry that the study is addressed.

C. PEAIRS WILSON
Administrative Adviser

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III. Joint Spatial Analysis of Regional Slaughter and the Flows and Pricing of Livestock and Meat*

R. L. RIZEK, G. G. JUDGE, and J. HAVLICEK†

I. INTRODUCTION

In the previous two bulletins of this series, the pricing and flows of slaughter livestock and meat were treated as independent activities for analysis purposes. The first bulletin of this series is concerned with the spatial flows, costs of transportation, and relative price differentials of beef, veal, pork, and lamb and mutton among 26 regions of the U. S. for 1955 and 1960. Regional levels of consumption were estimated and reported regional levels of commercial slaughter were used as available quantities of meat.

Attention was focused on determining the optimum flow patterns (least cost flows) and costs of transportation of meat from slaughter to consumption and the associated relative price differentials of meat among the regions. In the first bulletin, flow patterns of live slaughter animals and their possible effects on the flow patterns and transportation costs of meat were not considered.

The second bulletin of this series is concerned with spatial flows, transportation costs, and relative price differentials of slaughter cattle, calves, hogs, and sheep and lambs among 26 regions of the U. S. for 1955 and 1960. Quantities of production for slaughter purposes were generated for each of the 26 regions and reported commercial slaughter data were used as the quantities demanded in each of the regions. Emphasis was placed on deriving least cost flow patterns, costs of transportation, and relative price differentials among regions for each type of slaughter livestock. These analyses were performed independently of the transportation costs, consumption levels, and flow patterns of meat.

In practice the location of slaughter and the pricing and flows of slaughter livestock and meat are interdependent and jointly determined. The solutions of the types of analyses performed in the first two bulletins of this series are usually not optimal if the flows of live slaughter animals and meat are consid-

ered simultaneously. These are two different types of problems with different objectives. This study is concerned with a joint spatial analysis of live slaughter cattle and hog and beef and pork flows for 1955 and 1960. The purpose of this study is to (1) develop a model to handle the simultaneous solution for the processing and flow problem, (2) develop estimates of slaughtering capacity for cattle and hogs in each region, and (3) apply the model using estimates of regional levels of production, regional levels of consumption, regional slaughtering capacities, and transportation costs of live slaughter animals and meats. **Attention is focused at determining what regional levels of slaughter and directions and levels of inter-regional livestock and meat flows satisfy the regional production, consumption, and capacity constraints and make the total cost of transportation of live slaughter animals and meat a minimum.** The analysis is broadened to also obtain the impacts of alternative regional slaughter capacity restrictions and regional differences in the labor cost of slaughtering livestock.

*This is the third in a series of three North Central regional bulletins concerned with the spatial structure of the livestock marketing system. The studies are concerned with estimating the regional level and location of livestock production, slaughter, and meat consumption and deriving the competitive prices and flows of livestock and meat in 1955 and 1960. The two previous studies reported in this phase of the regional effort are:

1. Judge, G. G., Havlicek, J., and Rizek, R. L., Spatial Structure of the Livestock Economy, "I. Spatial Analyses of the Meat Marketing Sector in 1955 and 1960," North Central Livestock Regional Research Bulletin No. 157, South Dakota State University, Brookings, South Dakota, (Experiment Station Bulletin 520).
2. Havlicek, J., Rizek, R. L., and Judge, G. G., Spatial Structure of the Livestock Economy, "II. Spatial Analyses of the Flows of Slaughter Livestock in 1955 and 1960," North Central Livestock Regional Research Bulletin No. 159, South Dakota State University, Brookings, South Dakota, (Experiment Station Bulletin 521).

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II. THE MODEL

A. Assumptions

As a point of departure consider a multi-regional livestock industry that has the following simple structure: we are given in each of n regions a known non-negative quantity of four types of livestock (cattle, hogs, calves and sheep and lambs) for a time period t . Each type of livestock as it passes through a slaughtering plant is converted into the consumable products, beef, pork, veal, lamb and mutton. The rate (dressing percentage) at which each type of livestock may be transformed into a consumable product is known for each region, product, and time period. Each of the meat products is consumed in a non-negative quantity in each of the n regions and the regional consumption for each type of meat is known for time period t . Each region has some non-negative capacity for slaughtering each type of livestock and these capacities are known for any time period t . Processing costs per physical unit for slaughtering each type of livestock are known in time period t for each region. All possible pairs of regions are separated by a transport cost per physical unit of each type of livestock and meat and these transportation costs are known from region i to region j for time period t . It is assumed that when the sum of the regional supplies of each type of livestock are converted into meat the resulting total potential supply of meat is equal to or greater than the total consumption of each type of meat. Slaughter and consumption of each type of livestock and meat are assumed homogenous and thus slaughtering firms and consumers are indifferent about their source of supply. It is further assumed that all commodities are traded in competitive markets.

Given these specifications, we wish to formulate a model which accounts for the interaction of the spatially separated economic units (supply, slaughter and consumption locations). In particular, given the constraint set, we wish to specify a model to ascertain the level and location of the slaughter of each type of livestock and the volume and direction of livestock and meat flows that will **minimize the aggregate transport and slaughtering costs**. We are thus looking for the allocation and pricing system which will maximize the returns to each source (supplier) and minimize the cost to consumers subject to the constraint conditions postulated for the multi-region livestock industry.

B. Notation

As a basis for specifying the model in mathematical form the following notation will be used:

Let

- i, j denote the regions; $i, j = 1, 2, \dots, n$.
- p_i^l denote the quantity of the l th type of slaughter livestock produced in region i (quantity available before inshipments and outshipments) $l = 1, 2, \dots, L$.
- d_i^m denote the demand for the m th type of meat in region i ; $m = 1, 2, \dots, M$ and $M = L$.
- x_{ij}^l denote the quantity of the l th type of livestock shipped from region i to j .
- x_{ij}^m denote the quantity of the m th type of meat shipped between regions i to j .
- s_i^l denote the level of slaughter of the l th type of livestock in region i ; $(s_i^l = \sum_j x_{ij}^l)$
- c_i^l denote the unit cost of slaughtering the l th type of livestock in region i .
- t_{ij}^l denote the unit transport costs for a shipment of the l th type of livestock from region i to j .
- t_{ij}^m denote the unit transport cost for a shipment of the m th type of meat from region i to j .
- a_{lm} denote the rate at which the l th type of livestock is converted into the m th type of meat.
- r_i^l denote the capacity for slaughtering the l th type of livestock in region i .
- g_i^q denote net availability in region i ; $q = l, m, r$.

C. Mathematical Model

Given the foregoing restrictive and expository assumptions and using the above definitions and notations our constrained extremum problem may be expressed as follows:

To maximize

$$(1) \quad f = - \sum_{ijm} \sum t_{ij}^m x_{ij}^m - \sum_{ijl} \sum t_{ij}^l x_{ij}^l$$

$$\sum_{ij} x_{ij}^l = \sum_i \sum_l c_i^l s_i^l$$

subject to

$$(2) \quad g_i^m = - \sum_j x_{ij}^m + a_{is}^{1m} \frac{1}{i} = 0$$

The meat shipment of the i th region to itself and other regions is equal to the meat equivalent of the l th type of livestock slaughtered in region i

$$(3) \quad g_i^1 = p_i^1 - \sum_j (x_{ij}^1 - x_{ji}^1) - s_i^1 \geq 0$$

The quantity of the l th type of livestock used for slaughter in the i th region plus inshipments minus outshipments must be equal to or less than the production of slaughter animals in the i th region.

$$(4) \quad g_i^r = r_i^1 - s_i^1 \geq 0$$

The quantity of the l th type of livestock slaughtered in region i is less than or equal to the available regional slaughtering capacity.

$$(5) \quad g_i^m = \sum_j x_{ji}^m - d_i^m = 0$$

The shipment of the m th type of meat to region i from itself and other regions is equal to the demand in region i .

$$(6) \quad x_{ij}^m, x_{ij}^1, s_i^1 \geq 0$$

All choice variables have to be non-negative.

If the system (1) through (6) is defined as the primal problem then the corresponding dual or counterpart of the production and flow solution is as follows:

To minimize

$$(7) \quad G = -(\sum_i d_i^m u_i^m - \sum_i r_i^1 u_i^r - \sum_i p_i^1 u_i^1)$$

(If the u_i^q are interpreted as internal prices and

rents then the dual objective functions (7) may be interpreted as to minimize the cost of the predetermined quantities of final meat products to regional consumers or to maximize the returns to the livestock slaughter animal and slaughter plant owners.)

Subject to

$$(8) \quad u_j^m - u_i^m - t_{ij} \leq 0$$

(If u_j^m is interpreted as the value of the m th meat product in demand region j and u_i^m as the value

of the m th meat product at supply region i then the inequality system (8) states that the difference in value between regions i and j must be equal to or greater than t_{ij}^m (transportation cost). In order for

(1) to be a maximum and (7) to be a minimum (1) if,

$x_{ij}^m > 0$ (that is flows take place between i and j)

then $u_j^m - u_i^m = t_{ij}^m$, (2) if $x_{ij}^m = 0$ then

$$u_j^m - u_i^m \leq t_{ij}^m.$$

$$(9) \quad a_{is}^{1m} u_i^m - u_i^1 - u_i^r - c_i^1 \leq 0$$

The value of the m th type of livestock, in the i th region, after slaughter ($a_{is}^{1m} u_i^m$) is equal to or less than the value of the livestock animal in region i (u_i^1) plus the internal rent that may accrue to the slaughter plant in region i (u_i^r) plus the unit cost of slaughter of the l th type of livestock in region i (c_i^1). Internal rent on slaughtering plants (u_i^r) is positive only if the capacity of the plant is exhausted.

$$(10) \quad u_j^1 - u_i^1 - t_{ij}^1 \leq 0$$

The difference in value of the l th type of livestock between regions i and j is equal to or less than the transport cost (t_{ij}^1). If $x_{ij}^1 > 0$ then

$$u_j^1 - u_i^1 = t_{ij}^1$$

$$(11) \quad u_i^m, u_i^1, \text{ and } u_i^r \geq 0$$

The internal values and rents must be non-negative.

The above inequality systems (8), (9) and (10) spell out the profit conditions of competitive equilibrium, i.e., no activity (x_{ij}^m, x_{ij}^1 and s_i^1)

may permit a positive profit and for those activities that operate at positive levels the profit must be zero.

Therefore for (1) to be a maximum the internal prices and rents must satisfy conditions (8) through (11).

The programming tableau consistent with (1) through (6) and (7) through (11) is given in table 1 for a two region, two final meat product, two types of livestock example. In the example $l = 1, 2$, and $m = 3, 4$.

In the tableau the flow and producing activities appear along the top of table 1. The dual variables (U_i —the internal prices and rents) appear as the first column of the table and the region restrictions are given as the last column of the table. The unit transportation and slaughter cost associated with each flow and production activity are given in the last row of the tableau. The technical and transfer coefficients appear in the body of the table. The system of restrictions for the primal-dual programming problem are identified in the table and by reading across the columns restrictions (2) through (5) are reproduced and by reading across the rows of the table restrictions (8) through (10) are reflected.

The model as formulated will handle the case of n

regions, M types of meat products and L types of slaughter animals. As specified it is assumed that slaughter capacity in each region is not interchangeable among different types of slaughter animals. Thus analyses for each type of slaughter animal and meat product may be run individually or in a multiple product analysis. If the regional slaughter capacity is assumed interchangeable over types of slaughter animals then a coefficient for each type of slaughter animal could be used to put it on a standard unit basis for capacity purposes. In this case, of course, since the use of slaughter capacity is interdependent over types of slaughter animals a multiple product analysis would be required.

In the model as now specified, restrictions (2) and (5) appear as equalities. Therefore, these restrictions can be combined into one and written as:

$$(12) \quad g_i^m = - \sum_j (x_{ij}^m - x_{ji}^m) + a_{i1}^m s_1^1 - d_i^m = 0$$

Table 1. The Programming Tableau for a Two Region Two Commodity Example.

Internal Prices and Rents	Meat Flows								Livestock slaughter				Livestock flows				Regional constants
u_i	x_{11}^3	x_{12}^3	x_{21}^3	x_{22}^3	x_{11}^4	x_{12}^4	x_{21}^4	x_{22}^4	s_1^1	s_2^1	s_1^2	s_2^2	x_{12}^1	x_{21}^1	x_{12}^2	x_{21}^2	P_o
u_1	-1	-1							a^{13}								$= 0$
u_2			-1	-1					a^{13}								$= 0$
u_3					-1	-1				a^{24}							$= 0$
u_4							-1	-1			a^{24}						$= 0$
u_5									-1				-1	1			$\geq -p_1^1$
u_6									-1				1	-1			$\geq -p_2^1$
u_7										-1					-1	1	$\geq -p_1^2$
u_8											-1				1	-1	$\geq -p_2^2$
u_9									-1								$\geq -r_1^1$
u_{10}										-1							$\geq -r_2^1$
u_{11}											-1						$\geq -r_1^2$
u_{12}												-1					$\geq -r_2^2$
u_{13}	1		1														$= d_1^3$
u_{14}		1		1													$= d_2^3$
u_{15}					1		1										$= d_1^4$
u_{16}						1		1									$= d_2^4$
unit costs	t_{11}^3	t_{12}^3	t_{21}^3	t_{22}^3	t_{11}^4	t_{12}^4	t_{21}^4	t_{22}^4	c_1^1	c_2^1	c_1^2	c_2^2	t_{12}^1	t_{21}^1	t_{12}^2	t_{21}^2	
	Equation 8								Equation 9				Equation 10				

By combining these restrictions the size of the programming problem can be reduced by Mn equations. The only information that would be lost would be the level of x_{ij}^m and this could be recovered once the x_{ij}^m for $i \neq j$ were known in the abbreviated formulation.

Also the problem as structured has postulated the condition where total supplies of each type of meat are equal to or greater than total demand for each type of meat ($\sum_i a_{ij}^m s_i^l \geq \sum_i d_i^m$). Thus when the inequality holds, the degree of excess slaughter animal production in each region would be specified. If restriction (3) was made an equality (all the slaughter animals produced were slaughtered) and equation (2) an inequality then the regions where the excess supply of slaughtered meat (storage) could be estimated. If storage costs differed among regions then the differences could be added to the unit slaughter cost to obtain the optimum regional level and location of storage.

If on the other hand total meat supplies were less than total demands then restriction (5) would appear as an inequality and the regions where demands are not fulfilled could be estimated. Alternatively restrictions (2), (3) and (5) could appear as equalities (case where total supply is equal to total demand). Under each situation the degree of excess slaughter capacity could be estimated and the dual solution would provide the internal prices and rents consistent with the optimum production and flow pattern.

The model could of course be generalized to cover the producing activities for the alternative types of livestock. Under this formulation regional slaughter animal production (p_i^l) would be determined within the model. If the capacity restrictions were removed on regional plant slaughter then the optimum regional size and location of plants could be estimated under alternative regional slaughter costs and production and demand situations.

III. BASIC DATA

Given the conceptual framework and the specification of the type of data needed, the basic data used in joint annual spatial analysis for cattle and beef in 1955 and 1960 and in a joint fourth quarter analysis for hogs and pork in 1955 are presented in this section.

A. Regional Demarcation

The continental United States was partitioned into 26 geographically contiguous regions. States are the smallest geographical units for which data are

Table 2. Regional Demarcation and Demand and Supply Points

Region	State (s)	Demand and supply point
1	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	Boston, Mass.
2	Delaware, Maryland, New Jersey, New York, Pennsylvania, Washington, D. C.	Philadelphia, Pa.
3	North Carolina, Virginia, West Virginia	Richmond, Va.
4	Florida	Orlando, Fla.
5	Georgia, South Carolina	Atlanta, Ga.
6	Alabama, Mississippi	Columbus, Miss.
7	Kentucky, Tennessee	Nashville, Tenn.
8	Ohio	Columbus, Ohio
9	Indiana	Indianapolis, Ind.
10	Michigan	Detroit, Mich.
11	Illinois	Chicago, Ill.
12	Wisconsin	Milwaukee, Wis.
13	Arkansas, Louisiana	Alexandria, La.
14	Missouri	Columbia, Mo.
15	Iowa	Des Moines, Iowa
16	Minnesota	St. Paul, Minn.
17	Oklahoma, Texas	Ft. Worth, Texas
18	Kansas	Kansas City, Kan.
19	Nebraska	Lincoln, Nebr.
20	North Dakota, South Dakota	Bismarck, N. D.
21	Colorado	Denver, Colo.
22	Montana, Wyoming	Billings, Mont.
23	Arizona, New Mexico	Phoenix, Ariz.
24	Idaho, Nevada, Utah	Salt Lake City, Utah
25	California	Fresno, Calif.
26	Oregon, Washington	Portland, Ore.

available and thus each region is composed of one or more States. Homogeneity in terms of livestock production played an important role in suggesting the aggregation of States into regions. Major slaughter livestock producing States each constitute a region whereas other regions are composed of two to six States. Each regional market or source of supply is represented by a point which is identified with a city that is a major livestock market or a major consumption center or both and in most cases located near the geographical center of the region. The regional specification and basing point cities are presented in table 2.

B. Regional Estimated Slaughter Capacities

The meat packing industry considered in its entirety is faced by a substantial amount of excess capacity. Based on unpublished data received from the Meat Inspection Division of the U. S. Department of Agriculture, the rated slaughter capacity of all federally inspected slaughtering plants as of September 1, 1961, was approximately 56,000 head per hour in the case of hogs and 15,000 head per hour for cattle. Assuming a 38-hour work week, of which approximately 36 hours would be employed in slaughtering,

the percent of federally inspected hog slaughter capacity utilized during 1960 varied from a high of 82% in January to a low of 54% in July while in 1961 capacity utilization ranged from a low of 54% in July to 80% in November.¹ With respect to cattle slaughter, the percent of federally inspected capacity utilized in 1961 varied from 66% in March to 82% in May.

Excess capacity in the meat packing industry is comprised of two components, a planned component and an unplanned component. The planned component of excess capacity is that capacity which is built ahead of a growing market for both livestock and meat.² The unplanned component of excess capacity is that which results from unforeseen events or faulty planning. The meat packing industry is an industry which is ready to take all of a physical volume of livestock that producers want to market on a schedule convenient to the producers rather than on a schedule convenient to the packers. However, with a more seasonally balanced supply of livestock, part of the capacity built to handle the peak marketings has become unemployed throughout the year.

The more stable pattern of marketings is a result of the reduction in seasonal and cyclical variability of livestock production. The year-to-year variability in the livestock industry has been characterized by two major out-put cycles—a 4-year hog cycle and a somewhat longer cattle cycle. In addition to the major output cycles, there have been corresponding short-run, or month-to-month shifts in livestock marketings. To compare the two forms of market variability, the coefficients of variation for commercial slaughter cattle and hogs were computed using monthly and annual data for two 10-year periods, 1939-48 and 1949-58. The month-to-month variability in hog slaughter decreased from 0.20 to 0.11 between these two time periods, while the variability in cattle slaughter increased slightly from 0.05 to 0.08. For the 1949-58 period the magnitude of the monthly variability in commercial slaughter is approximately the same as the magnitude of the year-to-year variation in commercial slaughter—0.08 for cattle and 0.06 for hogs.

1. Number and location of slaughter facilities.

On March 1, 1960, there were 530 large federally inspected livestock slaughtering plants and 2,614 medium non-federally inspected livestock slaughtering plants in the United States. In addition, there were also about 6,500 small non-federally inspected plants. In 1955, there were 455 federally inspected plants and 2,762 large and medium non-federally inspected plants. In 1959, the 530 federally inspected and 2,614 large and medium non-federally inspected plants accounted for approximately 99% of the total commercial livestock slaughter in the United States.³

The number and location of federally inspected livestock slaughtering plants in 1960 for the United States are shown in figure 1.

There was a considerable change in the number and location of federally inspected plants between 1947 and 1963 (table 3). In 1947 there were 494 federally inspected plants as compared to 565 in 1963. In 1963, 198 of the 494 plants operating in 1947 were discontinued, 199 were still operating under the same name, and 97 were operating with changed names. There were 269 new plants by 1963. Although there was an increase of 71 plants, a number of States had fewer plants in 1963 than they did in 1947. The largest decrease in numbers of plants occurred in California and Massachusetts where the number decreased by nine, while New Jersey had eight fewer plants in 1963. Although there was no regional pattern in the decline of plant numbers, most States in the North Atlantic region had fewer plants in 1963. Nebraska, Iowa, Texas, and Colorado lead all other states in increases in the number of federally inspected plants. In terms of new plants added during this period, Illinois and Iowa had 22, Nebraska and New York had 20, while Colorado acquired 19 new plants.

The number and location of large and medium non-federally inspected livestock slaughtering plants are shown in figures 2 and 3, respectively. The number of these plants has decreased from 2,762 in 1955 to 2,614 in 1960. From 1955 to 1957 the number of large plants declined from 952 to 902 while the number of medium sized plants decreased from 1,810 to 1,712.

2. Procedures for estimating regional slaughter capacities.

a. Federally inspected plants.

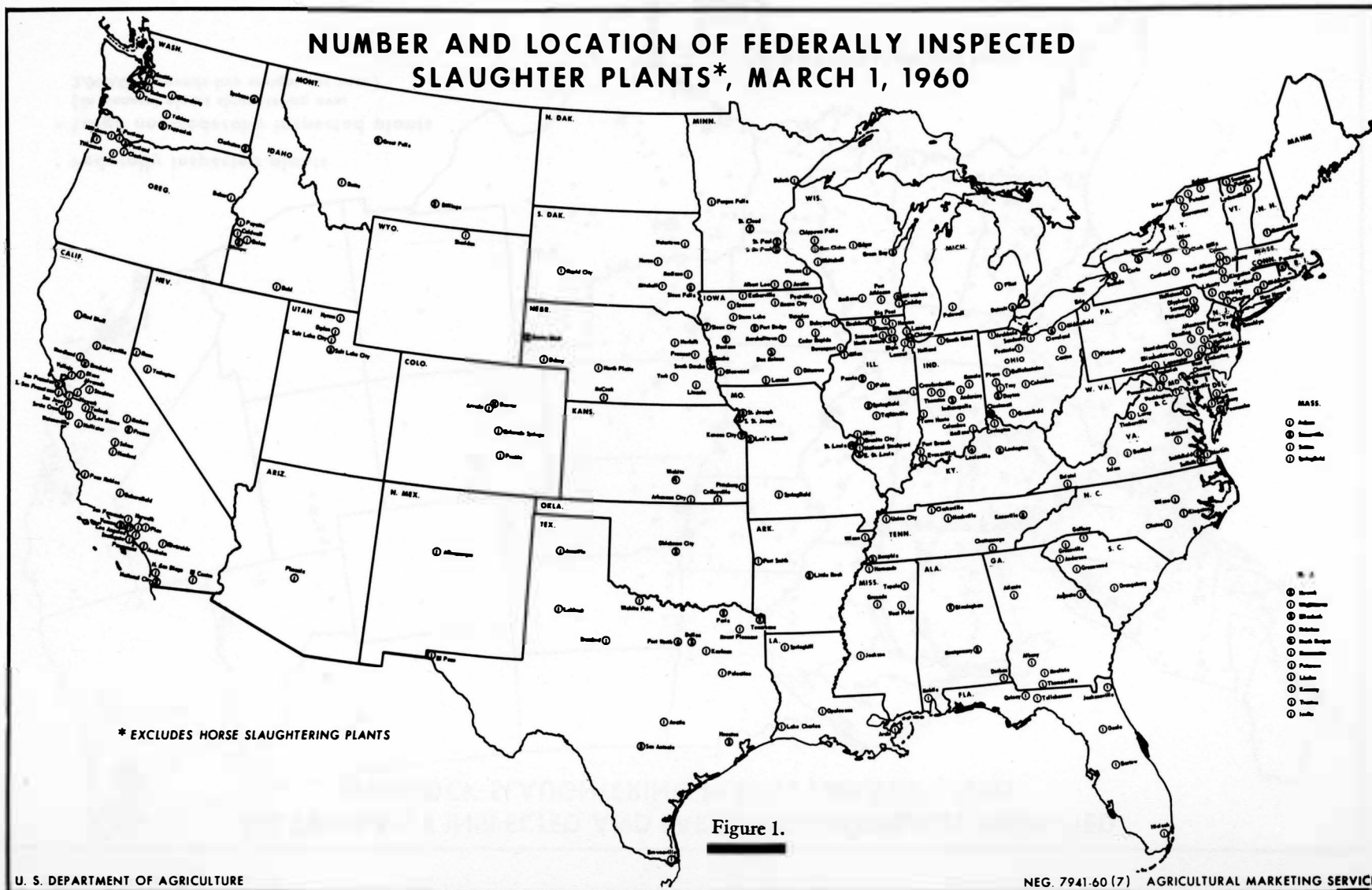
The regional slaughter capacities derived for federally inspected plants were obtained by multiplying the hourly rated capacities of each region in 1955 and 1960 by the total number of hours worked each year. The hourly rated slaughter capacities of each state were obtained from unpublished data provided by the Meat Inspection Division of the U. S. Department of Agriculture, while the total hours worked were derived by multiplying the hours worked each day by the number of days worked. In both years of

¹In general the meat packing industry is bound by labor contracts to a guaranteed work week, i.e., employees who work during any given week are guaranteed at least 36 hours of employment. However, an employee can be employed up to 40 hours per week before overtime pay goes into effect.

²It is not technically correct to designate new plants as excess capacity since in most cases they will be fully utilized. However, with a given supply of livestock, additional new plants increase total slaughter capacity, which consequently results in increases in excess capacity, unless obsolescent plants are phased out at the same time.

³Agricultural Marketing Service. "Number of Livestock Slaughter Plants March 1, 1960." USDA, Mt An 1-2-2 (60) 1960.

NUMBER AND LOCATION OF FEDERALLY INSPECTED SLAUGHTER PLANTS*, MARCH 1, 1960



**ALL FEDERALLY INSPECTED AND LARGE NON-FEDERALLY INSPECTED
LIVESTOCK SLAUGHTERING PLANTS*, MARCH 1, 1960**

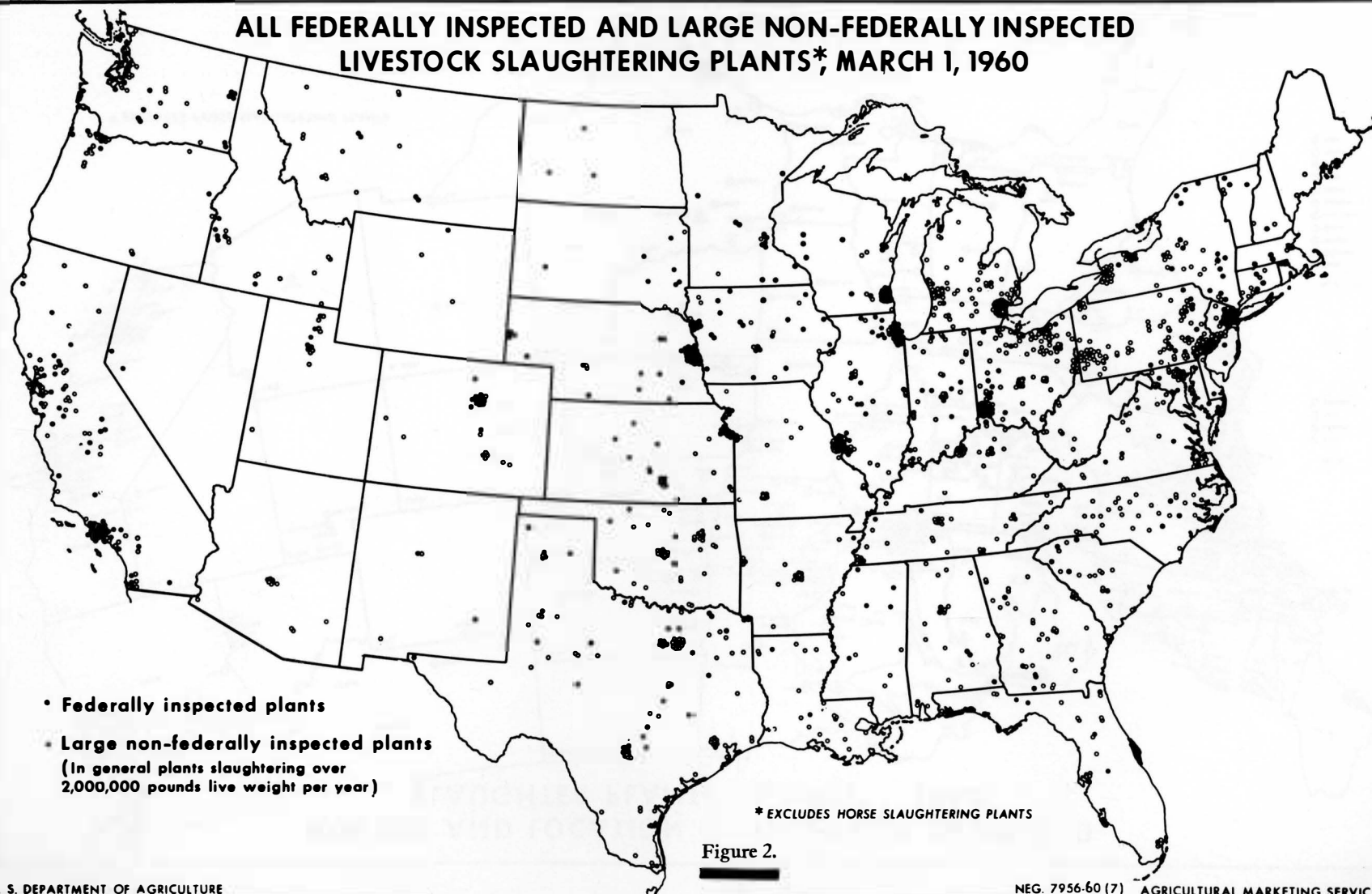
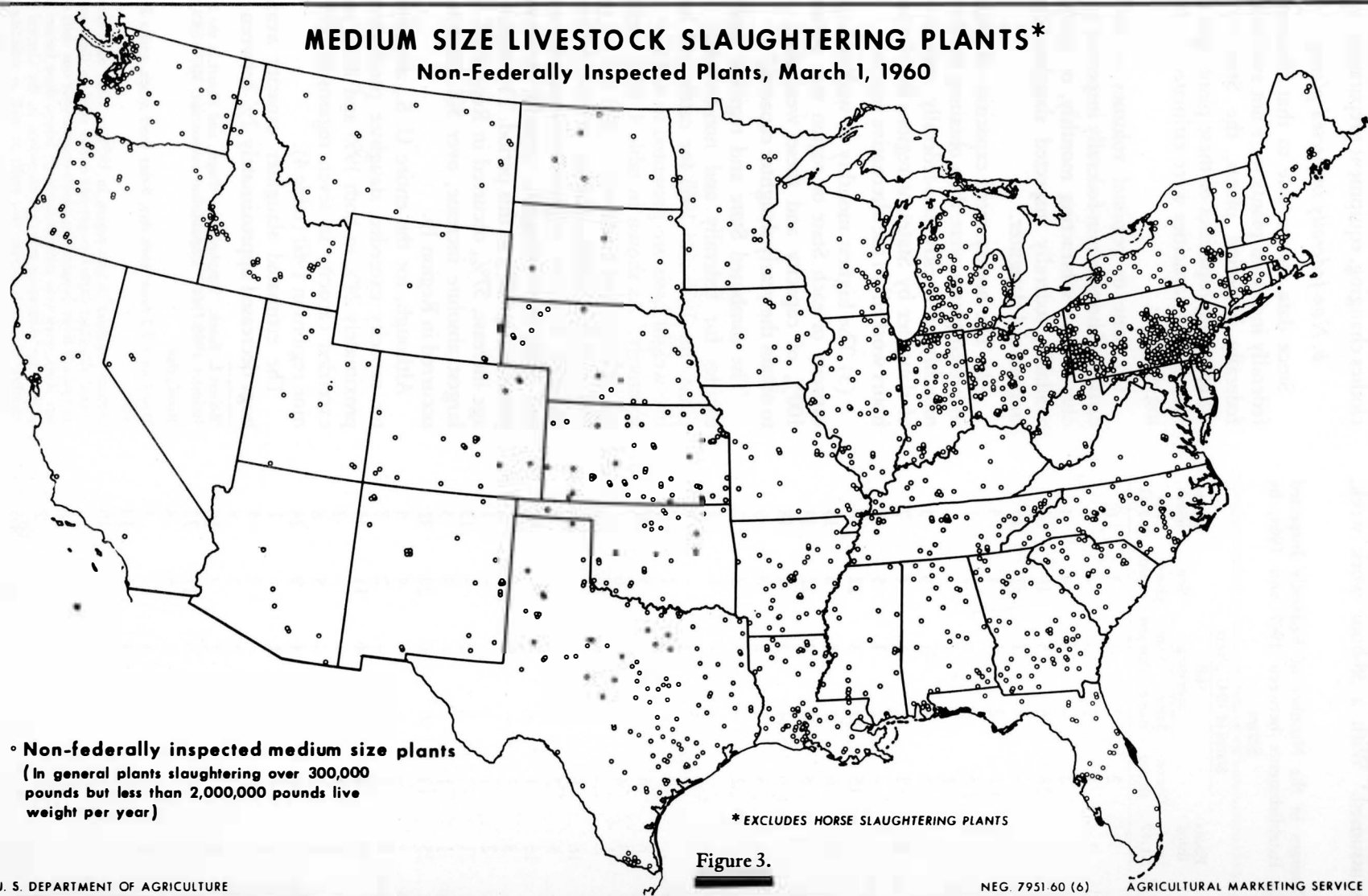


Figure 2.

MEDIUM SIZE LIVESTOCK SLAUGHTERING PLANTS*

Non-Federally Inspected Plants, March 1, 1960



analysis, 252 work days were used. To derive the number of hours worked each day, a 38-hour work week was assumed.⁴ With a 38-hour work week,

Table 3. Changes in the Number of Federally Inspected Slaughtering Establishments between 1947 and 1963, by States

State	Plants listed as of 7-1-47	Discontinued	Status of 1947 plants		New plants added	Plants listed as of 4-1-63
			Still operating	Name changed		
Alabama	5	2	2	1	3	6
Arizona	2	1	1	-	-	1
Arkansas	2	2	-	-	4	4
California	69	28	26	15	19	60
Colorado	7	-	6	1	11	18
Connecticut	4	1	2	1	1	4
Delaware	3	3	-	-	1	1
Dist. of Col.	1	1	-	-	-	-
Florida	4	2	1	1	5	7
Georgia	8	5	2	1	4	7
Idaho	3	-	2	1	5	8
Illinois	31	15	12	4	22	38
Indiana	16	6	6	4	3	13
Iowa	20	8	9	3	22	34
Kansas	22	6	11	5	2	18
Kentucky	6	3	1	2	6	9
Louisiana	2	2	-	-	2	2
Maine	-	-	-	-	1	1
Maryland	8	2	5	1	-	6
Massachusetts	12	10	2	-	1	3
Michigan	8	6	1	1	5	7
Minnesota	13	4	8	1	6	15
Mississippi	-	-	-	-	6	6
Missouri	16	6	9	1	10	20
Montana	5	2	3	-	2	5
Nebraska	13	1	6	6	20	32
Nevada	3	2	-	1	1	2
New Hamp.	2	1	1	-	-	1
New Jersey	21	12	7	2	4	13
New Mexico	1	1	-	-	3	3
New York	25	13	6	6	20	32
N. Carolina	-	-	-	-	4	4
North Dakota	3	3	-	-	2	2
Ohio	35	12	19	4	11	34
Oklahoma	6	4	2	-	-	2
Oregon	6	3	3	-	5	8
Pennsylvania	21	6	11	4	9	24
Rhode Island	2	1	-	1	-	1
S. Carolina	2	2	-	-	4	4
South Dakota	7	1	4	2	2	8
Tennessee	8	-	6	2	2	10
Texas	19	3	10	6	17	33
Utah	5	2	1	2	5	8
Vermont	6	3	-	3	-	3
Virginia	7	1	2	4	4	10
Washington	14	4	3	7	6	16
W. Virginia	-	-	-	-	-	-
Wisconsin	19	6	9	4	7	20
Wyoming	2	2	-	-	2	2
Total	494	198	199	97	269	565

Source: Agricultural Research Service, USDA

only 36 hours, or 7.2 hours per day would be spent in slaughtering, the other time being utilized for clothes changing, equipment preparation, etc.

b. Non-federally inspected plants.

Since data comparable to that obtained for the federally inspected plants were not available for non-federally inspected plants, the State or regional slaughtering capacities of these plants had to be estimated. The capacities were estimated in the following manner:

(1) State or regional volumes of slaughter of cattle and hogs in non-federally inspected plants were obtained by subtracting monthly, or weekly, when available, federally inspected slaughter from total commercial slaughter.

(2) The hourly rated capacities of non-federally inspected plants were then obtained by dividing the monthly or weekly non-federally inspected volume of slaughter by States or regions by the number of hours worked⁵ in the alternative region.

(3) The highest monthly or weekly hourly rated capacity of each State or region was assumed to be 100% of capacity and these were then expanded to obtain the yearly slaughter capacity.⁶

The combined State and regional estimated capacities for federally and non-federally inspected plants for 1955 and 1960 for cattle and hogs, on a live weight basis are presented in tables 4 and 5, respectively.⁷ As shown in table 4, total cattle slaughter capacity was estimated at 31.4 billion pounds in 1955 and 33.1 billion pounds in 1960. Although total capacity in seven regions decreased between 1955 and 1960, cattle slaughter capacity increased by approximately 5.5% in this period. The largest percentage increase, 57%, occurred in Region 23, while the largest absolute increase, over 500 million pounds, occurred in Region 15.

Although, for the entire U. S., available slaughter capacity exceeded slaughter production by approximately 24% in both 1955 and 1960, production exceeded capacity in seven regions in 1955 and in nine regions in 1960 (table 4).

The estimated slaughter capacity available for hogs decreased approximately 2% between 1955 and

⁴Robert L. Rizek, "Employment, Wages, and Hours in the Meat Packing Industry 1950-1960." Unpublished manuscript, MED-ERS, USDA.

⁵Rizek, *ibid.*

⁶Based on a 7.2-hour work day, 5-day work week, and a 252-day work year.

⁷Actual slaughter in any region in 1955 or 1960 may exceed the estimated slaughter capacities presented and used in these analyses. Since in practice most slaughtering plants operate only one shift and the average work week was approximately 38 hours, these factors were used as a basis for estimating capacity. However, in the Central Corn Belt, a number of plants operate two shifts as well as utilizing considerable overtime. Consequently, regional slaughter in these areas may be greater than the estimated available capacity.

Table 4. Estimated Commercial Slaughter Capacity and Commercial Slaughter Production of Cattle, 26 Regions of the United States, 1955 and 1960.

Region	Slaughter capacity		Change between 1955 and 1960	Commercial slaughter production	
	1955	1960		1955	1960
	(1,000 pounds live weight)		(per- cent)	(1,000 pounds live weight)	
1 ..	426,301	502,704	17.9	185,009	149,913
2 ..	2,786,329	2,794,019	0.3	908,525	875,177
3 ..	727,818	700,920	-3.7	477,842	520,317
4 ..	476,516	449,070	-5.8	128,746	143,197
5 ..	797,320	737,683	-7.5	159,238	99,155
6 ..	572,864	574,166	0.2	302,272	281,671
7 ..	937,667	1,053,420	12.3	413,153	412,570
8 ..	1,661,448	1,642,874	-1.1	616,576	588,737
9 ..	834,765	901,627	8.0	760,531	745,559
10 ..	966,583	861,840	-10.8	435,937	408,643
11 ..	2,723,907	2,072,045	-23.9	1,938,503	2,159,185
12 ..	906,427	1,213,899	33.9	569,464	498,099
13 ..	390,540	499,701	28.0	304,453	192,808
14 ..	1,187,869	1,254,155	5.6	1,156,322	1,270,807
15 ..	2,000,279	2,583,160	29.1	3,192,487	3,789,796
16 ..	1,466,721	1,482,894	1.1	1,227,056	1,621,086
17 ..	3,094,342	3,058,282	-1.2	1,849,662	1,860,991
18 ..	1,335,022	1,461,567	9.5	1,768,275	1,978,551
19 ..	2,069,214	2,448,835	18.3	2,376,275	2,214,325
20 ..	549,965	601,625	9.4	934,374	689,994
21 ..	920,400	1,058,793	15.0	943,134	1,216,031
22 ..	136,988	163,537	19.4	565,261	402,338
23 ..	211,245	333,542	57.9	457,850	670,703
24 ..	504,905	664,501	31.6	444,017	375,847
25 ..	2,632,782	2,892,311	9.9	1,659,797	1,879,717
26 ..	1,036,570	1,056,808	2.0	426,062	285,777
Total	31,354,787	33,063,978	5.5	24,200,821	25,330,994

1960, 29.9 billion pounds to 29.4 billion pounds (table 5). Of this estimated slaughter capacity, only 59 and 63% were utilized in 1955 and 1960, respectively. On an annual basis, production exceeded slaughter capacity in only three regions in 1955 and in two regions in 1960. With the type of model being used in this study slaughtering will take place at the point of production unless the production of a region exceeds the available slaughter capacity of the region. Since so few regions were deficit in available slaughter capacity on an annual basis, relatively little information could be gained from a spatial analysis of the annual data for slaughter hogs and pork. However, for the fourth quarter of 1955 production exceeded available slaughter capacity in eight regions and a jointly determined analysis for hogs and pork will be presented for the fourth quarter of 1955.

C. Regional Production of Cattle and Hogs

Commercial production in this study refers to the farm production in live weight which enters commercial slaughtering channels during the calendar year. This production excludes farm slaughter. Data on regional production for slaughter are not directly available from published sources.

The total commercial production for slaughter for the U. S. is synonymous with reported live weight or commercial slaughter. The regional estimate reflects a region's production contribution to the total commercial slaughter of the U. S. It is assumed that regional commercial production consists

Table 5. Estimated Commercial Slaughter Capacity and Commercial Slaughter Production of Hogs, 26 Regions of the United States, Fourth Quarter, 1955 and 1960

Region	Slaughter capacity		Change between 1955 and 1960 (percent)	Commercial slaughter production		Fourth quarter 1955	
	1955 (1,000 pounds live weight)	1960 (1,000 pounds live weight)		1955 (1,000 pounds live weight)	1960 (1,000 pounds live weight)	Slaughter capacity (1,000 pounds live weight)	Production (1,000 pounds live weight)
1	397,272	282,527	-28.9	45,417	47,877	99,318	14,932
2	3,919,215	3,170,470	-19.1	285,646	249,605	979,804	84,084
3	953,765	1,100,470	21.7	348,618	491,835	238,441	99,250
4	241,704	208,976	-13.5	69,682	69,815	60,426	24,125
5	808,606	923,154	14.2	361,141	497,931	202,152	116,747
6	340,139	497,514	46.3	312,556	391,151	85,035	92,625
7	1,144,480	1,347,880	17.8	507,012	715,367	286,120	151,473
8	2,113,965	1,840,180	-13.0	918,356	876,204	528,491	268,051
9	1,473,558	1,736,693	17.9	1,557,007	1,730,038	368,389	446,666
10	532,035	631,224	18.6	237,160	242,599	133,009	66,377
11	2,257,227	2,052,104	- 9.1	2,355,005	2,737,389	564,307	687,110
12	1,022,868	1,216,610	18.9	689,600	650,786	255,717	225,110
13	153,720	237,400	54.4	138,940	152,509	38,430	41,541
14	1,729,836	1,548,912	-10.5	1,166,771	1,293,774	432,459	435,283
15	3,192,220	3,688,186	15.5	4,499,199	4,478,148	798,055	1,438,070
16	1,816,880	1,807,514	- 0.5	1,372,938	1,345,487	454,220	459,153
17	1,556,569	1,123,179	-27.8	377,426	391,101	389,142	132,749
18	819,352	1,003,446	22.5	303,197	378,008	204,838	110,242
19	1,337,965	1,359,169	1.6	959,603	879,866	334,491	334,568
20	878,492	724,413	-17.5	766,695	673,732	219,623	242,372
21	298,397	269,733	- 9.6	44,243	56,622	74,599	13,304
22	266,512	218,222	-18.1	43,641	49,399	66,628	11,552
23	97,955	173,715	77.3	15,213	20,165	24,489	4,601
24	517,346	423,608	-18.1	40,811	57,263	129,336	11,694
25	1,191,298	948,421	-20.4	101,194	90,809	297,825	29,119
26	863,735	853,492	- 1.2	86,323	90,520	215,934	26,893
Total	29,925,109	29,447,213	- 1.6	17,603,394	18,658,000	7,481,278	5,567,751

of three components: (a) live weight of inshipments and weight added to inshipments, (b) live weight of a decrease in inventory numbers, and (c) live weight of production occurring in the region during the calendar year. If inventory numbers are stable or increasing during the year, commercial production consists of (a) and (c). The quantities attributable to each of these three components were estimated for each of the 26 regions. For each region the sum of the quantities of the three components is the total commercial production of the region and the sum of the commercial production of the 26 regions equals the total commercial slaughter live weights of the U. S.⁸ Regional estimates of the annual commercial production of cattle for 1955 and 1960 are presented in table 4.

The proportional distribution among quarters within the year of live weight slaughtered commercially in each region is assumed to be indicative of the proportional quarterly distribution of live weight production for slaughter. In each region the quarterly proportions of the live weight of commercial hog slaughter in 1955 were used to disaggregate the annual commercial hog production into quarterly estimates. The fourth quarter regional estimates for 1955 of commercial slaughter hog production are presented in table 5.

Average U. S. Federally Inspected Slaughter (FIS) dressing yields were used to convert the live weight of cattle and hogs at slaughter to beef and pork in each of the 26 regions. Reported FIS cattle dressing yields for 1955 and 1960 are 55.1% and 57.3%, respectively. The 1955 FIS dressing yield for hogs excluding lard is 56.8% and is used in the 1955 fourth quarter analysis of hogs and pork.

D. Regional Consumption of Beef and Pork

The household food consumption survey conducted in 1955 by USDA provides the basic data for regional consumption estimates of beef and pork. Results of the survey were reported for the Northeast, North Central, South, and West census regions. For reporting purposes households within each census region were grouped by urbanization and by family income.⁹

In general the survey results indicated that households in the West had the highest consumption rate per person for beef while households in the South and North Central regions had the highest consumption rates for pork. For purposes of generating regional consumption estimates in this study the weekly per capita quantities reported in the 1955 survey were converted to an annual basis and their carcass weight equivalents were then obtained.

Since the consumption of beef and pork varied by region and urbanization group, the distribution of urban, rural non-farm, and farm population for

each of the 26 regions of this study were used as a basis for obtaining regional consumption estimates. A population weighted average of the annual carcass weight equivalent for urban, rural non-farm, and farm per capita consumption was computed for each of the 26 study regions for 1955 and 1960 for beef and 1955 for pork. In order to generate total regional consumption estimates, the per capita consumption for each region was multiplied by the population of that region for the year concerned. The results were then summed and where necessary the totals were adjusted to agree with total slaughter data for each of the commodities and each of the years.

In the food consumption survey data used, Texas and Oklahoma were classified in the Southern census region. Since it was felt that consumption patterns for these two States were more closely related to the West than to the South, the consumption estimates for beef and pork used in his study were made under this assumption. This change in specification resulted in an increase in beef consumption and a decrease in pork consumption for Texas and Oklahoma relative to the estimates obtained when Texas and Oklahoma are viewed as being in the Southern census region.¹⁰ The annual regional consumption estimates of beef for 1955 and 1960 excluding farm slaughter are presented in table 6.

The regional pork consumption estimates for the fourth quarter of 1955 were derived from the urbanization weight annual estimates assuming Texas and Oklahoma in the Southern census region by using the relative proportion of commercial slaughter in the U. S. for the fourth quarter of 1955 as a weighting factor to obtain the fourth quarter estimate of pork consumption. Lard is excluded from the consumption estimates. Regional estimates of pork net of farm slaughter for the fourth quarter in 1955 are presented in table 7.

E. Transportation Rates

Transportation costs are basic to the spatial solutions and it is necessary to obtain estimates of these costs between geographical points that represent

⁸For a detailed description of the procedure used in generating regional slaughter production estimates see J. Havlicek, R. L. Rizek, and G. G. Judge, "Spatial Analysis of the Flows of Slaughter Livestock in 1955 and 1960."

⁹For the States within each census region, the definition of each urbanization group and income classes used see, "Food Consumption of Households in the United States and in the Northeast, North Central, South, and West," USDA, 1956, and for reported per capita quantities of meats used at home see "A Review of 1955 Survey Data on Household Meat Consumption" AMS-340, USDA, September 1959.

¹⁰For a discussion on generating alternative regional consumption estimates of beef, pork, veal, and lamb and mutton and a spatial analysis of geographical flows of meat in 1955 and 1960 see the regional publication by G. G. Judge, J. Havlicek, and R. L. Rizek entitled "Spatial Analyses of the Meat Marketing Sector in 1955 and 1960."

Table 6. Estimated Annual Regional Beef Consumption* Assuming Texas and Oklahoma in the Western Census Region, 1955 and 1960

Region	1955	1960
	(1,000 pounds)	(1,000 pounds)
1	781,472	841,637
2	2,840,025	3,001,461
3	507,277	546,441
4	219,791	304,153
5	318,791	342,290
6	271,851	292,498
7	333,429	353,050
8	836,489	900,051
9	397,769	424,908
10	674,607	730,239
11	856,985	935,463
12	324,150	351,198
13	257,487	281,518
14	390,712	398,193
15	222,895	229,914
16	274,543	294,584
17	1,107,037	1,192,712
18	183,112	189,139
19	113,177	117,883
20	105,275	104,733
21	156,597	171,119
22	90,202	96,514
23	180,867	227,612
24	161,714	181,488
25	1,299,302	1,550,747
26	429,096	455,115
Total	13,334,652	14,514,660

*Weighted by urbanization characteristics of each region.

each pair of regions. Joint analyses require two sets of transportation costs. Information is needed on the point-to-point transportation costs of moving live animals from regions of production to regions of slaughter and point-to-point transportation costs of moving meat from regions of slaughter to regions of consumption.

1. Livestock transportation rates

Estimated truck rates were used to represent the transportation costs of live animals between points of production and points of slaughter. Availability of data precluded the use of observed point-to-point transportation rates. In view of this restriction, a series of multiple regression equations were used to estimate the cost of transporting live animals among the regions.

The model postulated to reflect truck rates for livestock between production and slaughtering points is:

$$(13) \quad C_{ij} = b_0 + b_1 D_{ij} + b_2 \frac{1}{D_{ij}^2} + b_3 W_{ij} + b_4 \frac{D_{ij}}{T_{ij}}$$

where:

C_{ij} represents the costs in dollars of shipping 100 pounds of live animals by truck from region i to region j

D_{ij} is the highway mileage between region i and region j

W_{ij} is the total weight of livestock per shipment from region i to region j

T_{ij} is the time in hours required to haul livestock from region i to region j

$\frac{D_{ij}}{T_{ij}}$ is the average speed of haul between region i and region j

b 's are the estimated regression coefficients

Truck rates were postulated to increase with mileage, however, not necessarily at a constant rate. Rates may increase as a function of distance at a decreasing or increasing rate depending on the supply and demand for transportation facilities. The effective load density, load size, and size of truck were

Table 7. Estimated Regional Pork Consumption* Assuming Texas and Oklahoma in the Western Census Region, Fourth Quarter 1955

Region	Quantity
	(1,000 pounds)
1	174,675
2	666,351
3	192,128
4	84,266
5	114,166
6	102,819
7	120,316
8	198,111
9	91,528
10	161,242
11	199,620
12	72,340
13	99,194
14	79,119
15	45,783
16	59,093
17	183,088
18	40,795
19	23,747
20	20,077
21	28,200
22	15,409
23	32,369
24	28,958
25	247,130
26	78,720
Total	3,159,244

*Weighted by urbanization characteristics of each region.

measured by the weight of livestock transported and road conditions were accounted for by the average speed of the trip.

Due to institutional peculiarities in rate structure between alternative freight territories, separate functions for each freight territory were estimated using least squares regression techniques. Data for estimating the coefficients were obtained from a survey of truckers. Comparable data on truck transportation costs were not available for 1955. To obtain estimates of truck rates for 1955, the 1960 truck rates were adjusted by changes which occurred between 1955 and 1960 in rail rates for the different species.¹¹

2. Meat transportation rates

Transportation cost functions were estimated from samples of truck rates and these cost functions were then used to estimate the point-to-point rate structure. It is assumed that transportation rates for carcass beef are applicable to other types of meat considered in this study. The truck transportation cost functions for shipping carcass beef estimated by Judge and Wallace¹² were used for generating the 1955 transportation rate structure for all types of meat in this study. They obtained a sample of truck rates from Wilson and Company and Armour and Company. A square root functional form was postulated and least squares regression procedures were used to estimate the coefficients of the truck transportation cost functions. The estimated cost functions were as follows:

$$(14) \quad C_{ij} = .0015X_{ij} + .0226 X_{ij}^{1/2}; \quad r = .98$$

where:

C_{ij} is the cost per pound of shipping meat from region i to region j and

X_{ij} is the distance between region i and region j . The 1955 effective rate structure was developed by estimating the point-to-point transportation costs using the above transportation function.

To generate truck transportation cost functions for 1960, samples of truck rates for shipping carcass beef were obtained from the traffic department of John Morrell and Company. The sample of observations was partitioned into eastward shipments and westward shipments. Least squares regression methods were used to estimate a square root functional form of the truck transportation cost functions and yielded the following estimating equations:

West Shipments

$$(15) \quad C_{ij} = -.1039 + .0001X_{ij} + .0670X_{ij}^{1/2}, \quad r = .99$$

East Shipments

$$(16) \quad C_{ij} = -.6203 - .00007X_{ij} + .0805X_{ij}^{1/2}; \quad r = .94$$

where:

C_{ij} and X_{ij} are as previously defined.

Transportation costs for each of the designated pairs of points were estimated by the appropriate directional transportation function. In each case the estimated rates for shipments moving west were higher than for east shipments for the same mileage.¹³ The 1960 meat transportation rates used in these analyses are presented in Appendix table 1.

F. Regional Slaughter Costs.

Slaughtering costs per animal depend on costs such as labor, utilities, and taxes and vary according to plant size and geographical area. It is hypothesized that regional differences in slaughtering costs have a significant influence on the location of meat packing plants. However, only very limited data are available on slaughtering costs by regions in the United States. The most current information, relating to hogs only, is being developed under a U. S. Department of Agriculture project.¹⁴ It consists of samples of 22 packers during 1959-60 and 24 packers during 1960-61 in the North Central, Northeast, and South. The analyses of these data indicate a cost for slaughtering hogs to fresh pork of approximately \$1.75 per hundred pounds for areas in the Southeast compared to a cost of \$2.50 for other areas. These costs include kill and cut labor, packaging, order filling and shipping room. However, it should be pointed out that the variation in costs within a given State is nearly as great as that between the different regions. Comparable data dealing with the slaughter of cattle are not available.

Due to the lack of reliable and complete data and because studies made by the American Meat Institute indicate that wages and salaries make up more than 50% of the total operating costs in the meat packing industry, the portion of this study which investigates the influence of slaughtering costs

¹¹For additional information regarding the estimated transportation functions and transportation costs see J. Havlicek, R. L. Rizek, and G. G. Judge *op. cit.* and analyses for these estimated transportation cost data and other alternatives considered will be presented in a forthcoming North Central Regional publication by D. Brewer and R. L. Rizek entitled "Transportation Patterns and Cost of Livestock Movements."

¹²G. G. Judge and T. D. Wallace, "Spatial Price Equilibrium Analyses of the Livestock Economy," Oklahoma Experiment Station Bulletin TB-78, 1959.

¹³See G. G. Judge, J. Havlicek, and R. L. Rizek *op. cit.*

¹⁴Agnew, D. B., "Meat Packers Costs for Slaughtering, Cutting, and Marketing Fresh Pork," The Marketing and Transportation Situation. ERS-USA, July 1961.

on the spatial flows is based only on labor costs associated with the actual slaughtering of livestock. Since the level of technology varies considerably between plants within any one given region as well as between regions, labor requirements for synthesized or highly efficient actual plants are used to determine the labor costs associated with slaughtering.

1. Wage costs.¹⁵

The basic wage rates used in this analysis were derived from the 1954 and 1958 Census of Manufactures.¹⁶ These data were adjusted by the increases that occurred in the average hourly wages from 1954 to 1955 and from 1958 to 1960.¹⁷ The adjustment factor was 1.057 and 1.06 for 1955 and 1960, respectively.

The wage rates used were the average hourly wage costs of production workers in SIC Industry 2011, meat packing, wholesale; and SIC Industry 2012, custom slaughtering, wholesale. The adjusted average hourly wage costs by regions are presented in table 8. In 1955, the average hourly wages varied from a low of \$1.26 per hour in Region 13 to \$2.45 in Region 16. In 1960, Region 3 had the lowest average hourly wage of \$1.69 per hour while Region 16 had the highest of \$3.35 per hour. In both years of analysis, the lowest wage rates were in the southeastern states, Regions 3-6 and 13, while regions in the Corn Belt and the West Coast experienced the highest wage rates.

2. Labor requirements.

Labor requirements for this analysis were based on a study by Logan and King¹⁸ on economies of scale in cattle slaughtering plants and on data provided by Allbright-Nell Company, Chicago, Ill. For cattle, the labor requirements were based on an automated "on-the-rail dressing" system with an output of 75 head per hour. This system of slaughter would utilize 85 employees.¹⁹ Assuming an average weight of 1,004 pounds per animal, the average weight of all cattle slaughtered in the U. S. in 1960, each employee would handle 887 pounds of liveweight per hour.²⁰

For the analysis of the hog slaughtering operations, a 300 head per hour operation was selected as a basis for estimating labor requirements.²¹ In addition to the hog kill operations, pork cutting operations were also included. A total of 191 employees would be needed to operate a plant of this scale. With an average weight of 236 pounds per hog, an average of 370 pounds, live weight, would be handled by each employee.

3. Slaughter costs.

Given the regional wage rates, table 8, and the capacity per hour of each worker, in pounds live weight, the labor costs per hundred pounds of live

animal slaughtered are shown in table 9.²² In 1955, the estimated labor costs associated with slaughtering hogs and pork cutting ranged from a low of 34 cents per hundred pounds live weight in Region 13 to 66 cents in Region 16. The labor costs incurred in cattle slaughtering in 1955 were also the lowest in Region 13, 14 cents per hundred pounds live weight, while Region 16 had the highest labor cost at 28 cents per hundred pounds. In 1960, labor costs for slaughtering cattle varied from a low of 19 cents per hundred pounds in Regions 3 and 4 to a high of 38 cents per hundred in Region 16.

In addition to the labor requirements for the 75 head per hour rail dressing system used for the analysis of labor costs in cattle slaughtering, labor requirements were also obtained for 20 and 120 head per hour rail dressing systems.²³ The per hour capacity of each worker for these latter two systems were 690 and 916 pounds, respectively. Regional labor slaughtering costs for these two alternative systems are also shown in table 9 in the columns labelled B and C.

IV. EMPIRICAL RESULTS

In applying the general linear production and flow model previously specified the following modifications were made. The total supply of cattle and hogs over all regions when converted to beef and pork is specified to be equal to the total regional demands for these meat products. Thus restrictions (2), (3), and (5) appear as equalities and because of this restriction (2) and (3) are combined in the form of (12), (see mathematical model, Section II). Over the spatial dimensions of 26 regions the resulting

¹⁵A detailed study on the impact of geographical differences in wage rates and unionization on entry, exit and location of meat packing plants is being carried out at Michigan State University as a contributing phase of the overall North Central Regional project. The objectives of this study are:

1. To compare wage rates for meat packing operations by states and by regions.
2. To describe the nature and extent of unionization in the meat packing industry and relate this to regional differences in wage rates.
3. To determine the probable impact of wage rates and unionization on entry, exit and location of meat packing plants.

¹⁶U. S. Dept. of Commerce, Bureau of the Census, "Census of Manufactures." 1954 and 1958.

¹⁷U. S. Dept. of Commerce, Bureau of the Census, "Annual Census of Manufactures." 1956 and 1961.

¹⁸Samuel H. Logan and Gordon A. King, *Economies of Scale in Beef Slaughtering Plants*, Giannini Foundation Research Report No. 260, Berkeley, University of California, December 1962.

¹⁹*Ibid.*

²⁰U. S. Department of Agricultural Statistics Reporting Service, "Livestock and Meat Statistics 1962," Stat. Bulletin No. 333, 1963.

²¹Studies on economies of scale in hog slaughtering plants are now underway at Iowa State University and MED-ERS, USDA.

²²Labor cost for hogs also includes breaking down the carcass.

²³*Ibid.* Logan and King.

programming problem involves 72 equations and 1,326 activities for each slaughter animal and meat product combination. In the initial analyses the re-

Table 8. Average Hourly Wage Costs, Production Workers, SIC Industry 2011, Meat Packing Wholesale and SIC Industry 2012, Custom Slaughtering, 26 Regions of the U. S., 1955 and 1960

Average hourly wages			Average hourly wages		
Region	1955	1960	Region	1955	1960
1	1.96	2.67	14	2.12	2.77
2	1.97	2.51	15	2.16	2.90
3	1.42	1.69	16	2.45	3.35
4	1.36	1.72	17	1.75	2.22
5	1.62	1.89	18	2.03	2.53
6	1.30	1.89	19	2.22	2.80
7	1.83	2.37	20	2.11	2.69
8	1.99	2.54	21	2.08	2.73
9	2.14	2.67	22	1.77	2.33
10	2.01	2.52	23	1.59	2.27
11	2.19	2.81	24	1.96	2.60
12	2.24	2.87	25	2.29	2.99
13	1.26	1.82	26	2.10	2.69

Table 9. Labor Slaughtering Costs, per Hundred Pounds, Live Weight, Hogs 1955, and Cattle 1955 and 1960, 26 Regions of the U. S.

Region	Hogs	Cattle 1955	Cattle 1960*		
			A	B	C
(dollars per hundred pounds)					
1	.53	.22	.30	.39	.29
2	.53	.22	.28	.36	.27
3	.38	.16	.19	.24	.18
4	.37	.15	.19	.25	.19
5	.44	.18	.21	.27	.21
6	.35	.15	.21	.27	.21
7	.49	.21	.27	.34	.26
8	.54	.22	.29	.37	.28
9	.58	.24	.30	.39	.29
10	.54	.23	.28	.36	.28
11	.59	.25	.32	.41	.31
12	.61	.25	.32	.42	.31
13	.34	.14	.20	.26	.20
14	.57	.24	.31	.40	.30
15	.58	.24	.33	.42	.32
16	.66	.28	.38	.49	.37
17	.47	.20	.25	.32	.24
18	.55	.23	.28	.37	.28
19	.60	.25	.32	.41	.31
20	.57	.24	.30	.39	.29
21	.56	.23	.31	.40	.30
22	.48	.20	.26	.34	.25
23	.43	.18	.26	.33	.25
24	.53	.22	.29	.38	.28
25	.62	.26	.34	.43	.33
26	.57	.24	.30	.39	.29

*Labor Cost A based on 75 head per hour, B on 20 head per hour, and C on 120 head per hour.

gional slaughtering costs per unit are assumed equal to zero and thus zeros replace the c_i^1 in the programming formulation and tableau. In the final analyses the differences in labor costs are used as a basis for specifying the slaughtering costs per unit. Given the modified price and allocation model along with the regional consumptions, productions, plant capacities, technical coefficients for converting slaughter animals into meat, and the transportation and labor slaughtering costs the results of analyses for 1955 and 1960 for cattle and beef and for 1955 hogs and pork are given in this section.

A. Assuming no difference in regional labor slaughter costs.

1. *Cattle and beef, 1955, with estimated slaughter capacities.*

a. *Estimated flows and costs.*

Using the regional supplies of slaughter cattle and regional slaughter capacities, table 4, regional demands for beef, table 6, and the transportation costs among regions, a jointly determined spatial analysis for slaughter cattle and beef which minimizes the total transportation cost for both live slaughter animals and meat is presented. The flow quantities consistent with this objective are reported in the bodies of tables 10 and 11. These optimum geographical flows are presented graphically in figures 4 and 5. The shaded areas in figure 4 represent regions in which the supplies of slaughter cattle exceeded slaughter capacity while the shaded regions of figure 5 represent regions in which the supply of beef exceeds demand. The lines emanating in the surplus regions indicate the direction of slaughter cattle and beef flows, while the numbers appearing on the lines indicate the quantity of flow involved in each case.

There were seven regions in which the supply of slaughter cattle exceeded the estimated slaughter capacity (Regions 15, 18, and 19-23). Of these, Region 15 (Iowa) had the largest surplus of slaughter cattle of approximately 1.2 billion pounds live weight. Both Region 18 and 22 had in excess of 400 million pounds, while Region 21 (Colorado) had the smallest surplus of 22.7 million pounds. The major estimated flows were east and south from Regions 15, 18, 19 and 21. Region 20 shipped both east and west while Regions 22 and 23 only shipped westward. The total shipments involved were 3.0 billion pounds and approximately 12% of the total supply of slaughter cattle was estimated to be involved in interregional trade. Estimated total transportation cost was \$30 million which yields an average cost of \$1.01 per hundred. This is over 1.5 billion pounds less than was estimated in the separate analyses using

Table 10. Supplies, Price Differentials, Optimum Levels of Slaughter and Flows of Cattle for Slaughter, 26 Regions of the U. S., 1955

Destination	Origin and quantities of shipments (1,000 pounds)							Supply of slaughter cattle	Optimum slaughter demand	V [†]
	15	18	19	20	21	22	23			
1*								185,009	185,009	.00
2*								908,525	908,525	-.22
3*								477,842	477,842	-.25
4*								128,746	128,746	-.11
5*								159,238	159,238	-.55
6*								302,272	302,272	-.73
7		95,425						413,153	508,578	-.82
8	642,732	220,194						616,576	1,479,502	-.75
9*								760,531	760,531	-1.06
10	530,646							435,937	966,583	-.80
11			307,061					1,938,503	2,245,564	-1.19
12	18,830							569,464	588,294	-1.17
13		86,087						304,453	390,540	-.88
14		31,547						1,156,322	1,187,869	-1.47
16				158,832				1,227,056	1,385,888	-1.60
17					22,734			1,849,662	1,872,396	-1.15
24*								444,017	444,017	-1.91
25						301,153	246,605	1,659,797	2,207,555	-.85
26				225,577		127,120		426,062	778,759	-.98
Supply	3,192,487	1,768,275	2,376,275	934,374	943,134	565,261	457,850	24,200,821		
Slaughter	2,000,279	1,335,022	2,069,214	549,965	920,400	136,988	211,245		24,200,821	
U [†]	-1.71	-1.76	-1.96	-2.34	-2.18	-2.34	-1.83			

Total Cost—\$30,545,269

Total Shipments—3,014,543,000 pounds

*Received no shipments of slaughter cattle from other regions. Slaughter composed of production from within the region.

†The U[†] and V[†] are in terms of cents per pound.

actual regional slaughter.²⁴ Using actual regional slaughter, approximately 4.5 billion pounds or 19% of the total supply was estimated to have entered interregional trade. The total transportation cost in the separate analysis using actual regional slaughter was \$58 million or \$1.29 per hundred pounds. On the average, the distance slaughter cattle moved in the jointly determined analysis was shorter as indicated by the lower cost per hundred pounds.

There were seven fewer regions shipping slaughter cattle in the jointly determined model as compared to the separate analyses in which actual regional slaughter was used. However, the direction of the flows was quite similar for the two analyses. One of the major exceptions was that Region 21 (Colorado) shipped to Region 2 in the separate analyses, but only to Region 17 in the jointly determined analysis. In addition, Regions 13, 14, and 17 became receiving regions in the joint analysis whereas in the previous analysis they exported live slaughter cattle.

Advantages of shipping carcass beef rather than live slaughter cattle are suggested by the results of the joint analysis. Except for two flows, slaughter cattle from the seven surplus regions were shipped to the next closest region. As a result, Regions 1-6 did not receive any shipments of live slaughter cattle and consequently slaughtered only their own pro-

duction. Two exceptions were the shipments from Regions 15 and 18 to Region 8, bypassing Region 9, and the shipment from Region 22 to Region 25 which bypassed Region 24 (figure 4). In both cases, Regions 9 and 24 were surplus producers of beef. Due to the relative differences in transportation rates for both live cattle and beef and since both were considered, total transportation was minimized by shipping live slaughter cattle direct to the point of consumption, Regions 8 and 25, rather than shipping live cattle to Regions 9 and 24 to be slaughtered and then shipping the beef to Regions 8 and 25.

The results of the beef analysis for the 1955 joint model are presented in table 11 and figure 5. The estimated total shipment for this analysis was 4,244.4 million pounds which indicates that approximately 31% of the total supply of beef was involved in interregional trade. The total transportation cost was \$102.5 million, or approximately \$2.42 per hundred pounds.

The dominant surplus areas were the Corn Belt, Northern Plain States, and Colorado, while the East Coast was the major deficit area. Regions 1 and

²⁴In the separate analyses flows of live slaughter animals were analyzed without considering the regional demands and flows of meat, and meat flows were analyzed without considering regional levels of production and flows of live slaughter animals.

2 received over 70% of the beef that entered inter-regional trade. Major flows were from Regions 9, 11, 14, 15, 16 and 19 eastward, Regions 18 and 21 shipping eastward and south, Region 20 shipping both eastward and westward, and Region 24 shipping only westward to Region 25.

Due to changes in the shipping patterns of slaughter cattle and resulting levels of regional slaughter, there were considerable differences in the meat flows derived for the joint analysis as compared to the meat flows of the independently determined analysis. For example, in the joint analysis Regions 7 and 25 became deficit regions, Region 9 became a surplus region for beef, and Regions 12 and 26 slaughtered enough beef to fulfill their demands. Since regions along the East Coast did not receive any shipments of live slaughter cattle, shipments of dressed beef to these regions increased substantially.

The total minimum transportation cost associated with the joint analysis of shipping both live slaughter cattle and beef was \$133.0 million. Approximately \$30.5 million of this was for moving slaughter cattle and \$102.5 million for shipping beef. This is about \$11.3 million less than the costs estimated in the independently determined analysis in which actual regional slaughter was used. In the independently determined spatial analyses for slaughter cattle and beef, total transportation cost was \$144.3 million of which \$58.0 million was for shipments of live slaughter cattle and \$86.3 million was for beef shipments. The transportation cost of moving slaughter cattle was less in the joint analyses because both the quantity moved and length of shipment were reduced. The shorter shipping distance is exemplified by the average cost of \$1.01 per hundred pounds in the joint analysis as compared to \$1.29 in the independently determined analysis. However, total transportation cost of shipping beef was higher in the joint analysis. In addition to an increase in the quantity moved, there was also an increase in the length of the shipments. This is indicated by an increase in the average costs per hundred pounds from \$2.27 in the separate analyses to \$2.42 in the jointly determined model.

The results of the joint analyses illustrate that total transportation costs are substantially less when the livestock and meat sector are considered simultaneously. When only the existing structure of transportation rates for livestock and meat is considered, transportation costs are minimized by slaughtering the livestock at or near the producing areas.

b. Estimated regional slaughter and excess capacity

The levels of regional slaughter as derived by the joint analysis are shown in table 12. In comparison

Table 11. Excess Demands and Supplies, Optimum Flows and Price Differentials, 26 Regions of the U. S., Beef, 1955

Origins	1	2	3	4	5	6	7	8	10	12*	13	17	22	23	25	26*	Excess supplies	U†
9								21,284									21,284	.25
11	238,301								142,020								380,321	0
14		182,751	81,053														263,804	-.45
15	238,623	640,636															879,259	-.62
16		489,081															489,081	-.74
18			162,933		231,051	105,299	53,203										552,486	-.69
19		1,026,960															1,026,960	-.90
20	183,034												14,722				197,756	-1.46
21	19,574			148,852							42,299	75,347		64,471			350,543	-1.69
24															82,939		82,939	-1.30
Excess																		
Demands	679,532	2,339,428	243,986	148,852	231,051	105,299	53,203	21,284	142,020	0	42,299	75,347	14,722	64,471	82,939	0	4,244,433	
V†	2.16	1.76	1.71	1.97	1.17	.84	.68	.81	.83	.05	.70	.07	.32	.19	.63	.39		
Total Costs—\$102,528,633																		
Total Shipments—4,244,433,000 Pounds																		

*Received no shipments of beef from other regions. Slaughter fulfilled demand.

†The U† and V† are in terms of cents per pound.

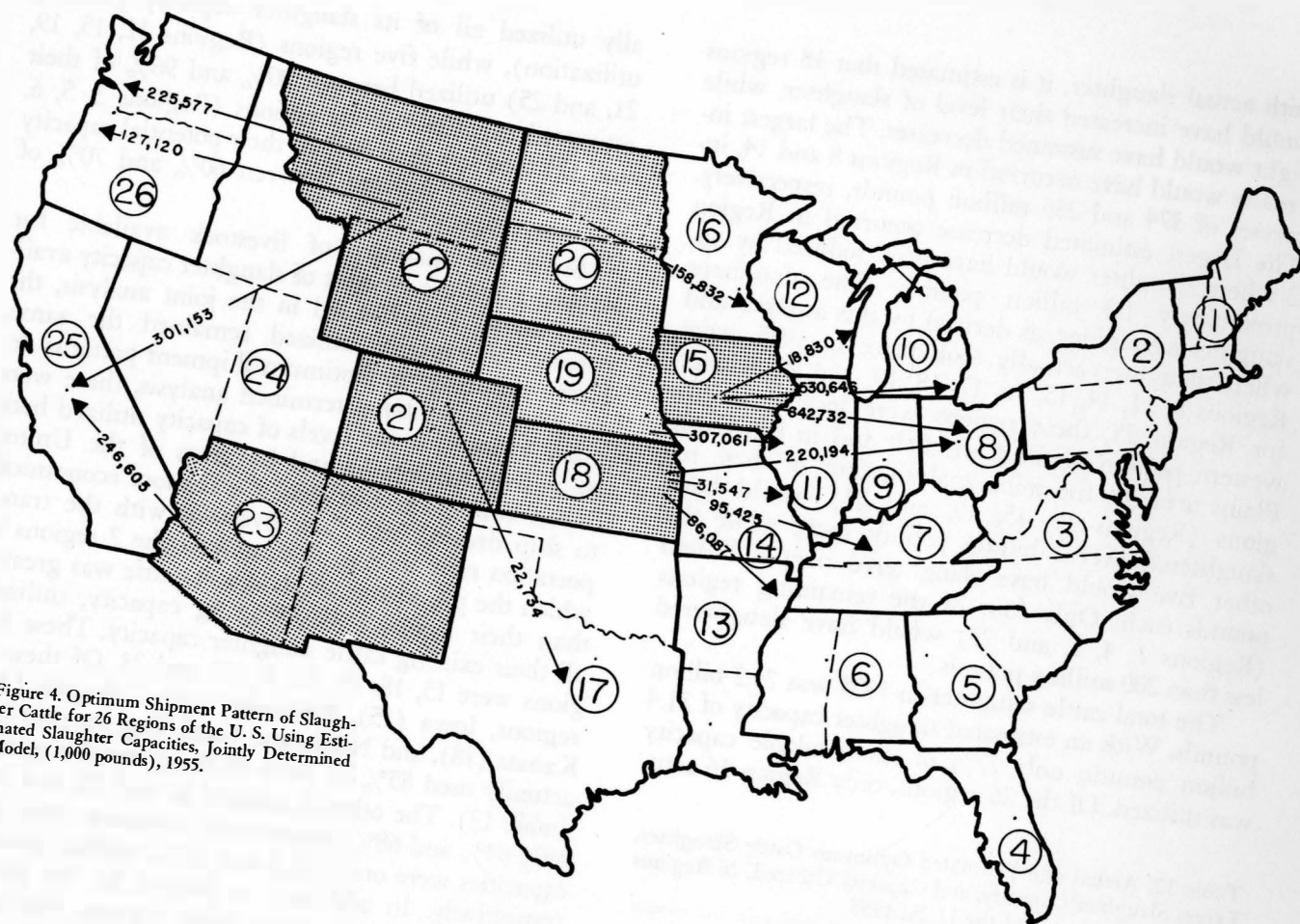


Figure 4. Optimum Shipment Pattern of Slaughter Cattle for 26 Regions of the U. S. Using Estimated Slaughter Capacities, Jointly Determined Model, (1,000 pounds), 1955.

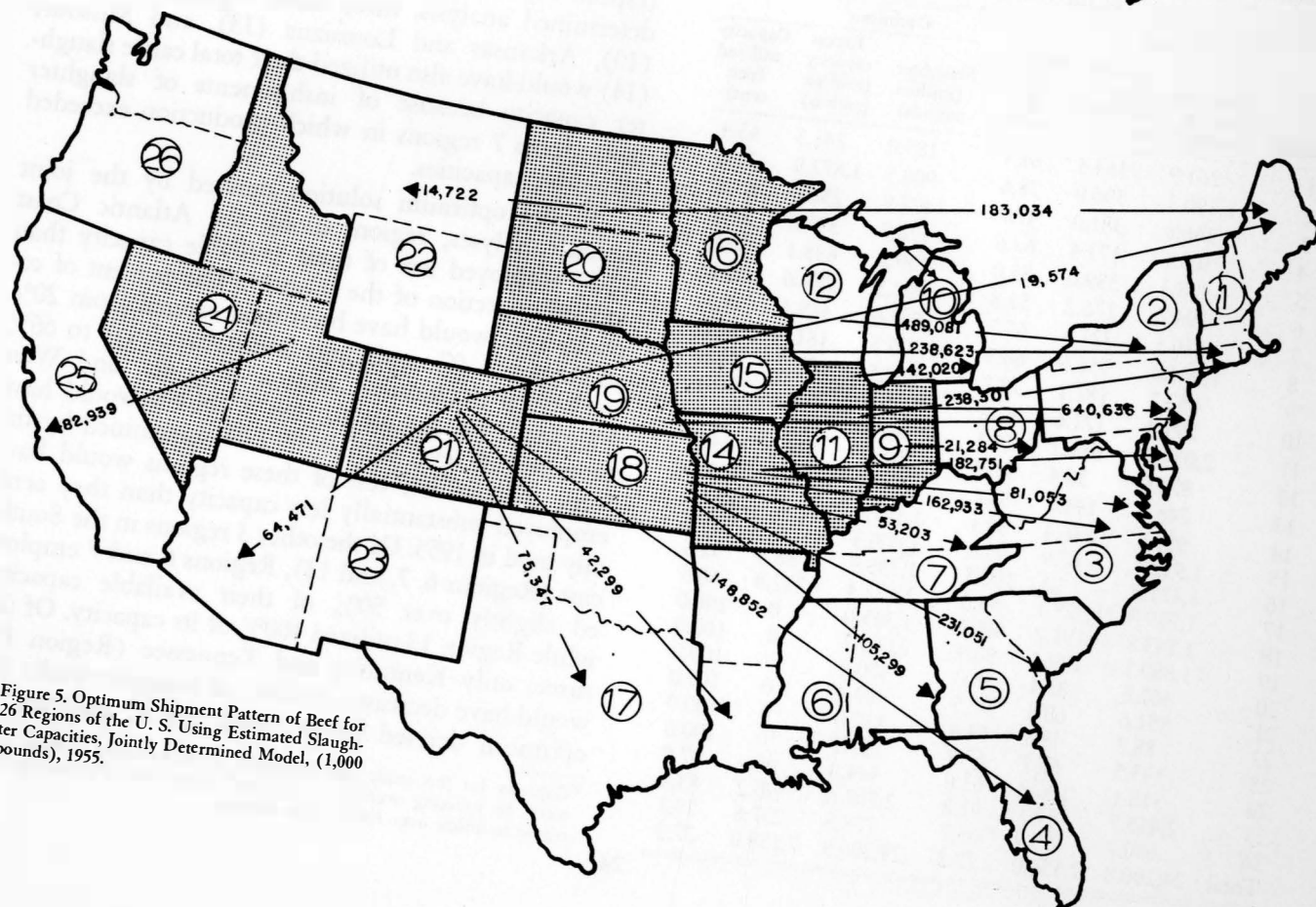


Figure 5. Optimum Shipment Pattern of Beef for 26 Regions of the U. S. Using Estimated Slaughter Capacities, Jointly Determined Model, (1,000 pounds), 1955.

with actual slaughter, it is estimated that 18 regions would have increased their level of slaughter, while eight would have sustained decreases. The largest increases would have occurred in Regions 8 and 14, increases of 374 and 236 million pounds, respectively. The largest estimated decrease occurred in Region 2 where slaughter would have been reduced by approximately 1.3 billion pounds. The dominant slaughtering regions, as derived by this analysis and where slaughter actually took place in 1955, were Regions 8, 11, 14, 15, 16, 17, 18, 19, and 25. Except for Region 25, these regions were located in the western portion of the Corn Belt and in the Great Plains area. In the joint analysis, four of these regions (Regions 11, 15, 19, and 25) would have slaughtered over 2 billion pounds each, while the other five would have slaughtered over 1 billion pounds each. Only four of the remaining regions (Regions 1, 4, 5, and 22) would have slaughtered less than 200 million pounds.

The total cattle slaughter in 1955 was 24.2 billion pounds. With an estimated slaughter capacity of 31.4 billion pounds, only 77% of the available capacity was utilized. Of the 26 regions, only Region 16 actu-

ally utilized all of its slaughter capacity (100.3% utilization), while five regions (Regions 12, 15, 19, 21, and 25) utilized between 90% and 96% of their estimated capacity.²⁵ Four regions (Regions 3, 5, 6, and 17) used less than 60% of their potential capacity while 9 regions utilized between 60% and 70% of their total capacity.

Since the quantity of livestock available for slaughter and the amount of slaughter capacity available remained unchanged in the joint analysis, the percent of capacity utilized remained the same. However, under the optimum shipment patterns derived by the jointly determined analysis, there were major changes in the levels of capacity utilized both by individual regions and by areas of the United States. Due to the fact that it was more economical to ship dressed beef than livestock with the transportation rates used in this analysis, the 7 regions to which the production of slaughter cattle was greater than their available slaughtering capacity, utilized all their existing cattle slaughter capacity. These Regions were 15, 18, 19, 20, 21, 22 and 23. Of these, 5 regions, Iowa (15), Nebraska (19), Colorado (21), Kansas (18), and North and South Dakota (20) had actually used 85% or more of their capacity in 1955 (table 12). The other 2 regions, 22 and 23, had used only 64% and 68%, respectively; however, their total capacities were only 137.0 and 211.2 million pounds, respectively. In addition, as derived by the jointly determined analysis, three other regions, Michigan (10), Arkansas and Louisiana (13), and Missouri (14) would have also utilized their total cattle slaughter capacity because of inshipments of slaughter cattle from 7 regions in which production exceeded slaughter capacities.

In the optimum solution derived by the joint spatial analyses, regions along the Atlantic Coast (1-5) employed less of their available capacity than any other section of the country. The percent of capacity that would have been used ranged from 20% in Region 5 (Georgia and South Carolina) to 66% in Region 3 (North Carolina, Virginia, and West Virginia). Except for Region 3, which would have increased its level of slaughter as determined by the joint analysis, the rest of these regions would have employed substantially less capacity than they actually used in 1955. Of the other 3 regions in the Southeast (Regions 6, 7, and 13), Regions 6 and 7 employed slightly over 50% of their available capacity, while Region 13 utilized 100% of its capacity. Of the three, only Kentucky and Tennessee (Region 13) would have decreased its level of slaughter under the optimum derived by the joint spatial analyses. In

²⁵Capacity for this study was estimated on a one-shift, 38-hour work week. By utilizing overtime or two-shift operations, it is possible for a region to utilize over 100% of its capacity.

Table 12. Actual and Estimated Optimum Cattle Slaughter, Excess Slaughter Capacity, and Capacity Utilized, 26 Regions of the U. S., 1955

Region	Actual			Optimum		
	Slaughter (million pounds)	Excess capacity (million pounds)	Capacity utilized (per cent)	Slaughter (million pounds)	Excess capacity (million pounds)	Capacity utilized (per cent)
1	261.9	164.4	61.4	185.0	241.3	43.4
2	2,190.3	596.0	78.6	908.5	1,877.9	32.6
3	346.8	381.0	47.7	477.8	250.0	65.6
4	303.1	173.4	63.6	128.7	347.8	27.0
5	438.3	359.0	55.0	159.2	638.1	20.0
6	296.7	276.2	51.8	302.3	270.6	52.8
7	616.1	321.6	65.7	508.6	429.1	54.2
8	1,104.8	556.6	66.5	1,479.5	181.9	89.1
9	652.7	182.1	78.2	760.5	74.2	91.1
10	795.0	171.6	82.2	966.6	0	100.0
11	2,034.7	689.2	74.7	2,245.6	478.3	82.4
12	870.0	36.4	96.0	588.3	318.1	64.9
13	246.4	144.1	63.1	390.5	0	100.0
14	951.5	236.4	80.1	1,187.9	0	100.0
15	1,912.4	87.9	95.6	2,000.3	0	100.0
16	1,471.5	4.8	100.3	1,385.9	80.8	94.5
17	1,719.3	1,375.1	55.6	1,872.4	1,222.0	60.5
18	1,143.8	191.2	85.7	1,335.0	0	100.0
19	1,880.1	189.1	90.9	2,069.2	0	100.0
20	467.6	82.4	85.0	550.0	0	100.0
21	851.6	68.8	92.5	920.4	0	100.0
22	88.2	48.8	64.4	137.0	0	100.0
23	143.5	67.7	67.9	211.2	0	100.0
24	318.1	186.8	63.0	444.0	60.9	87.9
25	2,415.7	217.1	91.8	2,207.6	425.2	83.8
26	680.7	355.9	65.7	778.8	257.8	75.1
Total	24,200.8	7,154.0	77.2	24,200.8	7,154.0	77.2

terms of the absolute quantity, New York, Pennsylvania, etc., (Region 2) would have had approximately 1.9 billion pounds of excess capacity or slightly over one-fourth of the total excess capacity in the U. S.

In the North Central and Great Plains Regions, all regions except Illinois (11), Wisconsin (12), and Texas and Oklahoma (17) utilized 90% or more of their total capacity under the optimum derived by the joint analyses. Only two regions, Wisconsin (12) and Minnesota (16) would have slaughtered less than that which actually occurred. While the change was relatively minor in Region 16, the amount of capacity left idle in Wisconsin increased from 36.4 to 318.1 million pounds. However, in terms of total absolute excess capacity, Texas and Oklahoma (17) had more (1.2 billion pounds) than the total for the rest of the regions in this area and ranked second to Region 2 with respect to excess capacity.

The only regions in the Mountain and Pacific Coast area that would have had excess capacity as indicated by this analysis were 24, 25, and 26. Of these, Washington and Oregon (25) and Idaho, Nevada, and Utah (24) would have had less unutilized capacity than they actually did, while California (26) would have increased its amount of excess capacity.

c. Price differentials and rents.

The sets of regional price differentials consistent with the optimum flow patterns for slaughter cattle and dressed beef as derived by the joint analysis are given in the last columns and rows of tables 10 and 11. Region 1 was chosen as the base region in the slaughter cattle analysis while Region 11 was chosen as the base region in the beef analysis and the respective price differentials are computed relative to these base regions. The price differentials for the surplus regions measure the comparative advantage of these regions relative to the base region while the price differentials for the deficit regions give the delivered price differentials relative to the base region. For example, as shown in table 11, beef is worth \$1.69 per hundred more in Region 11 (Illinois) than in Region 21 (Colorado) because of its proximity to the deficit regions in the East. Therefore, Region 11 has a comparative advantage of \$1.69 per hundred pounds over Region 21. In the other extreme, the price of beef in Region 1 because of its deficit position is \$2.16 higher per hundred pounds than in Region 11.

With Region 1, as the base region, the surplus slaughter cattle regions with the greatest comparative advantage were Iowa (15), Kansas (18), and Arizona and New Mexico (23). The surplus regions with the least comparative advantage were North and South Dakota (20), Montana and Wyoming

(22), and Colorado (21). The deficit regions, in addition to Region 1, with the highest relative prices were the other regions along the Atlantic Coast. Deficit regions with the lowest relative prices of slaughter cattle were located adjacent to the surplus regions of the Corn Belt and Mountain States.

For beef, with Illinois (11) as the base region, Indiana had the greatest comparative advantage of the surplus regions as a result of its location, to the large deficit areas in the East, while Colorado (21) had the least comparative advantage. Of the deficit areas, regions along the East Coast (1-5) had the highest relative prices, while Region 22 (Montana and Wyoming) had the lowest relative price, 32 cents less per hundred pounds than that of the base region. These estimated price differentials suggest that slaughter cattle prices as well as beef prices will be highest on the East and West Coasts and lowest in the Great Plains.

In comparison, only slight differences occurred between the price differentials derived by the jointly determined analysis and those derived in the independently determined analyses of slaughter cattle and beef.²⁶ Except for Region 2, where slaughter cattle prices would have been 21 cents less per hundred pounds in the joint analysis than in the initial analysis, there was a smaller differential between the other regions and that of the base region. In most cases, this differential was approximately 20 cents per hundred pounds or less. The exceptions were those regions that shipped slaughter cattle in the previous analysis, but were deficit regions in the joint analysis. The equilibrium prices in these regions (Regions 6, 13, 17, and 24) were increased between 29 and 78 cents per hundred pounds.

Although there were slight differences in the beef price differentials of the two alternative analyses, the major changes occurred in price differentials of Regions 24, 25, and 26. The largest of these changes occurred in Region 25, where the price differential changed from 49 cents less to 63 cents higher per hundred pounds than that of Region 11. This occurred because this region changed from a surplus region in the independently determined analysis to a deficit region in the joint analysis. Region 26 (Washington and Oregon) had an equilibrium price of \$1.30 per hundred pounds greater than the base region in the separate analyses, when it was deficit in beef; however, in the joint analysis when it was self-sufficient in beef, its beef price would have been only 39 cents per hundred pounds more. A pictogram of the spatial price structure of beef for the optimum solution is shown in figure 6.

²⁶The price differentials for slaughter cattle from the separate analysis are in table 4, "Spatial Analyses of the Flows of Slaughter Livestock in 1955 and 1960" while those for beef are in table 19, "Spatial Analyses of the Meat Marketing Sector in 1955 and 1960."

A by-product of the joint analyses are the "rents" for additional slaughter capacity that are consistent with the price and allocation solution and are derived from the analyses for those regions that utilize their entire capacity. These are the rents that accrue to the capacity of the region as a result of its locational advantage relative to the available supply of slaughter cattle, the capacity available, and the location of the deficit beef regions. The rent that accrues to a region gives an indication of the relative profitability of increasing slaughter capacity in that region. The regions in which slaughter rents accrued and the amount per hundred pounds, liveweight, are given in table 13.

In seven regions production of slaughter cattle exceeded capacity and three additional regions slaughtered to their capacity by importing cattle from the surplus regions and therefore accrued slaughter rents. The latter regions were Michigan (10), Arkansas and Louisiana (13), and Missouri (14). Since a cost was incurred in importing the slaughter cattle, the rents for these regions varied from 3 to 7 cents per hundred pounds of live weight and were low relative to the rents accrued in adjacent regions that had a surplus of slaughter cattle. The slaughter rent derived for Missouri (14) was only 3 cents per hundred as compared to 6 and 7 cents for the

Table 13. Slaughter Rents in Cents Per Hundred Pounds, Live Weight, Slaughter Cattle, for Estimated Capacity and Increased Capacity Levels, 1955

Region	Estimated actual capacity		Increased capacity level	
	Capacity (1,000 pounds)	Rent (dollars/cwt.)	Capacity (1,000 pounds)	Rent (dollars/cwt.)
10	966,583	.06	*	*
13	390,540	.07	*	*
14	1,187,869	.03	*	*
15	2,000,279	.16	3,192,486	.07
18	1,335,022	.19	1,768,274	.03
19	2,069,214	.27	2,376,274	.19
20	549,965	.34	934,373	†
21	920,400	.06	943,133	.04
22	136,988	.97	565,260	.04
23	211,245	.74	457,849	.18

*With capacity limitations increased in regions where production exceeded slaughter, these regions did not completely utilize their capacity in the alternative analysis.

†Did not utilize entire capacity in alternative analysis as a result of shipping out slaughter cattle in alternative analysis.

other two regions. This is because Missouri was a surplus producer of beef, while both of the other regions were still deficit areas, i.e. the demand for beef exceeded the estimated capacity.

Of the seven regions in which slaughter cattle production exceeded the estimated slaughter capa-

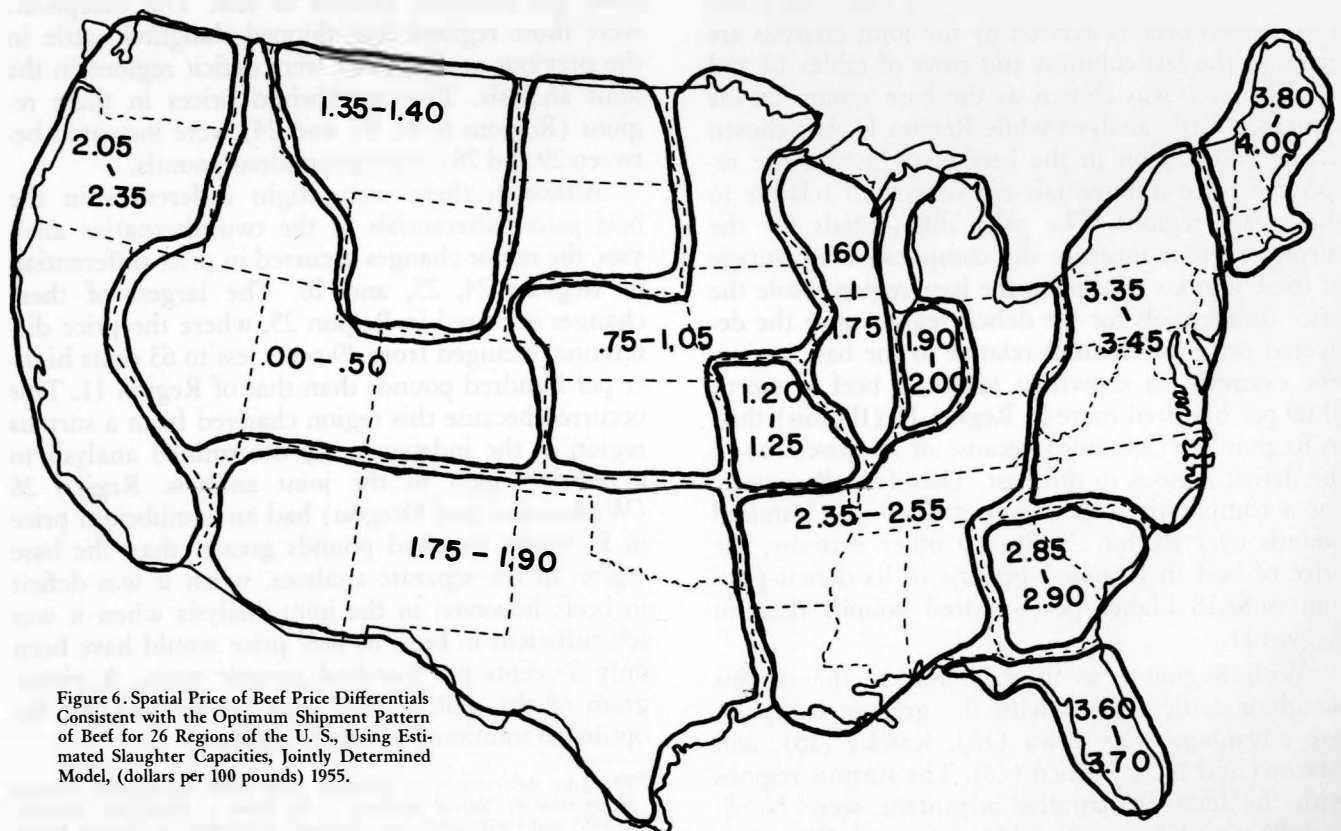


Figure 6. Spatial Price of Beef Price Differentials Consistent with the Optimum Shipment Pattern of Beef for 26 Regions of the U. S., Using Estimated Slaughter Capacities, Jointly Determined Model, (dollars per 100 pounds) 1955.

city, Region 21 accrued the lowest slaughter rent, while Regions 22 and 23 had the highest rents per hundred pounds. The low slaughter rent in Region 21, Colorado, is a result of its location with respect to the other surplus beef producing regions and the deficit beef regions. As shown in figure 5 the optimum flow patterns indicate that Colorado would ship its surplus beef greater distances than any other region. The highest accrued rents were in Montana and Wyoming (22) and Arizona and New Mexico (23), 97 and 74 cents per hundred pounds, respectively. In both cases, these regions imported dressed beef, even though they had exported slaughter cattle since their slaughter cattle production exceeded their capacity.

2. Cattle and beef 1955, with increased slaughter capacities assumed for surplus production region.

In the past decade there has been a trend toward locating new slaughtering facilities in the main areas of production. As shown in table 4, cattle slaughter capacity was increased by 1.7 billion pounds between 1955 and 1960. Fifty-seven percent of this increase, 962.5 million pounds, was in Regions 15 (Iowa) and 19 (Nebraska). Slight decreases in slaughter capacity occurred in the southeastern regions, eastern Corn Belt and in Texas and Oklahoma (Region 17).

In view of the trend which has been occurring in the relocation of slaughtering facilities, an alternative analysis was performed which focused on the following areas:

- i. the gain in efficiency (i.e., minimizing total transportation costs), by locating slaughtering facilities in the areas of production, provided that dressed meat has an advantage over live animals with respect to transportation costs.
- ii. the effect on other regions as slaughtering facilities are increased in the dominant areas of production.
- iii. the effect on the absolute levels of slaughter rents as capacity is increased in regions where it is presently a restriction.
- iv. the comparative advantage of these alternative regions as determined by slaughter rents.

In the preceding jointly determined analysis seven regions in which production exceeded the available slaughter capacity slaughtered at full capacity and three additional regions (Regions 10, 13, and 14) imported slaughter cattle to their capacity limits. In this analysis the regional slaughter capacity restrictions of the surplus slaughter cattle producing regions (Regions 15, 18, 19, 20, 21, 22 and 23) are set at 1,000 pounds less than the regional production

for slaughter. These restrictions on regional slaughter capacities permit slaughter rents for limited slaughter facilities to be derived and allow determining which regions would continue to receive surplus production as slaughter capacities were increased in deficit capacity regions.

a. Estimated flows and costs.

The results of the alternative analysis for slaughter cattle and beef for 1955 in which increased slaughter capacities were used for the surplus production regions are presented in tables 14 and 15 and figures 7 and 8. A total of 51.5 million pounds of slaughter cattle and 5.3 billion pounds of dressed beef would have been shipped interregionally under these conditions.

As shown in table 14 and figure 7, a considerable change occurred in the flows and quantities of slaughter cattle shipped when the slaughter capacities of surplus production regions were increased to within 1,000 pounds of production.²⁷ Except for Regions 16 (Minnesota) and 20 (North and South Dakota), which shipped 18.8 and 32.7 million pounds of slaughter cattle to Regions 12 and 26, respectively, none of the other surplus regions shipped more than 1,000 pounds, the amount by which production exceeded capacity. Of the six regions shipping only 1,000 pounds of live slaughter cattle (Regions 15, 18, 19, 21, 22 and 23), only two regions, 19 (Nebraska) and 21 (Colorado), shipped to regions other than those to which they shipped in the preceding analysis. Initially, Region 19 had shipped to Region 11, while Region 21 had shipped to Region 17 (table 10). However, in this alternative analysis, both Regions 19 and 21 shipped to Region 13, as did Region 18, which had shipped to Region 7, 8 and 14 in addition to Region 13 in the previous analysis.

Of the two regions shipping more than 1,000 pounds of live slaughter cattle, only Region 20 was a surplus region in the initial jointly determined analysis. Region 16, Minnesota, which shipped 18.8 million pounds of slaughter cattle in this analysis was, in fact, an importing region, receiving 158.8 million pounds from Region 20 (North and South Dakota) in the preceding analysis. Although Region 20 did ship 32.7 million pounds of slaughter cattle to Region 26, it did utilize a large proportion of the capacity assumed available for this analysis.

With slaughter being centered, in most cases, at the point of production in this alternative analysis, a number of changes occurred both in quantity of dressed beef moved interregionally as well as in the direction of the shipments (table 15 and figure 8). In addition, Regions 22 and 23, which were deficit

²⁷Surplus production regions refer to regions in which production of slaughter cattle exceeded slaughter capacity in the preceding jointly determined analysis.

Table 14. Supplies, Price Differentials, Optimum Levels of Slaughter and Flows of Cattle for Slaughter, with Increased Slaughter Capacities, 26 Regions of the U. S., 1955

Destination	Origins and quantities of shipments (1,000 pounds)								Supply of slaughter cattle	Optimum slaughter demand	V ₁ †
	15	16	18	19	20	21	22	23			
1*									185,009	185,009	0
2*									908,525	908,525	-.22
3*									477,842	477,842	-.22
4*									128,746	128,746	-.06
5*									159,238	159,238	-.52
6*									302,272	302,272	-.70
7*									413,153	413,153	-.79
8*									616,576	616,576	-.67
9*									760,531	760,531	-.98
10	1								435,937	435,938	-.70
11*									1,938,503	1,938,503	-1.16
12		18,830							569,464	588,294	-1.09
13			1	1		1			304,453	304,456	-.70
14*									1,156,322	1,156,322	-1.40
17*									1,849,662	1,849,662	-1.05
24*									444,017	444,017	-1.56
25								1	1,659,797	1,659,798	-.50
26					32,706		1		426,062	458,769	-.67
Supply	3,192,487	1,227,056	1,768,275	2,376,275	934,374	943,134	565,261	457,850	24,200,821		
Slaughter	3,192,486	1,208,226	1,768,274	2,376,274	901,668	943,133	565,260	457,849		24,200,821	
U ₁ †	-1.61	-1.59	-1.58	-1.87	-1.99	-2.06	-1.99	-1.48			
Total Cost—\$6,692,514											
Total Shipments—51,542,000 pounds											

*Received no shipments of slaughter cattle from other regions. Slaughter composed of production from within the region.

†The U₁ and V₁ are in terms of cents per pound.

beef regions in the preceding analysis, were surplus beef regions in this analysis, while Region 26 which was self-sufficient previously, became a deficit region.

In this analysis, a total of 5.5 billion pounds of dressed beef would have been shipped interregionally. This is approximately 1.4 billion pounds more than would have entered interregional trade in the previous analysis. Over 40% of the total quantity of dressed beef in 1955 would have been moved interregionally in this analysis. Of the deficit areas, Region 2 would have received over 2.3 billion pounds, while Regions 15 and 19 were the dominant surplus regions with excess supplies of 1.5 and 1.2 billion pounds, respectively.

With the increased slaughter capacity levels, two major directional shifts occurred in flows of dressed beef. In the previous analysis Region 20 would have shipped beef both East (Region 1) and West (Region 22); however, in this analysis, the optimum shipment pattern included only shipments to Region 1. The other region whose markets would have been changed as derived by this analysis was Region 21 (Colorado). In the preceding analysis, Region 21 would have shipped beef South (Region 23), to the Southeast (Regions 4, 13 and 17) and to the East (Region 1). However, with the changes that occur-

red when the slaughter capacities were increased in the seven regions in which production exceeded capacity, the optimum shipment pattern showed Colorado shipping west to California as well as to Regions 13 and 17.

The total transportation cost associated with this analysis was approximately 129 million dollars, of which 6.7 million was for shipping slaughter cattle and 122.3 million was incurred in beef shipments. By allowing slaughter to take place in the regions of production there was a net savings in transportation costs of 4.1 million dollars, as compared to the optimum derived when estimates of actual slaughter capacity were used as restrictions.

This portion of the analysis indicates there may be major structural changes in the livestock-meat economy as slaughter facilities are increased in the chief producing regions. In general, with the relative cattle and meat transportation rates used in this analysis, efficiency, measured in terms of total transportation costs, would be increased. However, even though it was possible for each region to slaughter its entire production (except for 1,000 pounds in the seven surplus production regions), it may be advantageous to ship slaughter cattle in some instances rather than beef. In this analysis this was exemplified by the shipment patterns of Regions 16 and 20.

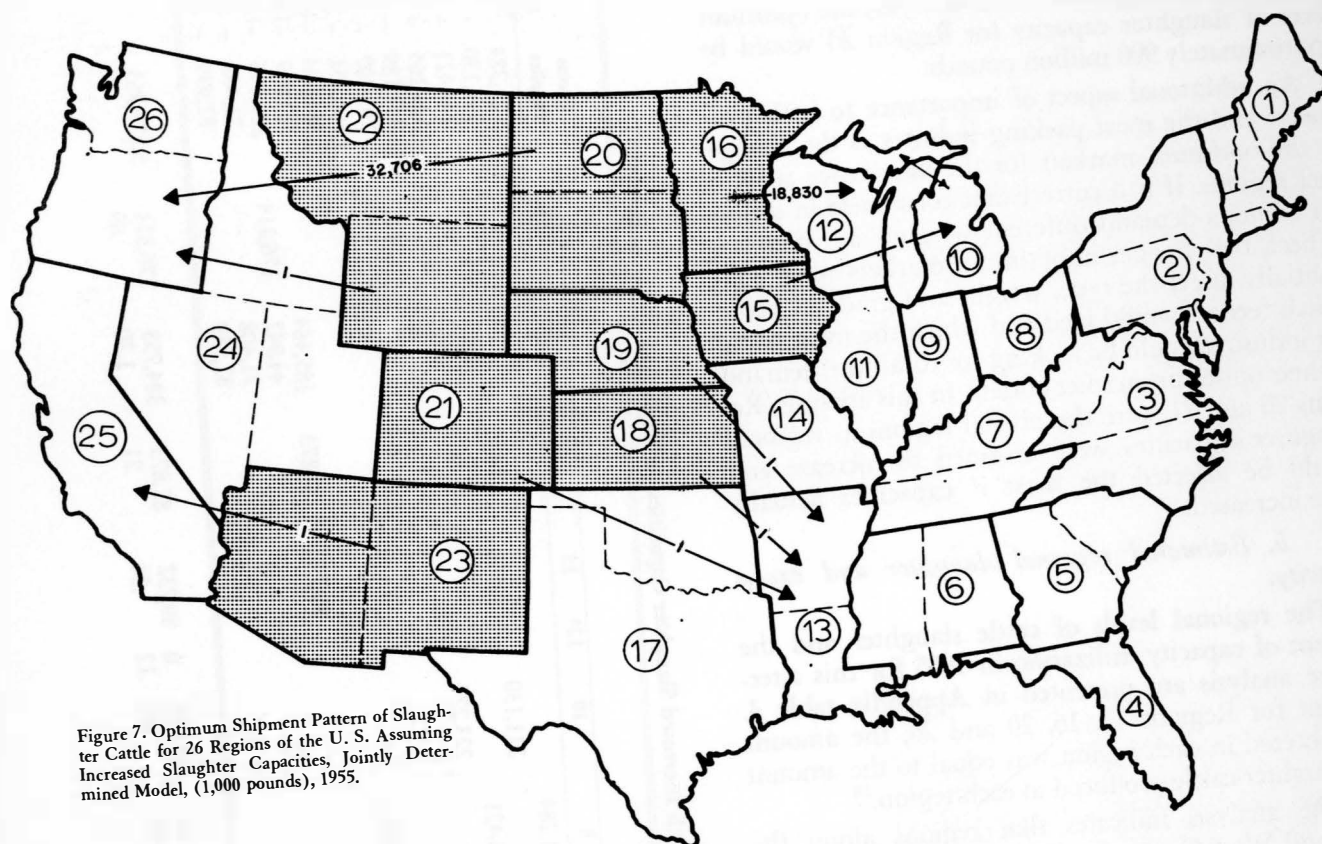


Figure 7. Optimum Shipment Pattern of Slaughter Cattle for 26 Regions of the U. S. Assuming Increased Slaughter Capacities, Jointly Determined Model, (1,000 pounds), 1955.

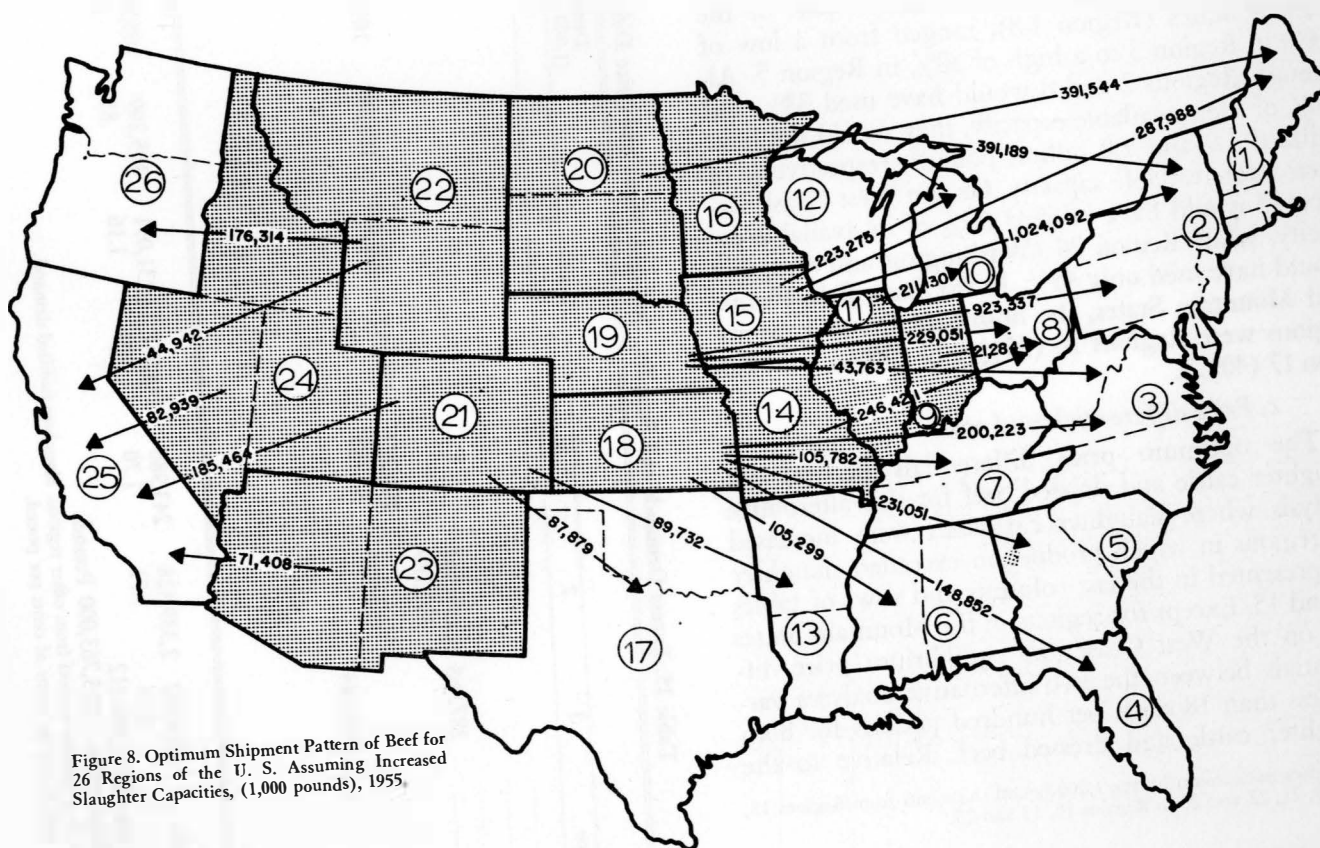


Figure 8. Optimum Shipment Pattern of Beef for 26 Regions of the U. S. Assuming Increased Slaughter Capacities, (1,000 pounds), 1955.

Under the assumptions of this analysis, the optimum level of slaughter capacity for Region 20 would be approximately 900 million pounds.

An additional aspect of importance to both producers and the meat packing industry is the change in the optimum markets for the alternative surplus beef regions. If it is correct that consumers in different sections demand different weights and qualities of beef, the changes in optimum markets could substantially affect the type, weight and grade of cattle which feeders would feed and which the meat packing industry would be looking for to fill the demand of their optimum market outlets. In this analysis, Regions 20 and 21 were the pivotal regions as regional slaughter capacities were assumed to increase and would be affected the most if capacities actually were increased.

b. Estimated regional slaughter and excess capacity.

The regional levels of cattle slaughter and the percent of capacity utilization in 1955 for this alternative analysis are presented in Appendix table 3. Except for Regions 12, 16, 20 and 26, the amount slaughtered in each region was equal to the amount of slaughter cattle produced in each region.²⁸

The analysis indicates that regions along the East and West Coasts would be affected most by increases in the amount of slaughter capacity in the dominant production regions. The quantity of excess capacity in regions in the eastern part of the United States (Region 1-8), ranged from a low of 34% in Region 3 to a high of 80% in Region 5. Although Regions 2 and 8 would have used 33% and 37% of their available capacity, they would not have utilized 1.9 and 1.0 billion pounds, respectively, of their total available capacity. On the West Coast, Region 25 would have utilized 63% of its available capacity, while Region 26 (Washington and Oregon) would have used only 45%. In the Corn Belt, Plains, and Mountain States, the dominant excess capacity regions were Regions 10 (55%), 12 (35%), and Region 17 (40%).

c. Price differentials and rents.

The optimum price differentials derived for slaughter cattle and dressed beef for this alternative analysis where slaughter capacities were increased for regions in which production exceeded slaughter are presented in the last columns and rows of tables 14 and 15. Except for regions in the Mountain States and on the West Coast, the equilibrium price differentials between the two alternative analyses varied less than 18 cents per hundred pounds for both slaughter cattle and dressed beef. Relative to the

²⁸This does not account for the 1,000 pound shipments from Regions 15, 18, 19, 21, 22 and 23 to Regions 10, 13 and 25.

Table 15. Excess Demands and Supplies, Optimum Flows and Price Differentials, With Increased Slaughter Capacities, 26 Regions of the U. S., Beef, 1955

Origins	Destination (1,000 pounds)													Excess supplies	U†
	1	2	3	4	5	6	7	8	10	12*	13	17	25	26	
9								21,284						21,284	.32
11									211,130					211,130	0
14								246,421						246,421	.44
15	287,988	1,024,902							223,275					1,536,165	.69
16		391,189												391,189	.79
18			200,223	148,852	231,051	105,299	105,782							791,207	.70
19		923,337	43,763					229,051						1,196,151	.95
20	391,544													391,544	-1.51
21											89,732	87,873	185,464	363,069	-1.55
22													44,942	221,256	-1.52
23													71,408	71,408	.27
24													82,939	82,939	.73
Excess Demands	679,532	2,339,428	243,986	148,852	231,051	105,299	105,782	496,756	434,405	0	89,732	87,873	384,753	176,314	5,523,763
U†	2.11	1.71	1.70	2.00	1.16	.83	.67	.88	.83	.12	.84	.21	1.20	.89	
Total Cost—\$122,303,212															
Total Shipments—5,523,763,000 Pounds															

*Received no shipments of beef from other regions. Slaughter fulfilled demand.

†The U₁ and V₁ are in terms of cents per pound.

Table 16. Supplies, Price Differentials, Optimum Levels of Slaughter and Flows of Cattle for Slaughter, 26 Regions of the U. S., 1960

Destination	Origins and quantities of shipments (1,000 pounds)									Supply of slaughter cattle	Optimum slaughter demand	V _i †
	11	14	15	16	18	20	21	22	23			
1*										149,913	149,913	.00
2*										875,177	875,177	-.12
3*										520,317	520,317	-.14
4*										143,197	143,197	-.04
5*										99,155	99,155	-.34
6		16,652								281,671	298,323	-.49
7					17,749					412,570	430,139	-.58
8			840,579							588,737	1,429,316	-.58
9					137,444					745,539	883,003	-.82
10	87,140		366,057							408,643	861,840	-.63
12				138,192						498,099	636,291	-1.07
13					298,498					192,808	491,306	-.65
17					63,293		157,238			1,860,991	2,081,522	-.76
19*										2,214,325	2,214,325	-1.35
24*										375,847	375,847	-.92
25									337,161	1,879,717	2,216,878	-.18
26						88,369		238,801		285,777	612,947	-.19
Supply	2,159,185	1,270,807	3,789,796	1,621,086	1,978,551	689,994	1,216,031	402,338	670,703	25,330,994		
Slaughter	2,072,045	1,254,155	2,583,160	1,482,894	1,461,567	601,625	1,058,793	163,537	333,542		25,330,994	
U _i †	-1.28	-1.38	-1.67	-1.64	-1.65	-1.73	-1.96	-1.74	-1.30			
Total Cost — \$30,075,946												
Total Shipments — 2,787,173,000 pounds												

*Received no shipments of slaughter cattle from other regions. Slaughter composed of production from within the region.

†The U_i and V_i are in terms of cents per pound.

base region equilibrium, prices of slaughter cattle in this analysis were increased by approximately 35 cents per hundred pounds in Regions 20, and 22-26. With Regions 22 and 23 becoming self-sufficient in dressed beef the equilibrium prices of beef were decreased by \$1.20 and 46 cents per hundred pounds, respectively. However, the equilibrium prices in Regions 24-26 were increased between 50 and 63 cents per hundred pounds because of a reduction in the quantity of slaughter cattle shipped into the regions and consequently they had to import greater quantities of dressed beef from other regions.

In general, only slight changes occurred in the equilibrium prices of slaughter cattle throughout all regions and in beef prices in regions east of the Continental Divide when increases in regional slaughter capacities were assumed. However, as capacities were increased, there was a substantial decrease in the equilibrium prices of beef in Regions 22 and 23 as they were permitted to slaughter a quantity great enough to fulfill their demand. This in turn resulted in slightly higher prices of beef in Regions 24-26.

In this analysis, only six regions (Regions 15, 18, 19, and 21-23) received a return for completely utilizing their slaughter capacity.²⁹ These rents ranged from 3 cents per hundred in Region 18 (Kansas) to 19 cents per hundred in Region 13. Of the major slaughter regions, Region 19 would receive the greatest returns for additional facilities and Region 15

(Iowa) would be second. This is the same as the results of the previous analysis. Region 23 had the greatest return for additional slaughter facilities of the Western and Mountain Regions slaughtering at capacity. This is primarily due to its proximity to Region 25, the dominant deficit region in the West.

3. Cattle and Beef, 1960, with estimated slaughter capacities.

a. Estimated flows and costs.

Results based on the jointly determined model for slaughter cattle and beef, 1960 are given in tables 16 and 17 and figures 6 and 7. The estimated total interregional shipments of slaughter cattle from the nine regions in which production exceeded slaughter capacity were approximately 2.8 billion pounds, live weight, or 11% of the total supply. Of nine surplus producing regions (Region 11, 14-16, 18 and 20-23), Region 15 (Iowa) had the largest surplus of 1.2 billion pounds and Region 18 (Kansas) had an excess of over 500 million pounds while Regions 11, 14 and 20 each had surpluses of less than 90 million pounds. Major flows consist of Regions 11, 15, 16 and 18 shipping East; Regions 14, 18 and 21 shipping

²⁹As indicated previously, Region 20 (North and South Dakota) did not utilize their entire capacity as a result of shipping slaughter cattle to Region 26. It would appear that in 1955 this region would approach a zero return to slaughtering facilities at approximately 900 million pounds liveweight.

South and Southeast, and Regions 20, 22 and 23 shipping West.

The estimated total costs of shipping the 2.8 billion pounds of slaughter cattle was \$30.1 million, a reduction of approximately \$28 million from the analysis where slaughter cattle and beef were each considered separately. Transportation costs were reduced by 49% although only 39% less slaughter cattle were shipped. The average costs per hundred pounds were reduced from \$1.28 in the separately determined analysis to \$1.08 in the jointly determined analysis. The reductions in the cost per hundred pounds are a result of the slaughter cattle being moved shorter distances.

Although the number of regions shipping slaughter cattle decreased from 14 in the separately determined analysis to nine (those in which the production exceeded capacity) in the jointly determined analysis, the direction of the flows were similar. The major change which occurred was that in the separately determined analysis, Region 21 (Colorado) shipped West to Regions 24 and 25, however, in the joint analysis, Colorado shipped only to Region 17 (Oklahoma and Texas). In addition to the directional change in shipments indicated in figure 9, the advantage of shipping carcass beef rather than live cattle is illustrated. Because of this advantage, Regions 1-5 did not receive any shipments of slaughter cattle while Regions 25 and 26, which were both major deficit beef areas, received only the surpluses of Regions 20, 22, and 23.

The results of the beef portion of the jointly determined analysis are given in table 17 and figure 10. Estimated total interregional shipments in this analysis for 1960 were 4,980.8 million pounds, approximately 33.5% of the total supply, while the estimated transportation cost was approximately \$98 million. In total, 13 regions were deficit in beef, 11 had surpluses, and in two regions slaughter fulfilled demand. Of the deficit regions, Regions 1 and 2 received 65% of the shipments of beef, 3,255.7 million pounds, while Regions 3, 4, 5, 10, and 25 each had an excess demand of over 200 million pounds. Regions 15 (Iowa) and 19 (Nebraska) supplied approximately 50% of the total surplus even though 11 regions had surpluses of beef.

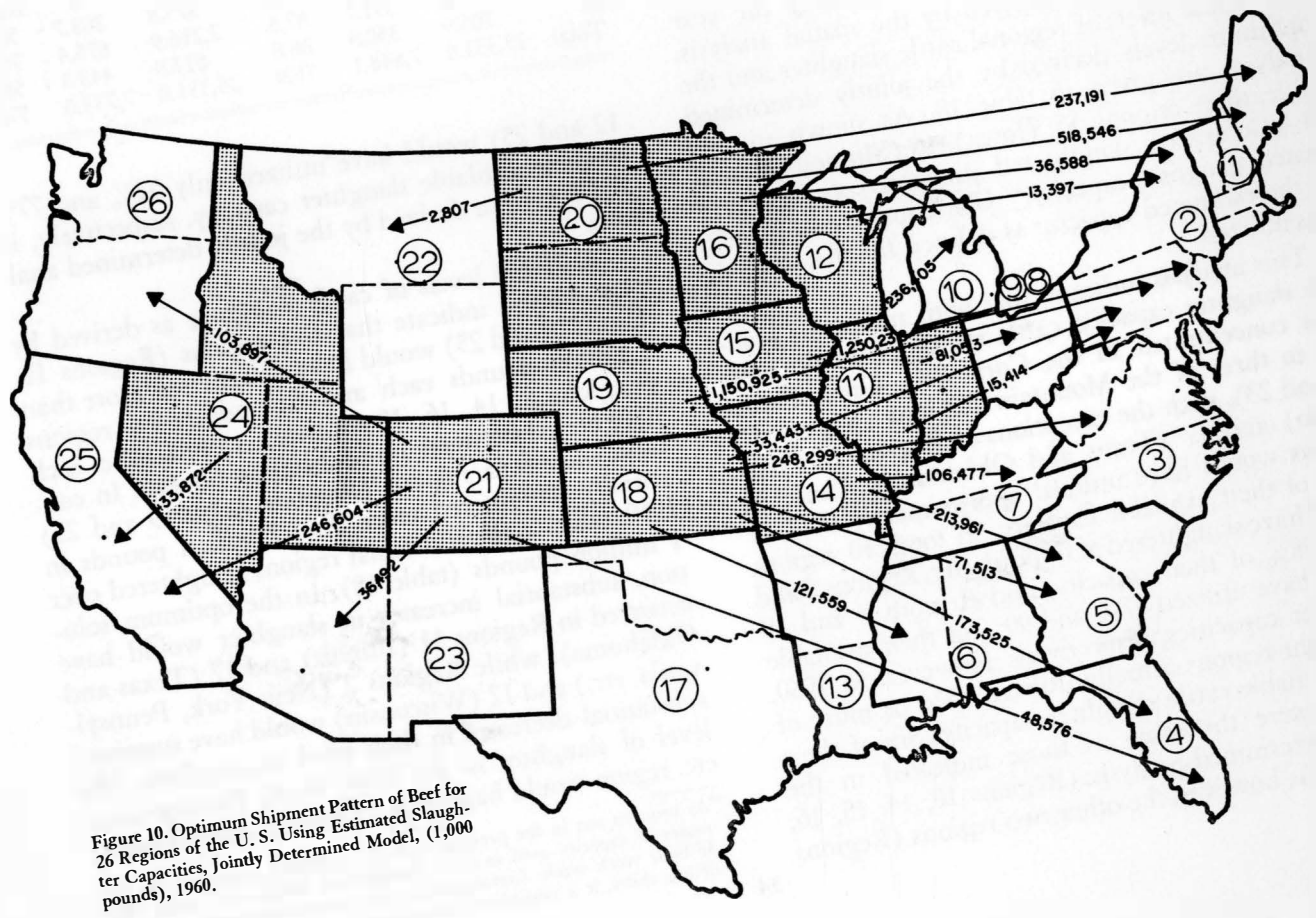
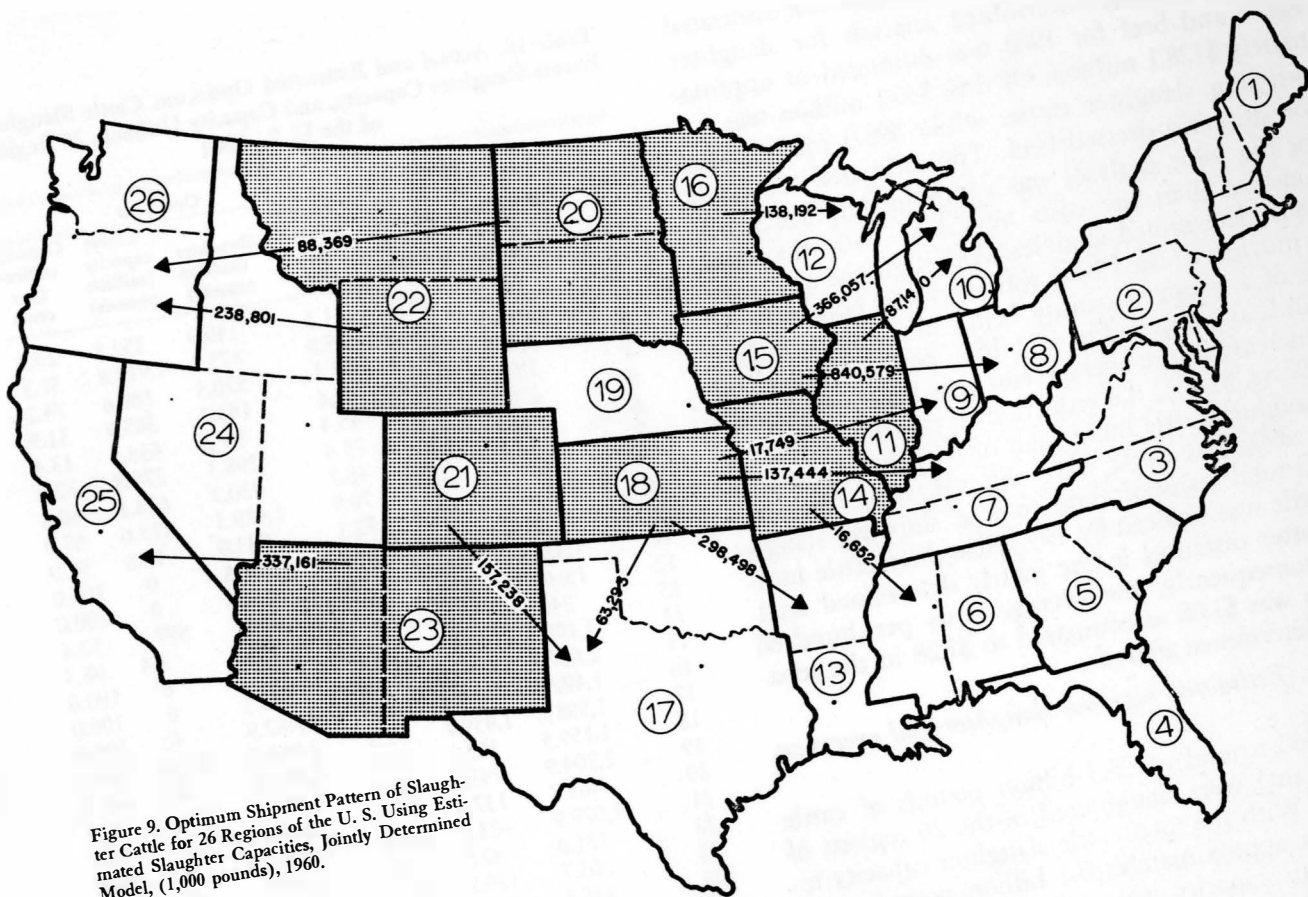
Even though the number of regions shipping beef increased from nine in the separately determined analysis to 11 in the joint analyses, (Regions 9 and 11 became surplus regions and Regions 13 and 17 became self-sufficient) the direction of the flows were quite similar for the two analyses. Regions 20 and 21 were the pivotal regions, shipping both East and West. The dominant surplus areas of the Corn Belt shipped only to the East, while Region 24 (Idaho, Nevada and Utah) shipped to California.

Table 17. Excess Demands and Supplies, Optimum Flows and Price Differentials, 26 Regions of the U. S., Beef, 1960.

Origin	1	2	3	4	5	6	7	8	10	13*	17*	22	23	25	26	Excess supplies	U†
9								81,053								81,053	.32
11		15,414														251,819	0
12		13,397														13,397	.12
14																320,438	.30
15					213,961		106,477									1,250,238	.43
16																555,114	.50
18	518,546															648,339	.46
19			248,299	173,525	71,513	121,559										1,150,925	.60
20																239,998	.91
21	237,191											2,807				435,569	-1.02
24				48,576									36,492	246,604	103,897	33,872	.15
Excess																	
Demands	755,737	2,499,985	248,299	222,101	285,474	121,559	106,477	81,053	236,405	0	0	2,807	36,492	280,476	103,897	4,980,762	
V _j †	1.76	1.54	1.50	1.69	1.15	.90	.74	.74	.78	.62	.43	.40	.88	1.43	1.42		
Total Costs—\$98,039,392																	
Total Shipments—4,980,762,000 Pounds																	

*Received no shipments of beef from other regions. Slaughter fulfilled demand.

†The U_i and V_j are in terms of cents per pound.



The minimum total transportation cost associated with the jointly determined analysis for slaughter cattle and beef for 1960 was estimated at approximately \$128.1 million. Of this, \$30.1 million was for shipping slaughter cattle, while \$98.0 million was for shipping dressed beef. The estimated total cost for the joint analyses was approximately \$16.3 million less than the costs associated with the separately determined analyses. Although the total cost of moving dressed beef was increased both as a result of a greater quantity being moved (5.0 billion pounds as compared to 4.6 billion pounds) as well as an increase in the average costs per hundred pounds (\$1.97 vs. \$1.85), the reduction in the shipment cost of slaughter cattle more than offset this increase. In total, 39% less cattle were shipped, while the estimated total transportation costs of shipping slaughter cattle was reduced by 49%. Slaughter cattle moved shorter distances in the jointly determined analyses, consequently, the average costs per hundred pounds was \$1.08 as compared to \$1.28 in the separately determined analysis.

b. Estimated regional slaughter and excess capacity.

In 1960 a total of 25.3 billion pounds of cattle (live weight) were slaughtered in the 26 regions of the U. S. With the total cattle slaughter capacity estimated at approximately 33.1 billion pounds, only 77% of this capacity was utilized during the year under the optimum derived by the spatial analysis. The actual levels of regional cattle slaughter and the optimum levels derived by the jointly determined analyses are given in table 18. As shown in this table, three regions, 15, (Iowa), 16 (Minnesota), and 21 (Colorado) slaughtered in excess of their estimated slaughter capacity.³⁰ Consequently, only 76% of the estimated capacity as defined for this analysis was utilized.

This analysis indicates that with respect to available slaughter capacity, cattle slaughter would have been concentrated in the Corn Belt, Great Plains and in three of the Mountain Regions (Region 21, 22, and 23), with the exceptions of Regions 12 (Wisconsin) and 17 (Texas and Oklahoma). These 14 regions would have utilized approximately 90% or more of their available capacity. In total, 10 regions would have slaughtered at full capacity, Regions 9 and 13 at 98% of their capacity, and Regions 8 and 19 would have utilized 87% and 90% of their available slaughter capacities, respectively. However, in 1960, only eight regions actually utilized 85% or more of their available cattle slaughter capacity. Six of these regions were the same as those indicated in the jointly determined analysis (Regions 10, 14, 15, 16, 19 and 21); however, the other two regions (Regions

Table 18. Actual and Estimated Optimum Cattle Slaughter, Excess Slaughter Capacity, and Capacity Utilized, 26 Regions of the U. S., 1960

Region	Actual			Optimum		
	Slaughter (million pounds)	Excess capacity (million pounds)	Capacity utilized (per cent)	Slaughter (million pounds)	Excess capacity (million pounds)	Capacity utilized (per cent)
1	207.2	295.5	41.2	149.9	352.8	29.8
2	2,096.1	697.9	75.0	875.2	1,918.8	31.3
3	358.0	342.9	51.1	520.3	180.6	74.2
4	281.2	167.9	62.6	143.2	305.9	31.9
5	335.2	402.5	45.4	99.2	638.5	13.4
6	432.9	141.3	75.4	298.3	275.8	32.0
7	513.2	540.2	48.7	430.3	623.1	40.8
8	1,165.1	477.8	70.9	1,429.3	213.6	87.0
9	650.3	251.3	72.1	883.0	18.6	97.9
10	731.9	129.9	84.9	861.8	0	100.0
11	1,483.1	588.9	71.6	2,072.0	0	100.0
12	1,040.6	173.3	85.7	636.3	577.6	52.4
13	246.3	253.4	49.3	491.3	8.4	98.3
14	1,105.1	149.1	88.1	1,254.2	0	100.0
15	2,667.7	-84.5	103.3	2,583.3	0	100.0
16	1,492.5	-9.6	100.6	1,482.9	0	100.0
17	1,598.6	1,459.7	52.3	2,081.5	976.8	68.1
18	1,159.5	302.1	79.3	1,461.6	0	100.0
19	2,204.9	243.9	90.0	2,214.4	234.5	90.4
20	463.7	137.9	77.1	601.6	0	100.0
21	1,079.9	-21.1	102.0	1,058.8	0	100.0
22	121.0	42.5	74.0	163.5	0	100.0
23	203.7	129.8	61.1	333.5	0	100.0
24	446.8	217.7	67.2	375.8	288.7	56.6
25	2,540.6	351.7	87.8	2,216.9	675.4	76.6
26	705.9	350.9	66.8	612.9	443.9	58.0
Total	25,331.0	7,848.1	76.0	25,331.0	7,733.0	77.0

12 and 25) would have utilized only 52% and 77% of their available slaughter capacity, respectively, in the optimum derived by the jointly determined analysis.

Regional levels of cattle slaughter as derived by this analysis indicate that five regions (Regions 11, 15, 17, 19 and 25) would have slaughtered more than 2 billion pounds each and five additional regions (Regions 8, 14, 16, 18 and 20) would have each slaughtered between 1 and 2 billion pounds. In contrast, only four regions (Regions 2, 15, 19 and 25) actually slaughtered more than 2 billion pounds in 1960, while eight additional regions slaughtered over 1 million pounds (table 18). In the optimum solution, substantial increases in slaughter would have occurred in Regions 11 (Illinois) and 17 (Texas and Oklahoma), while Regions 2 (New York, Pennsylvania, etc.) and 12 (Wisconsin) would have sustained substantial decreases in their level of slaughter. The level of slaughter in the New York, Pennsylvania, etc. region would have been 1.2 billion pounds below

³⁰As brought out in the previous section on capacity estimates, the estimates of capacity used in these analyses are based on a single shift, 38-hour work week. Consequently, due to overtime work or the use of two shifts, it is possible to exceed the estimated capacity restrictions.

the amount that was actually slaughtered in this region in 1960.

In jointly determined analysis regions along the East Coast, Regions 1-7 primarily slaughtered their own production, consequently, these regions utilized only a small proportion of their available capacity. Estimated proportions of capacities utilized in these regions ranged from 75% in Region 3 to only 13% in Region 5. With the exceptions of Region 3 and Region 6, which utilized slightly over 50% of their available capacity, all other regions in the eastern part of the U. S. would have operated at 40% or less of their total available capacity.

In the West, Regions 24, 25, and 26 would have decreased their level of slaughter under the optimum derived by this analysis. As a result, the amount of excess capacity in these regions would have been increased relative to what actually prevailed. Region 25 (California) would have utilized 77% of its capacity compared to only 56% for Regions 24 and 26, however, Region 25 had 675 million pounds of unused capacity while Regions 24 and 25 had 288 million and 444 million pounds, respectively.

c. Price differentials and rents.

The sets of regional price differentials derived for slaughter cattle and beef for 1960 in the jointly determined analyses are given in tables 16 and 17, respectively. As in the jointly determined analysis for 1955, Region 1 (New England) was selected as the base region for slaughter cattle, while Region 11 (Illinois) was used as the base region in the beef analysis.

In the slaughter cattle portion of the analysis, the deficit regions with the greatest comparative advantage were those along the East and West Coasts, while deficit regions in the interior portion of the country had the least comparative price advantage. Of the deficit regions, Regions 12 (Wisconsin) and 19 (Nebraska) had the lowest relative equilibrium prices, \$1.07 and \$1.35 per hundred pounds, respectively, less than the base region. Although Region 19 did not receive any inshipments of slaughter cattle, it was classified as a deficit slaughter cattle region since its estimated slaughter capacity exceeded its production. Since it was able to slaughter all its production, the equilibrium price of this region in comparison with the base region was greater than the equilibrium prices of adjoining surplus regions (i.e., Iowa (15) -\$1.67, Kansas (18) -\$1.65, North and South Dakota (20) -\$1.73). Of the surplus slaughter cattle regions, Regions 11, 14, and 23 had the greatest comparative price advantage because of their proximity to dominant beef deficit areas, while Region 21 (Colorado) had the lowest equilibrium price, \$1.96 per hundred pounds less than that of Region 1.

This is a result, as shown in figure 10 of Colorado being the farthest from the deficit beef areas.

In general, the regional equilibrium price levels for slaughter cattle were closer to the price of the base region in the jointly determined analysis than in the separately determined analysis.³¹ Exceptions occurred in Regions 3, 23, and 25 and in each of these cases the equilibrium price was decreased 11 to 13 cents relative to the base region. Of the regions in which the equilibrium price was increased relative to the base region, the largest increase occurred in Region 17, where the equilibrium price changed from a -\$2.13 in the separately determined analysis as compared with the base region to only -76 cents less than the base region in the joint analyses.

Although there were a number of changes in the equilibrium prices derived for beef in the jointly determined analysis as compared to those derived in the separately derived analysis, the changes in absolute terms were minor.³² In general, in the jointly determined analysis the equilibrium beef prices would have increased in the eastern and southeastern regions (Regions 1-7) and in the western Corn Belt and northern Plain States. However, the equilibrium prices would have decreased slightly in the eastern Corn Belt (Regions 8-11), the West (Regions 25 and 26), and in the Southwest and Southern Plains areas, (Regions 21, 23, 13, and 17). Figure 11 depicts the spatial price structure derived by this analysis.

In this analysis, 10 regions utilized their entire slaughter capacity and consequently accrued a slaughter rent (table 19). This includes the nine regions in which the production of slaughter cattle exceeded slaughter capacity and Region 10 (Michigan) which imported slaughter cattle to its capacity limit. The rents accruing to these regions ranged from a low of 7 cents per hundred pounds live weight in Region 10 to a high of 97 cents per hundred pounds in Region 22, Montana and Wyoming (table 19). The relative low return for the complete utilization of slaughter capacity in Region 10 is due to the fact that slaughter cattle had to be imported from the surplus production regions (Regions 11 and 15) to completely utilize the available slaughter capacity. Consequently, the transportation costs of shipping the slaughter cattle reduced the rent going to the slaughter facilities.

The highest rents derived for the complete usage

³¹The price differential for slaughter cattle derived by the independently determined analysis are in table 5, "Spatial Analyses of the Flows of Slaughter Livestock in 1955 and 1960," while those for beef are in table 22, "Spatial Analyses of the Meat Marketing Sector in 1955 and 1960."

³²In comparing the equilibrium price differentials between the two analyses, it should be noted that Region 12 was used as the base region in the separately determined analysis, while Region 11 was used in the jointly determined analysis. However, in the discussion that follows, the equilibrium prices were adjusted to the same base region.

Table 19. Slaughter Rents in Cents per Hundred Pounds, Live Weight Slaughter Cattle, for Estimated Actual Capacity and Increased Capacity Levels, 1960.

Region	Estimated actual capacity		Increased capacity levels	
	Capacity (1,000 pounds)	Rent (dollars)	Capacity (1,000 pounds)	Rent (dollars)
10	861,840	.07	*	*
11	2,072,045	.28	2,159,184	.18
14	1,254,155	.20	1,270,806	.19
15	2,583,160	.42	3,789,795	.18
16	1,482,894	.35	1,621,085	.10
18	1,461,567	.38	1,978,550	.19
20	601,625	.20	689,993	.12
21	1,058,793	.37	1,216,030	.32
22	163,537	.97	402,337	.38
23	333,702	.80	670,702	.20

*With capacity limitation increased in regions where production exceeded slaughter capacity, Region 10 did not utilize its capacity in the alternative analysis.

of slaughter facilities occurred in Regions 22 and 23. In both cases, these regions were net exporters of slaughter cattle (production exceeded slaughter capacity), but were importers of dressed beef to meet the demand of the regions. Consequently, with the demand for dressed beef within the regions being greater than the available slaughter capacity, the rents going to the slaughter facilities reflect proportionately the transportation costs of shipping in dressed beef. Of the other regions which received returns to

slaughter facilities, Region 15 (Iowa) showed the greatest comparative advantage with a return of 42 cents per hundred pounds. These returns to the facilities in Iowa, in part, explain the large increase in slaughter capacity (over 580 million pounds) which occurred in Iowa between 1955 and 1960.

4. Cattle and beef 1960, with increased slaughter capacities assumed for surplus production regions.

The results of the jointly determined spatial analysis for slaughter cattle and beef for 1960 when increases in slaughter capacities were assumed for the surplus production regions of the preceding analysis (Regions 11, 14-16, 18, and 20-23) are presented in tables 20 and 21 and figures 12 and 13.

a. Estimated flows and costs.

When the slaughter capacity levels were increased to within 1,000 pounds of production for the nine regions in which production exceeded capacity in the initial jointly determined analysis for 1960, the only quantities of slaughter cattle being shipped inter-regionally in the optimum solution were the 1,000 pounds by which production exceeded capacity. Although the quantity shipped was reduced from 2.8 billion pounds live weight in the previous analysis to only 9,000 pounds in this analysis, the direction of the flows were the same (tables 16 and 20), Regions

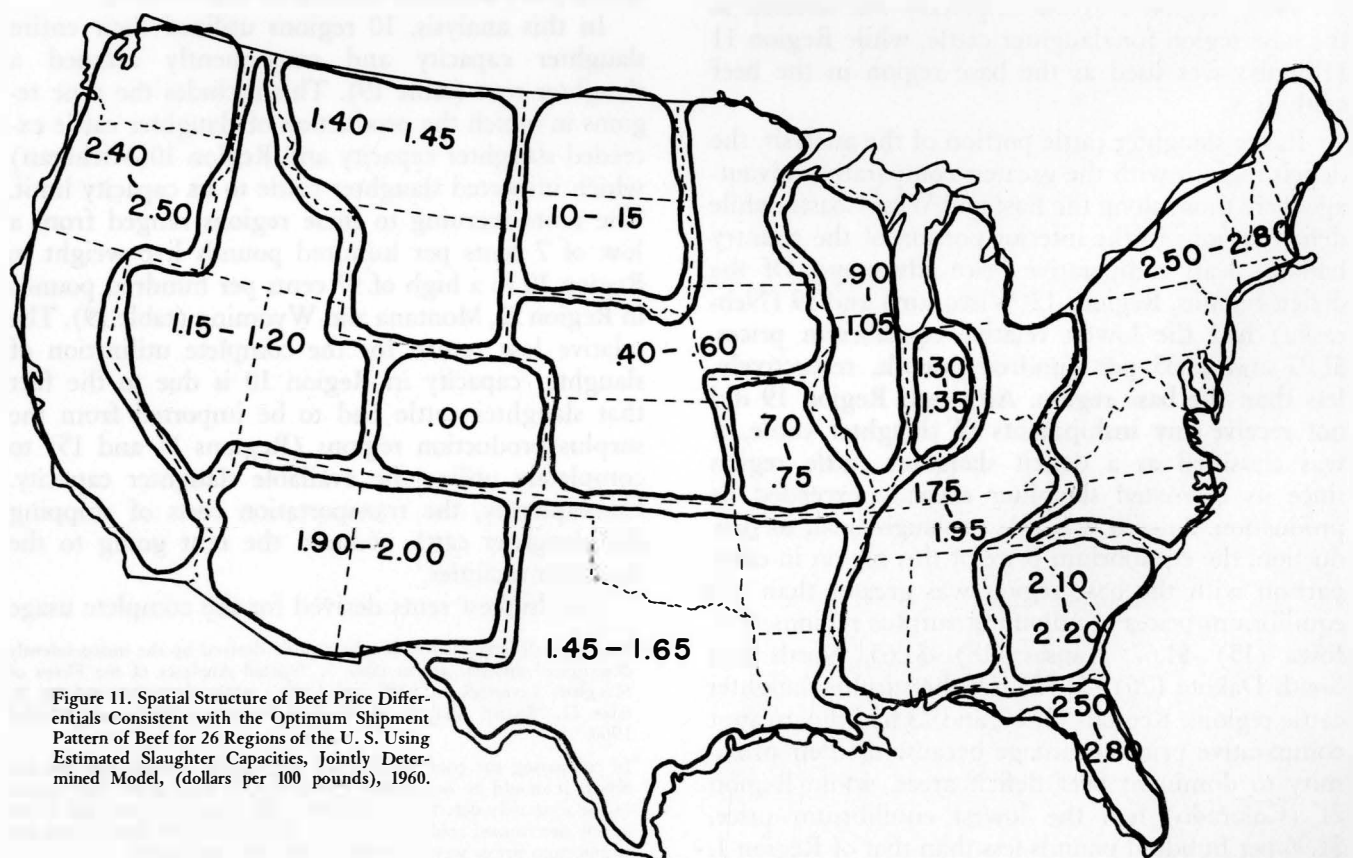
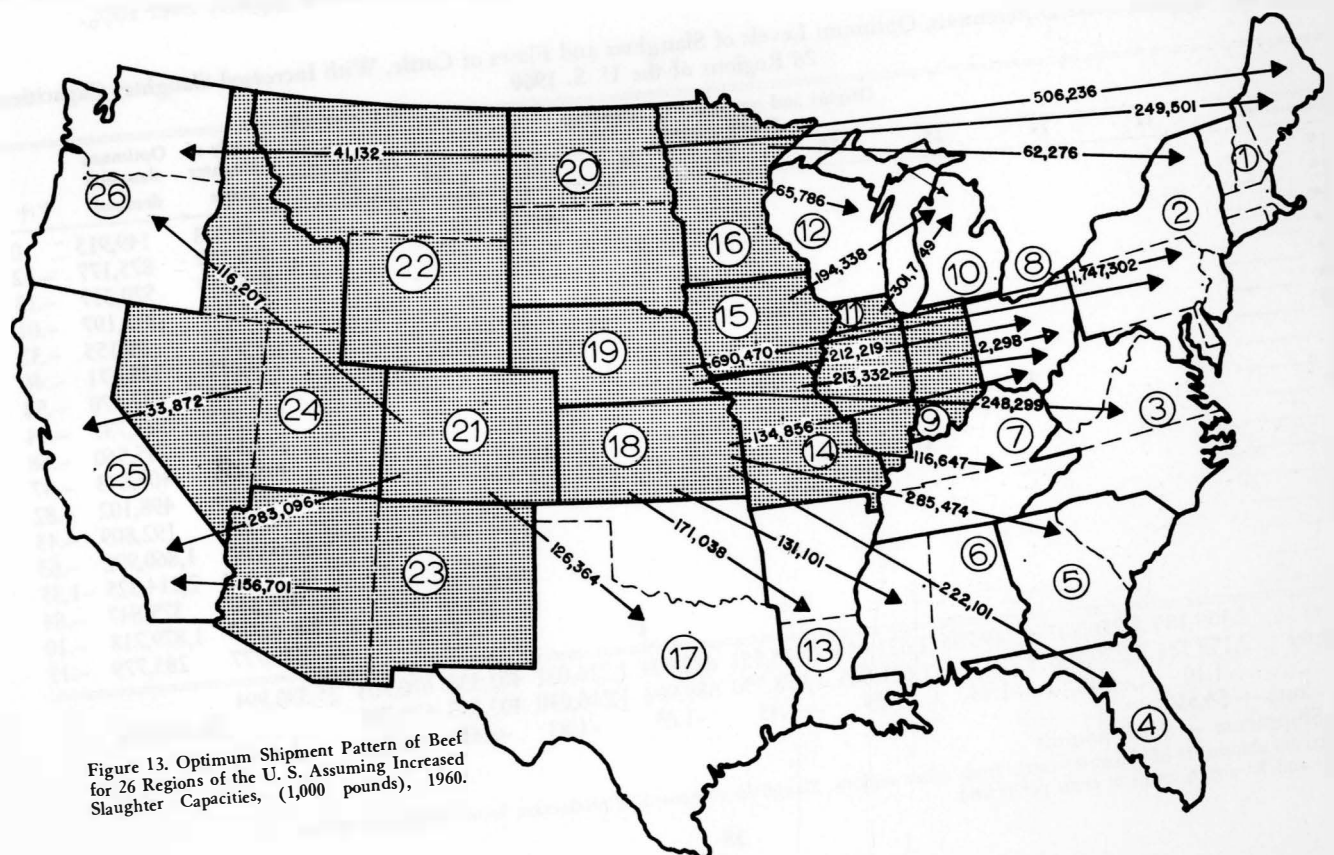
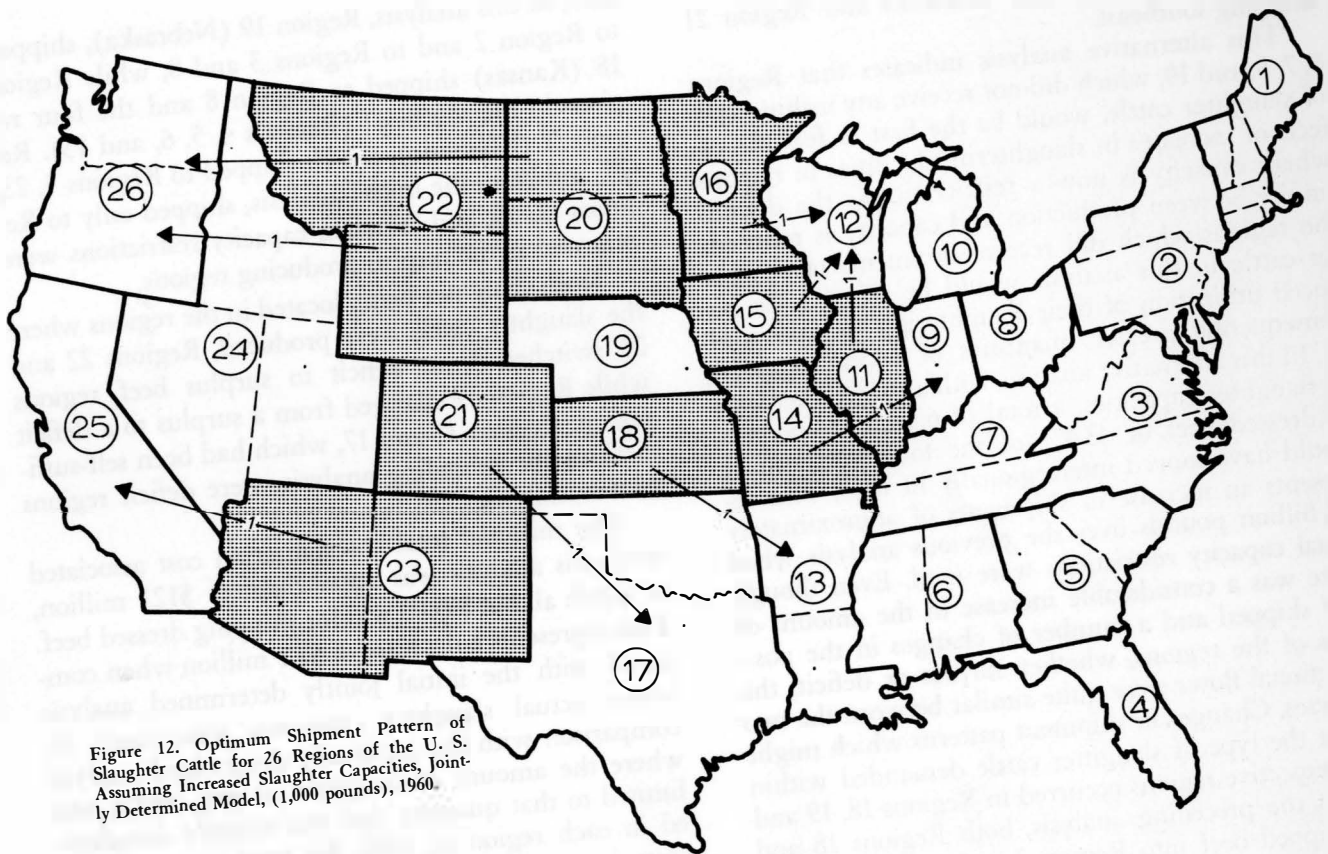


Figure 11. Spatial Structure of Beef Price Differentials Consistent with the Optimum Shipment Pattern of Beef for 26 Regions of the U. S. Using Estimated Slaughter Capacities, Jointly Determined Model, (dollars per 100 pounds), 1960.



20 and 21 were the pivotal regions, with Region 20 shipping slaughter cattle westward and Region 21 shipping southeast.

This alternative analysis indicates that Regions 6, 7, 8, and 10, which did not receive any inshipments of slaughter cattle, would be the first to feel the effects of increases in slaughtering facilities in regions where capacity is now a restriction. As the discontinuity between production and capacity is reduced, the regions which did receive shipments of slaughter cattle in this analysis would be affected via reduced utilization of their slaughtering facilities and consequently greater quantities of excess capacity.

In this alternative analysis with assumed increases in slaughter capacities, a total of 6.4 billion pounds of dressed beef or 43.4% of the total beef supply would have moved interregionally in 1960. This represents an increase in shipments of approximately 1.4 billion pounds over the previous analysis when actual capacity restrictions were used. Even though there was a considerable increase in the amount of beef shipped and a number of changes in the positions of the regions, whether surplus or deficit, the directional flows were quite similar between the two analyses. Changes in shipment patterns which might affect the type of slaughter cattle demanded within the respective regions occurred in Regions 18, 19 and 21. In the preceding analysis, both Regions 18 and 19 shipped beef into Region 2 and in addition Region 18 shipped into regions in the southeast. How-

ever, in this analysis, Region 19 (Nebraska), shipped to Region 2 and to Regions 3 and 8, while Region 18 (Kansas) shipped to Region 8 and the four regions in the southeast (Regions 4, 5, 6, and 13). Region 21 (Colorado), which shipped to Regions 4, 23, 25, and 26 in the initial analysis, shipped only to Regions 17, 25, and 26 when capacity restrictions were removed in the surplus producing regions.

With slaughter being located in the regions where the slaughter cattle were produced, Regions 22 and 23 switched from deficit to surplus beef regions while Region 12 changed from a surplus to a deficit region. Regions 13 and 17, which had been self-sufficient in the preceding analysis, were deficit regions in this analysis.

The minimal total transportation cost associated with this analysis was approximately \$121 million, of which all but \$9,000 was for shipping dressed beef. This represents a decrease of \$7.1 million when compared with the initial jointly determined analysis where actual slaughter capacities were used. In comparison with the separately determined analysis where the amount of slaughter in any region was limited to that quantity that was actually slaughtered in each region in 1960, the total transportation costs were reduced by \$23.5 million, from \$144.5 million to \$121 million. This represents a reduction in total transportation costs of slightly over 16%.

Table 20. Supplies, Price Differentials, Optimum Levels of Slaughter and Flows of Cattle, With Increased Slaughter Capacities, 26 Regions of the U. S. 1960

Destination	Origins and quantities of shipments (1,000 pounds)									Supply of slaughter cattle	Optimum slaughter demand	U†
	11	14	15	16	18	20	21	22	23			
1*										149,913	149,913	0
2*										875,177	875,177	-.12
3*										520,317	520,317	-.13
4*										143,197	143,197	-.01
5*										99,155	99,155	-.32
6*										281,671	281,671	-.46
7*										412,570	412,570	-.53
8										588,737	588,737	-.44
9		1								745,559	745,560	-.68
10*										408,643	408,643	-.47
12	1		1	1						498,099	498,102	-.82
13					1					192,808	192,809	-.43
17							1			1,860,991	1,860,992	-.63
19*										2,214,325	2,214,325	-1.35
24*										375,847	375,847	-.84
25									1	1,879,717	1,879,718	-.10
26							1		1	285,777	285,779	-.11
Supply	2,159,185	1,270,807	3,789,796	1,621,086	1,978,551	689,994	1,216,031	402,338	670,703	25,330,994		
Slaughter	2,159,184	1,270,806	3,789,795	1,621,085	1,978,550	689,993	1,216,030	402,337	670,702		25,330,994	
U†	-1.10	-1.32	-1.43	-1.39	-1.43	-1.65	-1.83	-1.66	-1.22			
Total Costs — \$8,510												
Total Shipments — 9,000 pounds												

*Received no shipments of slaughter cattle from other regions. Slaughter composed of production from within the region.

†The U_i and V_j are in terms of cents per pound.

Table 21. Excess Demands and Supplies, Optimum Flows and Price Differentials, With Increased Slaughter Capacities, 26 Regions of the U. S., Beef, 1960

Origins	1	2	3	4	5	6	7	8	10	12	13	17	25	26	Excess supplies	U*
9								2,298							2,298	.42
11									301,749						301,749	0
14							116,647	213,332							329,979	-.36
15		1,747,302							194,338						1,941,640	-.58
16	506,236	62,276								65,786					634,298	-.65
18								134,856			171,038				944,570	-.56
19		690,407	248,299	222,101	285,474	131,101		212,219							1,150,925	-.75
20	249,501											126,364	283,096	41,132	290,633	-1.06
21														116,207	525,667	-1.03
22													156,701	134,025	134,025	.64
23													33,872	156,701	156,701	-.19
24														33,872	33,872	.14
Excess Demands	755,737	2,499,985	248,299	222,101	285,474	131,101	116,647	562,705	496,087	65,786	171,038	126,364	473,669	291,364	6,446,357	
V*	1.61	1.39	1.37	1.59	1.05	.80	.68	.84	.78	.17	.86	.51	1.42	1.41		
Total Costs—\$121,001,917																
Total Shipments—6,446,357,000 Pounds																

*The U_i and V_i are in terms of cents per pound.

b. Estimated regional slaughter and excess capacity.

The regional levels of cattle slaughter and the percent of capacity utilization are presented in Appendix table 3. Excluding the 1,000 pound shipments, the amount slaughtered in each region assuming the increased slaughter capacities was equal to the production of slaughter cattle. Region 15 (Iowa) would have been the dominant slaughtering region with 3.8 billion pounds of slaughter, followed by Regions 11 and 19, with 2.2 billion pounds live weight. Other regions slaughtering over 1 billion pounds were Regions 14, 16, 17, 18, 21, and 25.

By removing the restrictions on slaughter capacity, slaughter concentrated in the Corn Belt and Mountain Regions, the dominant producing regions. Consequently, regions along the East and West Coasts would have been affected the most as additional slaughter facilities were introduced into regions where slaughter cattle production exceeded the available capacity. The percent of capacity utilization of the eastern regions 1-7, would have varied from a low 13% in Region 5 (Georgia and South Carolina) to 74% in Region 3 (West Virginia, Virginia, and North Carolina). However, in terms of absolute excess capacity, Region 2 would have been affected the most with 1.9 billion pounds of unused slaughter capacity. Region 26 would have been affected the most of the regions along the West Coast.

In the preceding analysis, this region would have slaughtered 444 million pounds, however, with the increases in capacity assumed in this analysis, only 286 million pounds of its capacity, or 27% of its total would have been utilized.

In addition to the regions on both coasts, the increase in slaughter facilities would have considerable effects on Regions 8 and 10 in the eastern Corn Belt, and Region 13 (Arkansas and Louisiana). When capacity levels were increased in this analysis, the percent of capacity utilized in Regions 8 and 10 decreased from 87% and 100% to 35% and 47%, respectively. In Region 13, the quantity of excess capacity was increased from 8.4 million to 306.9 million pounds.

The analysis indicates that with corresponding transportation rates for slaughter cattle and beef, and assuming no changes in other costs, considerable reductions in total transportation costs would occur if slaughter concentrated in the areas of production. In addition to regions on the east and west coasts, which would have experienced decreases in slaughter in the preceding analysis, Regions 8, 10, 13, and 26 would slaughter substantially less than (a) quantities of slaughter estimated under the optimum of the preceding analyses and (b) quantities actually slaughtered in these regions in 1960.

c. Price differentials and rents.

The optimum price differentials for slaughter cattle and dressed beef for this alternative analysis are presented in the last columns and rows of tables 20 and 21. With respect to slaughter cattle, there was a narrowing of the differences in between the equilibrium price of the base region (Region 1) and the equilibrium price of the other regions (i.e., relative to Region 1 the equilibrium prices of slaughter cattle were increased in all other regions). The greatest price increases, 22-25 cents per hundred pounds, occurred in Regions 12, 13 and 18.

Except for six regions (Regions 8, 9, 12, 13, 17, and 22) the equilibrium price of beef in each region decreased relative to the base region (Region 11) in this analysis when compared with the preceding analysis which utilized estimated slaughter capacities. In general, these decreases were 15 cents per hundred pounds or less, except in Region 23, where the decrease was \$1.07 per hundred pounds. This region changed from a deficit beef region and an exporter of live slaughter cattle in the previous analysis to a surplus region in this analysis. The increases in the equilibrium prices in the above six regions was a result of either decreases in the amount of beef that could be moved interregionally or increases in the amount of beef that had to be imported.

In this analysis, each of the nine regions for which increased slaughter capacities were assumed, accrued a rent for their slaughtering facilities. The returns varied from a low of 10 cents per hundred pounds in Region 16 to a high of 38 cents per hundred pounds in Region 22 (table 19). When the capacity levels were increased in these regions, the amounts by which rents decreased ranged from 1 cent in Region 14 to 60 cents per hundred pounds in Region 23. The relatively large decreases in Regions 22 and 23 occurred because these regions became surplus beef regions in this alternative analysis. However, it should be noted that even with these large decreases, these two regions as well as Region 21 accrued the greatest returns.

5. Comparison of the results of 1955 and 1960.

There were no drastic changes between 1955 and 1960 in the optimum flows of slaughter cattle and beef when estimated slaughter capacities were used. The percent that flows were of total cattle production decreased slightly from an estimated 12% in 1955 to 11% in 1960, while the flows of beef increased from 31% of total beef production in 1955 to 33.5% in 1960. Beef shipments increased by 700 million pounds from 1955 to 1960, while cattle shipments decreased by 200 million pounds and total transportation costs were reduced from \$133.1 million in 1955 to \$128.1 million in 1960.

All regions except Region 20 increased consumption from 1955 to 1960 with Region 2 (New York, Pennsylvania, etc.) and Region 25 (California) leading all regions (table 6). Of the 1.2 billion pound increase in beef consumption between 1955 and 1960, these two regions accounted for over 500 million pounds. Of the regions which increased production of slaughter cattle, Regions 15 and 16 had increases of 600 million and 400 million pounds, respectively, while Regions 11, 18, 21, 23, and 25 each had increases of 200 million pounds or over (table 4). Of the 15 regions that decreased slaughter production between 1955 and 1960, a majority were located in the East.

In 1955, production exceeded capacity in seven regions (Regions 15, 18-23). As shown in table 4, cattle slaughter capacity was increased in each of these regions between 1955 and 1960. In terms of total capacity, the greatest increases occurred in Regions 15 and 19. Although total capacity increased by 5% in the U. S. between 1955 and 1960, seven regions which had considerable excess capacities under the 1955 optimum solution reduced their slaughter capacities during this period.

In 1960, production of slaughter cattle exceeded capacity in nine regions (Regions 11, 14-16, 18, 20-23). Six of these regions (Regions 15, 18, 20-23) were also deficit in capacity in 1955. Region 19, which was a deficit capacity region in 1955, had 234.5 million pounds excess capacity in 1960. This change in the capacity position of Region 19 was a result of capacity being increased by 380 million pounds, while production was decreased by 162 million pounds. From 1955 to 1960 slaughter capacity increased in Regions 14 and 16 but slaughter production increased by a greater amount and consequently these regions were deficit in capacity in 1960. Region 11 (Illinois) had 478 million pounds of excess capacity in 1955, however, from 1955 to 1960 capacity was reduced by 24% to 2,072.0 billion pounds while production was increased by 220.7 million pounds to 2,159 billion pounds.

In general, regions along the East and West Coasts and Regions 12 and 17 had substantial amounts of excess capacity in both 1955 and 1960. When increased slaughter capacities were assumed in the predominant producing regions, the amounts of excess capacity increased in these regions between 1955 and 1960.

In the analyses of the two years considered, 10 regions utilized their entire capacities and consequently received a slaughter rent. Even though slaughter capacity of the entire U. S. and in each of these regions in particular was increased during this time period, the rents accruing to complete capacity utilization were increased in all regions except Region

20. These increases in slaughter rents between 1955 and 1960 resulted in part from increases in transportation rates that occurred during this period and in turn increased the comparative advantage of those regions in which production exceeded capacity. With the changes that occurred in production and slaughter capacity, the optimum markets for Region 20 were changed. Consequently the decrease in slaughter rent for this region was due to the increased transportation cost associated with the greater distance to its markets in the optimum solution.

Several major changes occurred when slaughter capacities were assumed to increase to a level 1,000 pounds less than slaughter cattle production in those regions that had deficit capacity in 1955 and 1960. Except for Regions 16 and 20, which continued to ship small amounts of slaughter cattle in 1955, slaughter took place at the point of production. As a result, it was estimated that over 40% of the total beef supply moved interregionally in both years analyzed. As indicated by these analyses, a considerable gain in efficiency could be realized through reduced transportation costs by locating slaughter in the areas of production. For example, when increased capacities were assumed, total transportation costs were reduced \$4.1 million and \$7.1 million in 1955 and 1960, respectively. In comparison with the separately determined analyses for 1960, transportation costs in this alternative jointly determined analysis were reduced by 16% or \$23.5 million.

The jointly determined spatial analyses of cattle and beef in this study point out several major aspects of the present structure of the livestock-meat economy and suggest probable future changes. The analyses indicate that there is considerable excess slaughter capacity in the meat packing industry. In general, as indicated both by these analyses and where cattle slaughter actually took place in 1955 and 1960, the major portion of the excess capacity was located in regions in the Southeast, and on the East and West Coasts. Between 1955 and 1960 slaughter capacities were reduced in seven regions and the analyses suggest that increasing slaughter capacities in regions where production for slaughter exceeds available slaughter capacity is the most economical in terms of reducing the total transportation cost of live slaughter cattle and dressed beef.

Although changes in the equilibrium prices of cattle and beef were minor in most cases, the analyses indicate that part of the reduced transportation costs associated with locating slaughter at the point of production would be passed on to the producers of slaughter cattle. In general, the equilibrium prices of slaughter cattle of the dominant producing regions were increased relative to the base region when increased slaughter capacities were assumed and when

the livestock and meat sectors were considered jointly. In the same manner, beef consumers, especially those in regions where the demand for beef exceeded slaughter capacity, would benefit from lower beef prices.

In view of the gains in efficiency that may be attained by locating slaughter at the point of production, the present trend in locating new slaughter facilities in these areas is likely to continue. An area of consideration for both the producers of slaughter cattle and the meat-packing industry are the possible changes in their markets as slaughter capacity is increased in the major areas of production. If consumers in different sections of the country actually prefer different types of beef (i.e., carcass weight, grade, etc.), producers and meat packers in certain pivotal regions may need to change their product to meet the type of demand of their new markets as slaughter capacities are increased in the major producing regions.

6. Hogs and pork, fourth quarter, 1955, with estimated slaughter capacities.

On an annual basis production exceeded hog slaughter capacity in only three regions in 1955. These three regions were Indiana (9), Illinois (11), and Iowa (15), the three leading hog producing regions in 1955. When regional hog production for slaughter and slaughter capacity were apportioned into the four quarters of the year, hog production for slaughter exceeded slaughter capacity in eight regions in the fourth quarter (October-December) of 1955. With so few regions deficit in available slaughter on an annual basis very little information could be obtained from a joint annual analysis of slaughter hogs and pork. However, with eight regions having excess supplies of slaughter hogs in the fourth quarter of 1955 a joint spatial model can provide insight about optimum flow patterns, cost of transportation, regional price differentials, and accrual of rents for that time period. Thus a joint spatial analysis was performed for the fourth quarter of 1955 and the results are presented in this section.

a. Estimated flows and costs.

Results of the jointly determined spatial analysis for slaughter hogs and pork for the fourth quarter (October-December) of 1955 are presented in tables 22 and 23 and figures 14 and 15. As indicated in table 22 a total of 878.3 million pounds of slaughter hogs would have been shipped from the eight regions in which the production of slaughter hogs exceeded slaughter capacity. These eight regions were Regions 6, 9, 11, 13-16, and 20. Of these, Region 15 (Iowa) shipped 638.5 million pounds and Region 11 (Illinois) shipped 121.1 million pounds. In total,

these two regions accounted for 87% of the interregional shipments of slaughter hogs. Except for Region 9 which shipped 77.8 million pounds and Region 20 which shipped 22.5 million pounds, the shipments from each of the other regions was less than 7.5 million pounds. The major flows of live slaughter hogs were: Region 15 shipping in all directions, Region 20 shipping west to Region 26, and other surplus regions shipping east and south (figure 14). In all, six regions (Regions 3, 18-22, and 24) did not receive any shipments of slaughter hogs. Regions 18 and 19 were surplus producers of pork, while the other four were deficit pork regions (table 23).

In comparison, seven regions shipped a total of 1.1 billion pounds of slaughter hogs in the fourth quarter of 1955 under the optimum derived by the separately determined analysis (Appendix table 4). The regions which exported live slaughter hogs were the same in the separately determined analysis and the jointly determined analysis except for Region 16 which was a deficit region in the separately determined analysis. The only directional changes in the optimum flows between the two analyses were that Regions 13 and 14 shipped to Region 16 in the separately determined analysis (Appendix figure 1), while in the jointly determined analysis they shipped mainly to the Southeast. Since six regions did not re-

ceive any shipments of slaughter hogs in the jointly determined analysis the number of shipments was substantially reduced relative to the separately determined analysis.

Although the quantity of slaughter hogs shipped interregionally was 180.9 million pounds, less in the jointly determined analyses than in the separately determined analyses, the total transportation costs were increased by approximately \$648,000. This occurred because slaughter hogs had to move a greater distance from the surplus to deficit regions in the jointly determined analysis and is also reflected by average transportation costs increasing from \$1.16 to \$1.47 per hundred pounds.

The results of the pork portion of the jointly determined analysis are given in table 23 and figure 15. Total interregional pork shipments in this analysis were estimated to be 1.4 billion pounds, approximately 44% of the total supply and transportation costs were estimated to be approximately \$29.4 million. In total, 10 regions had a surplus of pork, 15 were deficit, and Region 7 was neither surplus nor deficit. The deficit area was Region 2 (New York, Pennsylvania, etc.) which imported 526.5 million pounds of pork. Iowa was the leading surplus producer of pork, 407.5 million pounds, however, six additional regions (Regions 9, 11, 14, 16, 19, and 20) each had surpluses in excess of 100 million pounds.

Table 22. Supplies, Price Differentials, Optimum Levels of Slaughter and Flows of Hogs for Slaughter, 26 Regions of the U. S., Fourth Quarter, 1955

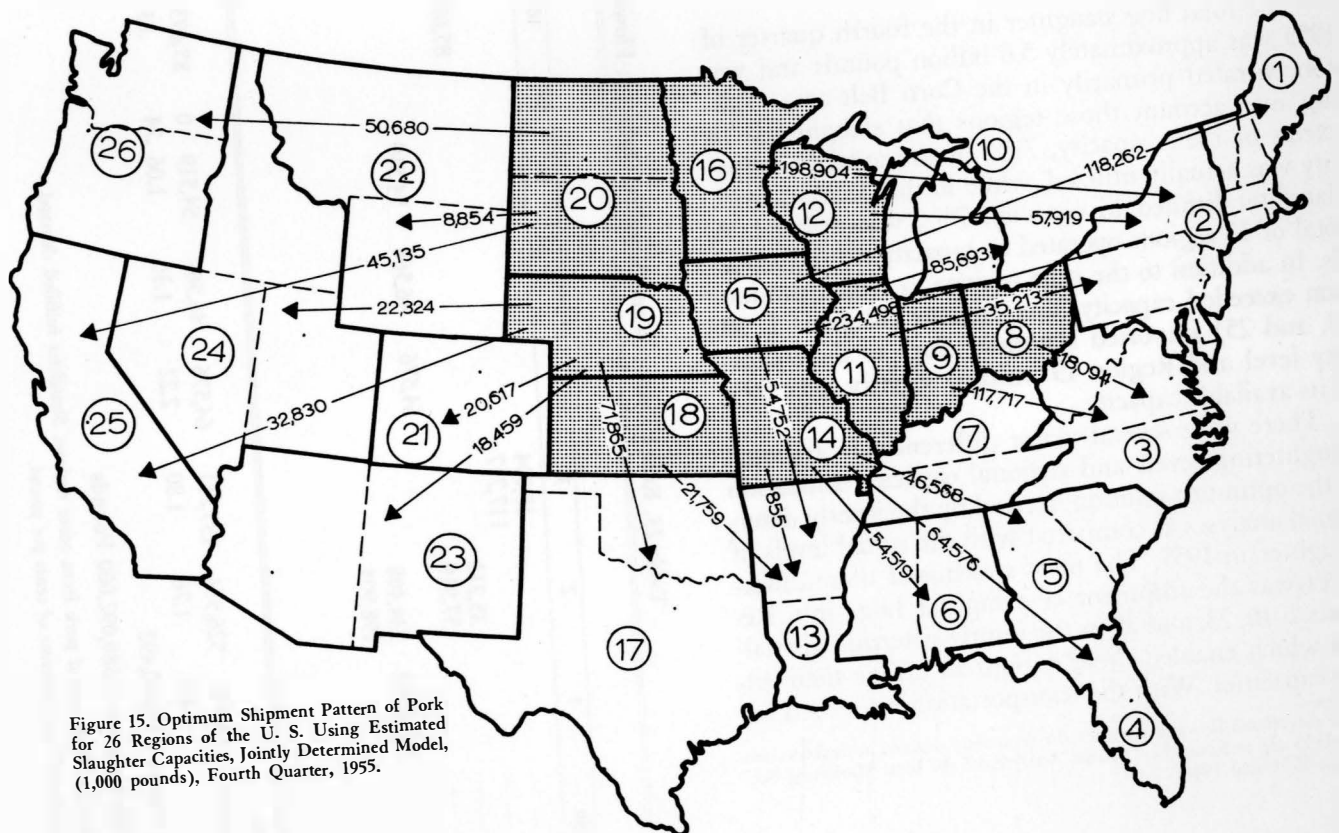
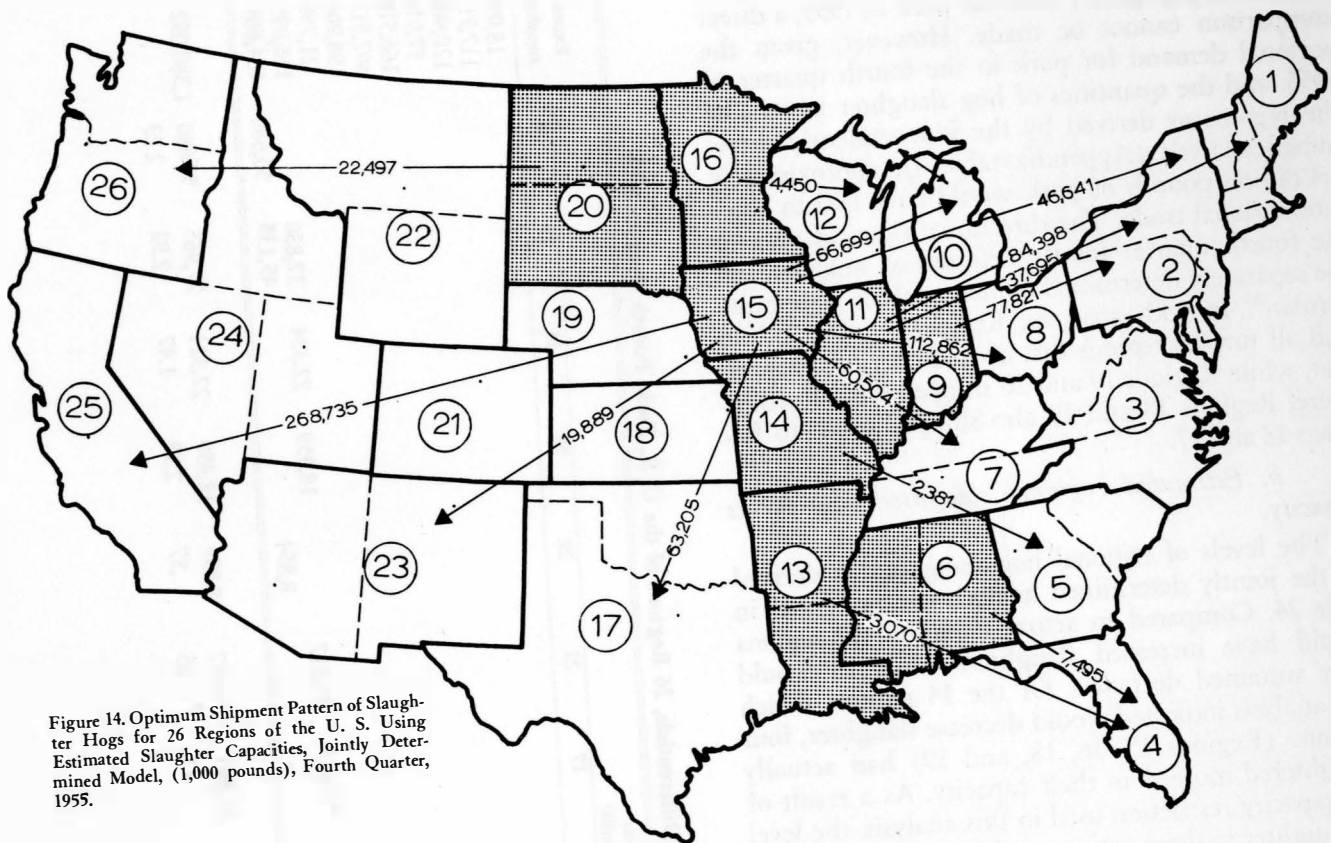
Destination	Origins and quantities of shipments (1,000 pounds)								Supply of slaughter hogs	Optimum slaughter demand	U†
	6	9	11	13	14	15	16	20			
1			84,398						14,920	99,318	.00
2		77,821	37,695			46,641			84,000	246,157	-.21
3*									99,150	99,150	-.18
4	7,495			3,070					24,100	34,665	.05
5					2,381				116,630	119,011	-.44
7						60,504			151,320	211,824	-.79
8						112,862			267,780	380,642	-.85
10						66,699			66,310	133,009	-.88
12							4,450		224,880	229,330	-1.30
17						63,205			132,610	195,815	-.68
18*									110,130	110,130	-1.39
19*									334,230	334,230	-1.54
21*									13,350	13,350	-.84
22*									11,540	11,540	-.88
23						19,889			4,600	24,489	.03
24*									11,680	11,680	-.37
25						268,735			29,090	297,825	.42
26								22,497	26,870	49,367	.06
Supply	92,530	446,210	686,400	41,500	434,840	1,436,590	458,670	242,120	5,562,052		
Slaughter	85,035	368,389	564,307	38,430	432,459	798,055	454,220	219,623		5,562,050	
U†	-1.04	-1.23	-1.36	-1.17	-1.50	-1.79	-1.83	-1.55			

Total Cost—\$12,917,864

Total Shipments—878,342,000 pounds

*Received no shipments of slaughter hogs from other regions. Slaughter composed of production from within the region.

†The U and V are in terms of cents per pound.



Since separately determined analyses were performed on a quarterly basis for pork in 1955, a direct comparison cannot be made. However, given the regional demand for pork in the fourth quarter of 1955, and the quantities of hog slaughter in each of the regions as derived by the independently determined analysis (Appendix table 4), approximately 1.4 billion pounds of pork would have had to enter interregional trade. The directional flows of pork of the fourth quarter jointly determined analysis and the separately determined annual analysis were quite similar.³³ In both analyses, Regions 14, 15, and 16 and all surplus regions east of these regions shipped east, while Regions 19 and 20 shipped west. Furthermore, Regions 18 and 19 also shipped south to Regions 13 and 17.

b. Estimated regional slaughter and excess capacity.

The levels of regional hog slaughter, as derived by the jointly determined analysis are presented in table 24. Compared to actual slaughter, 12 regions would have increased slaughter, while 14 would have sustained decreases. Of the 14 regions which this analysis indicated would decrease slaughter, four regions (Regions 15, 16, 18, and 19) had actually slaughtered more than their capacity. As a result of the capacity restriction used in this analysis, the level of slaughter in these regions could not exceed slaughter capacity. Consequently, slaughter was reduced to 100% of capacity in Regions 15, 16, and 19, and to 54% of capacity in Region 18.

The total hog slaughter in the fourth quarter of 1955 was approximately 5.6 billion pounds and was concentrated primarily in the Corn Belt area. Taking into account those regions that slaughtered in excess of their capacity, 71% of the available capacity was actually utilized, while in this analysis, with slaughter limited to capacity, 74% was utilized. A total of 13 regions operated at capacity in this analysis. In addition to the nine regions in which production exceeded capacity, four regions (Regions 1, 10, 23, and 25) imported slaughter hogs to their capacity level and Region 19 utilized slightly over 99% of its available capacity.

There were several major differences in regional slaughtering levels and regional capacity utilization in the optimum solution derived by the jointly determined analyses as compared with the actual levels of slaughter in 1955. The most striking of these differences was the shipment of slaughter hogs into Regions 1, 10, 23, and 25 in the jointly determined analysis which enabled these regions to utilize their entire capacities. With the transportation rates used for

³³The directional flows of pork for the separately derived annual analysis for 1955 are in figure 11, "Spatial Analyses of the Meat Marketing Sector in 1955 and 1960."

Table 23. Excess Demands and Supplies, Optimum Flows and Price Differentials, 26 Regions of the U. S., Pork, Fourth Quarter, 1955

Origin	Destination (1,000 pounds)																Excess supplies	U†
	1	2	3	4	5	6	7*	10	13	17	21	22	23	24	25	26		
8			18,094														18,094	.63
9			117,717														117,717	.32
11		35,213															120,906	0
12		57,919						85,693									57,919	-.17
14				64,576	46,568	54,519											166,518	-.28
15	118,262								855								407,512	-.64
16		234,498							54,752								198,904	-.74
18		198,904															21,759	-.32
19										71,865	20,617		18,459	22,324	32,830		166,095	-.59
20												8,854			45,135	50,680	104,669	-.57
Excess																		
Demands	118,262	526,534	135,811	64,576	46,568	54,519	0	85,693	77,366	71,865	20,617	8,854	18,459	22,324	77,965	50,680	1,380,092	
V†	2.16	1.76	1.80	2.22	1.36	1.06	.74	.83	1.29	.93	.65	.57	2.18	1.47	2.92	2.23		
Total Costs—\$29,410,492																		
Total Shipments—1,380,092,000 Pounds																		

*Received no shipments of pork from other regions. Slaughter fulfilled demand.

†The U† and V† are in terms of cents per pound.

hogs and pork, transportation costs could be minimized by shipping hogs directly from the surplus producing areas to the pork deficit areas as compared to shipping hogs to adjacent surplus capacity regions which would slaughter the hogs and then ship pork to the deficit regions. However, this was not possible with slaughter limited to the estimated level of capacity in the surplus producing region. The restriction on the level of slaughter had a major effect on the utilization of capacity in Region 18 and to a lesser extent in Region 21. In the separately determined analysis, (Appendix table 4), Region 18 imported 122 million pounds of slaughter hogs and utilized 113% of its capacity; however, in this analysis, when it slaughtered only its own production, 110.1 million pounds, 54% of its available capacity was utilized.

Except in Region 1, capacity utilization would have decreased in all regions along the East Coast. The percent of excess capacity varied in the regions (Regions 2-5) from a high of 75% in Region 2 to 41% in Region 5. Except for Regions 23 and 25, which would have operated at full capacity, other regions in the Mountain States and along the West Coast (Regions 21, 22, 24, and 26) were characterized by large amounts of unused capacity. Excess capacity varied from a low of 77% in Region 26 to 91% in Region 24.

c. Price differentials and rents.

The regional price differences consistent with the optimum flows derived by the jointly determined analysis for slaughter hogs and pork in the fourth quarter of 1955 are presented in the last rows and columns of tables 22 and 23. As in the analysis for slaughter cattle and beef, Region 1 was selected as the base region for slaughter hogs, while Region 11 was selected as the base region for pork. Of the surplus hog producing regions, Regions 6 and 13 had the greatest comparative price advantage, while Regions 15 and 16 had the lowest equilibrium prices compared to the base, Region 1. In the surplus hog regions, the comparative advantage in the equilibrium prices of Regions 6 and 13 was a consequence of these regions being deficit in pork even though they slaughtered at full capacity. Correspondingly, Regions 15 and 16, as a result of being the largest surplus producers of pork and having to ship the greatest distances to deficit areas, had the lowest equilibrium prices for hogs.

Although the levels of price differentials differed only slightly between this analysis and the separately determined analysis, the change in the regional price differences may be important. In general, the equilibrium prices of those regions in the eastern part of the U. S. (Regions 1-15) were increased in the jointly

Table 24. Actual and Estimated Optimum Hog Slaughter, Excess Slaughter Capacity, and Capacity Utilized, 26 Regions of the U. S., Fourth Quarter, 1955

Region	Actual			Estimated optimum		
	Slaughter (1,000 lbs.)	Excess capacity (1,000 lbs.)	Capacity utilized (percent)	Slaughter (1,000 lbs.)	Excess capacity (1,000 lbs.)	Capacity utilized (percent)
1	72,300	27,018	73	99,318	0	
2	452,730	527,074	46	246,157	733,647	25
3	143,000	95,441	60	99,150	139,291	42
4	36,790	23,636	61	34,665	25,761	57
5	128,990	73,162	64	119,011	83,141	59
6	58,940	26,095	69	85,035	0	100
7	173,650	112,470	61	211,824	74,296	74
8	278,970	249,521	53	380,642	147,849	72
9	252,440	115,949	68	368,389	0	100
10	104,320	28,689	78	133,009	0	100
11	479,910	84,397	85	564,307	0	100
12	239,850	15,867	94	229,330	26,387	90
13	26,850	11,580	70	38,430	0	100
14	333,520	98,939	77	432,459	0	100
15	968,870	170,815	121	798,055	0	100
16	487,090	32,870	107	454,220	0	100
17	217,610	171,532	56	195,815	193,327	50
18	232,110	27,272	113	110,130	94,708	54
19	341,510	7,019	102	334,230	261	100
20	200,440	19,183	91	219,623	0	100
21	47,720	26,879	64	13,350	61,249	18
22	14,710	51,918	22	11,540	55,088	17
23	13,310	11,179	54	24,489	0	100
24	26,560	102,776	20	11,680	117,656	9
25	148,980	148,845	50	297,825	0	100
26	80,880	135,054	38	49,367	166,567	23
Total	5,562,050	2,157,204	71	5,562,050	1,919,228	74

determined analysis while the equilibrium prices of regions in the western part were decreased. Except in Region 16, where the equilibrium price was decreased by 51 cents per hundred, the changes in equilibrium prices were less than 27 cents per hundred pounds. Region 16 was a surplus slaughter hog region in the jointly determined analysis and a deficit slaughter hog region in the separately determined analyses.

Surplus pork regions with the greatest comparative price advantage were Regions 8 and 9, while those with the least comparative price advantage were Regions 15 and 16 (table 23). The price advantage of Regions 8 and 9 was a result of their location with respect to the large deficit regions in the East, while the price disadvantage of Regions 15, 16, 19, and 20 was due largely to the distance between these regions and the primary deficit regions. Deficit regions on the West and East Coasts had the highest relative prices as compared with the base region, while the deficit regions adjacent to the surplus regions (Regions 7, 10, 21, and 22) had the lowest relative prices. Since a separately determined analysis was not performed for pork in the fourth quarter, it is not possible to make comparisons of price differentials. The regional price structure for pork as derived in this analysis is shown in figure 16.

The slaughter rents accruing to those regions that utilized their entire capacity are shown in table 25.

Table 25. Slaughter Rents in Cents Per Hundred Pounds, Live Weight, Slaughter Hogs, for Estimated Actual Capacity and Increased Capacity Levels, Fourth Quarter 1955

Region	Estimated actual capacity		Increased capacity levels	
	Capacity (1,000 pounds)	Rent (dollars)	Capacity (1,000 pounds)	Rent (dollars)
1	99,318	.02	*	*
6	85,035	.43	92,529	.43
9	368,389	.20	446,209	.10
10	133,009	.14	*	*
11	564,307	.15	686,399	.10
13	38,430	.69	41,499	.67
14	432,459	.13	434,839	.07
15	798,055	.22	1,436,589	.07
16	454,220	.21	458,669	.13
20	219,623	.02	242,119	.02
23	24,489	.00	*	*
25	297,825	.03	*	*

*When capacity was increased in the eight surplus producing regions of the initial analysis, these regions did not utilize their entire capacity.

These rents ranged from a high of 69 cents per hundred pounds in Region 13 to a low of zero return in Region 23. Even though Region 13 and also Region 6 exported slaughter hogs relatively high rents accrued to slaughter facilities because they were deficit in pork in the fourth quarter of 1955. The low returns to slaughter facilities in Regions 1, 23, and 25 occurred because these regions had to import slaughter hogs in order to slaughter at capacity. Of the major surplus producing regions, the highest returns

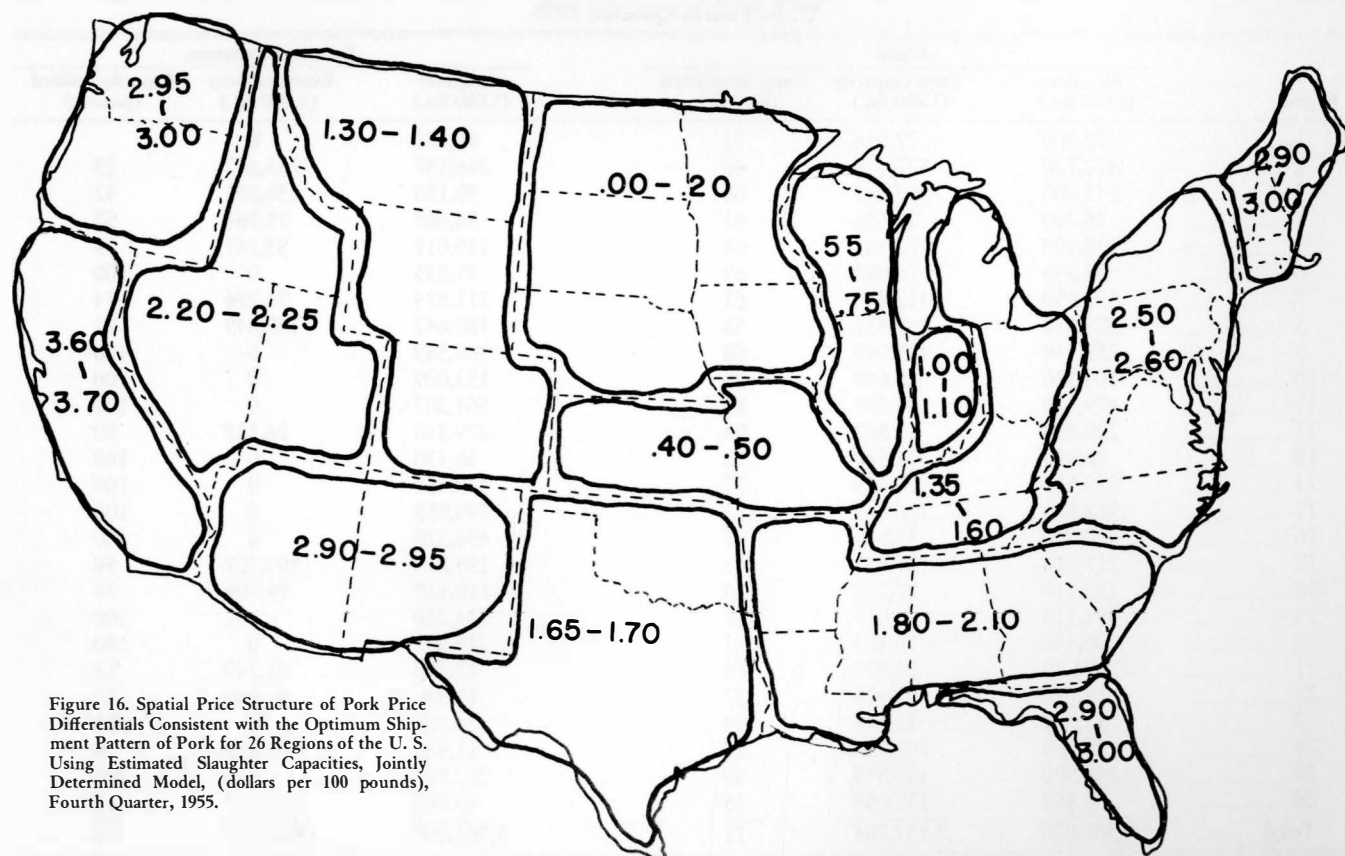


Figure 16. Spatial Price Structure of Pork Price Differentials Consistent with the Optimum Shipment Pattern of Pork for 26 Regions of the U. S. Using Estimated Slaughter Capacities, Jointly Determined Model, (dollars per 100 pounds), Fourth Quarter, 1955.

for complete usage of slaughter facilities accrued in Regions 15 and 9.

7. Hogs and pork, fourth quarter, 1955, assuming increased slaughter capacities.

Although total hog slaughter capacity decreased between 1955 and 1960, a number of regions increased their slaughter capacities (table 5). Of the eight regions which had production in excess of capacity in the previous analysis, four regions (Regions 6, 11, 13, and 15) increased their capacity between 1955 and 1960, three sustained decreases, (Regions 11, 14, and 20), while the capacity of Region 16 remained approximately the same. Because of overtime and through the use of more than one shift, Regions 15, 16, 18, and 19 actually slaughtered in excess of their actual capacities in 1955. In an attempt to evaluate the impact of changes in the regional location of slaughter capacity levels, an alternative analysis is presented in which the slaughter capacities in the eight surplus regions of the previous analysis are assumed to increase to within 1,000 pounds of their total production for slaughter.

a. Estimated flows and costs.

The results of the jointly determined analysis for slaughter hogs and pork when the slaughter capacities of the eight surplus producing regions (Regions 6, 9, 11, 13-16, and 20) of the previous analysis

are assumed to increase, are presented in tables 26 and 27 and figures 17 and 18.

As shown in table 26, the only shipments of slaughter hogs occurring in the optimum solution of this alternative analysis were the 1,000 pounds from those regions in which production exceeded capacity. The only regions receiving shipments of slaughter hogs were Regions 4, 7, 8, 10, and 26 (figure 17). Although the number of shipments were substantially reduced, the directions of the flows for this and the previous analysis were similar.

A total of 1.9 billion pounds of pork, or 59% of the total supply, would have moved interregionally under the optimum derived by this analysis. This represents an increase of 472 million pounds over the pork shipments of the previous analysis when slaughter was restricted to the estimated capacity levels. Even though there was a considerable increase in the quantity of pork moved interregionally, only one major directional change occurred between the two analyses. As shown in figure 15, Iowa shipped only to the East (Regions 1 and 2) and to Region 13 in the analysis based on estimated capacity levels. In this analysis, the quantity of surplus pork in Region 15 increased from 407.5 to 770.2 million pounds and it shipped pork west (92 million pounds) to Region 25 as well as to regions in the South, Southeast, and Northeast.

Table 26. Supplies, Price Differentials, Optimum Levels of Slaughter and Flows of Slaughter Hogs, With Increased Slaughter Capacities, 26 Regions of the U. S., Fourth Quarter, 1955

Destination	Origin and quantities of shipments (1,000 pounds)								Supply of slaughter hogs	Optimum slaughter demand	V _{ij} †
	6	9	11	13	14	15	16	20			
1*									14,920	14,920	0
2*									84,000	84,000	-.23
3*									99,150	99,150	-.20
4	1			1					24,100	24,102	.05
5*									116,630	116,630	-.44
7					1				151,320	151,321	-.74
8		1				1			267,780	267,782	-.72
10			1				1		66,310	66,312	-.76
12*									224,880	224,880	-1.35
17*									132,610	132,610	-.62
18*									110,130	110,130	-1.37
19*									334,230	334,230	-1.45
21*									13,350	13,350	-.75
22*									11,540	11,540	-.79
23*									4,600	4,600	.12
24*									11,680	11,680	-.28
25*									29,090	29,090	.54
26								1	26,870	26,871	.15
Supply	92,530	446,210	686,400	41,500	434,840	1,436,590	458,670	242,120	5,562,050		
Slaughter	92,529	446,209	686,399	41,499	434,839	1,436,589	458,669	242,119		5,562,050	
U _{ij} †	-1.04	-1.14	-1.33	-1.17	-1.45	-1.66	-1.78	-1.46			
Total Costs—\$7,580											
Total Shipments—8,000 pounds											

*Received no shipments of slaughter hogs from other regions. Slaughter composed of production from within the region.

†The U_{ij} and V_{ij} are in terms of cents per pound.

The estimated transportation cost for this analysis was \$33.6 million. Of this, all except \$7,580 was the cost of shipping pork. This represents a savings of \$8.7 million when compared with the total transportation cost of the jointly determined analysis in which actual capacity restrictions were used. This reduction in transportation costs was a result of two factors. With the present transportation structure, it is more economical to ship pork than live hogs, while secondly, the relative rates are lower as the length of haul is increased. This is indicated by the average per hundred pound pork transportation cost for the two analyses. In the initial model, the average costs were \$2.13 per hundred as compared to \$1.82 in this analysis.

b. Estimated regional slaughter and excess capacities.

The regional levels of slaughter, excess capacity, and capacity utilization when the hog slaughter capacity restrictions were realized in the surplus producing regions are given in Appendix table 3.

Excluding the 1,000 pound shipments to Regions 4, 7, 8, 10, and 26, the amount slaughtered in each region was equal to production (table 26). Region 15 was the major slaughtering region, with a total slaughter of 1.4 billion pounds, or 26% of the fourth quarter slaughter. Regions 9, 11, 14, 16, and 19 were the other leading slaughter regions and accounted for an additional 42% of the total slaughter.

The increase in quantity of slaughter capacity in the eight regions in which production exceeded capacity resulted in major changes in the amount of capacity utilized in other regions. All regions in the East (Regions 1-5, and 7) would have sustained decreases in the quantity slaughtered. The major decline would have occurred in Region 1 where capacity utilization would have decreased from 100% to only 15%. In the Mountain States and western regions, the most significant changes would have occurred in Regions 23 and 25 where capacity utilization would have been reduced from 100% to 19% and 10%, respectively. The quantity of excess capacity in the regions of these areas, as derived by this analysis, ranged from a low of 81% in Region 21 to a high of 91% in Region 24. In the Corn Belt and Central Plains regions, only Regions 8 and 10 would have been affected by the increase in quantity of capacity available.

c. Price differentials and rents.

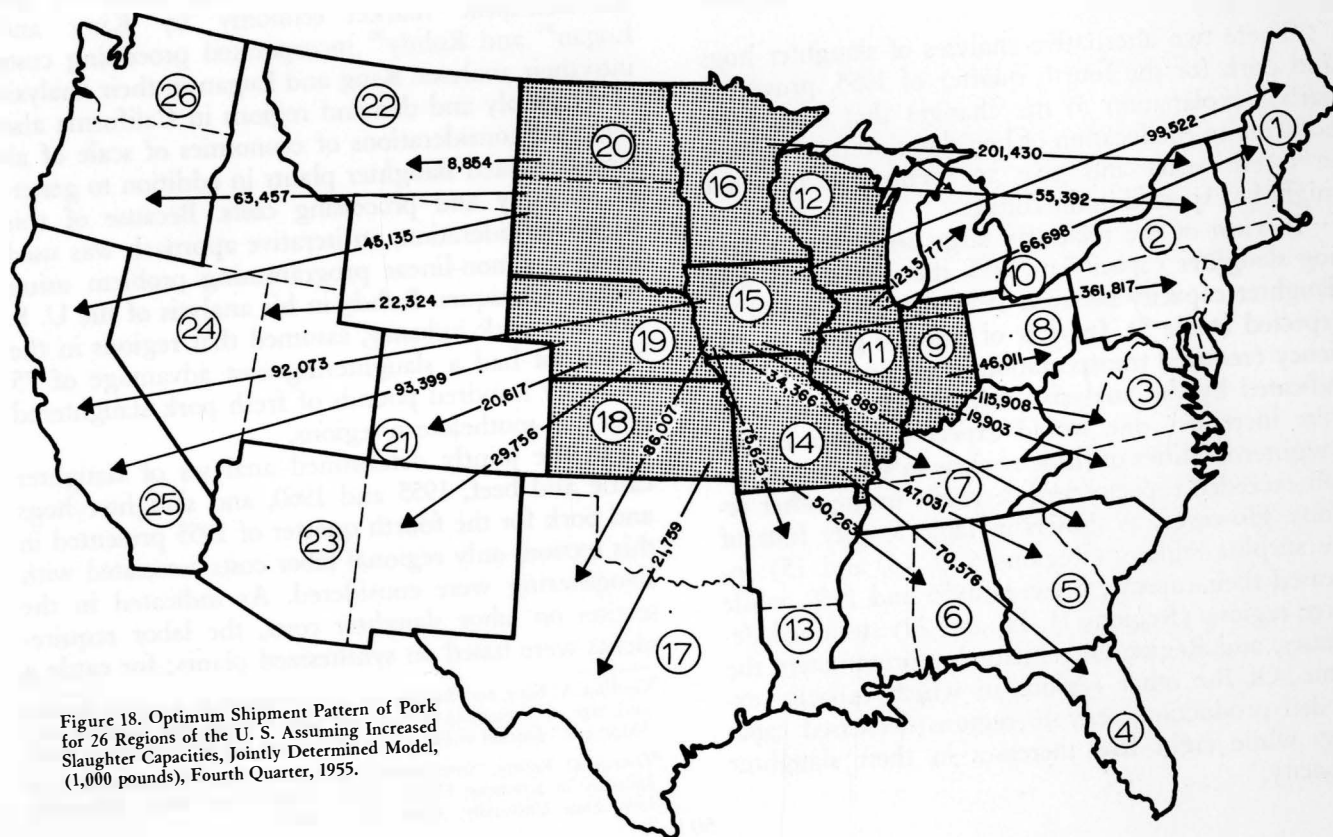
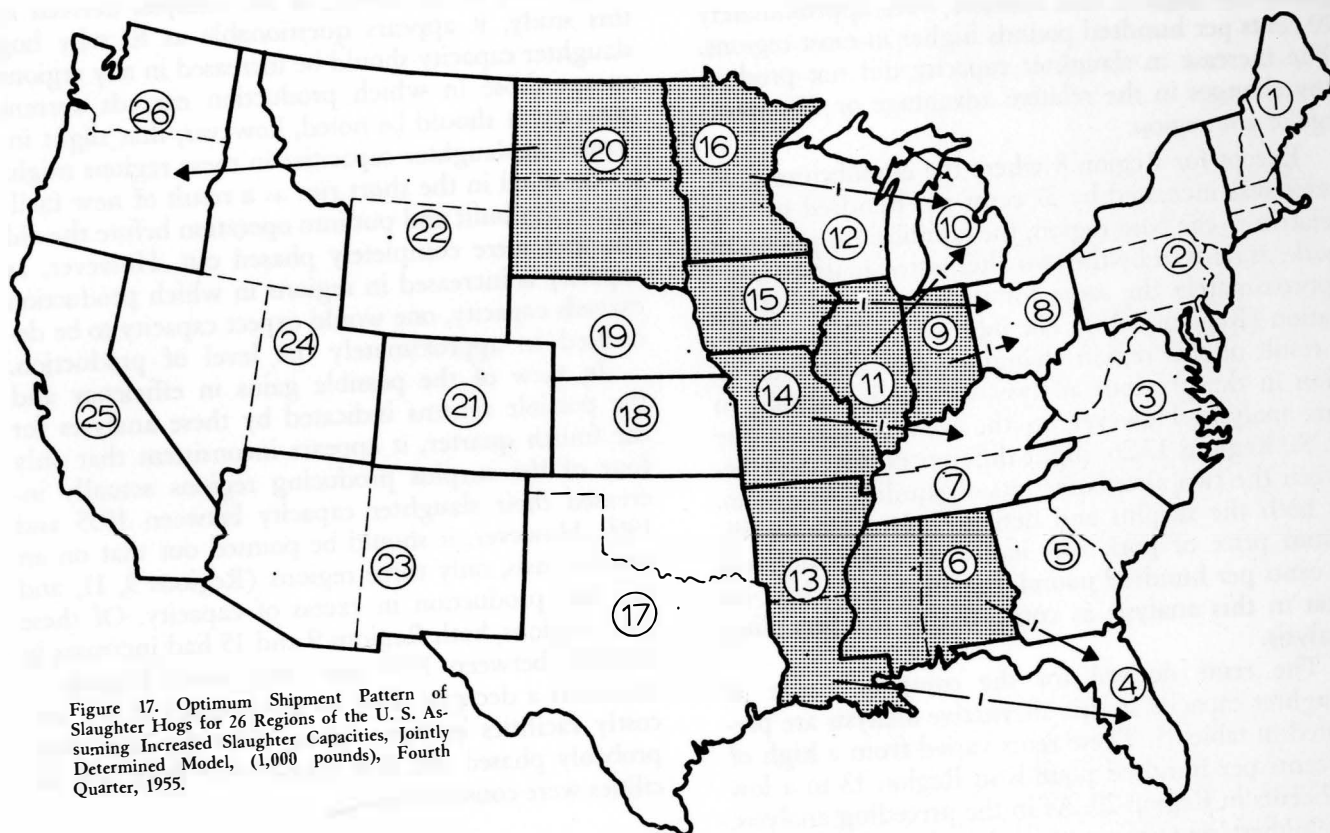
The price differentials derived for hogs and pork for this analysis in which slaughter capacities were increased for eight regions are given in the last columns and rows of tables 26 and 27.

In the slaughter hog portion of the analysis, only slight changes occurred between the two alternative

Table 27. Excess Demands and Supplies, Optimum Flows and Price Differentials, With Increased Slaughter Capacities, 26 Regions of the U. S., Pork, Fourth Quarter, 1955

Origin	1	2	3	4	5	6	7	8	10	13	17	21	22	23	24	25	26	Excess supplies	U ¹ *
9			115,908					46,011										161,919	.34
11	66,678								123,577									190,255	0
12		55,392																55,392	-17
14																		167,870	-25
15	99,522	361,817	19,903	70,576	47,031	50,263	34,366			75,623	86,007					92,073		770,200	-64
16		201,430			889													201,430	-74
18																		21,759	-24
19											21,759	20,617		29,756	22,324	93,399		166,096	-39
20													8,854			45,135	63,457	117,446	-37
Excess Demand	166,200	618,639	135,811	70,576	47,920	50,263	34,366	46,011	123,577	75,623	107,766	20,617	8,854	29,756	22,324	230,607	63,457	1,852,367	
U ¹ *	2.16	1.76	1.82	2.25	1.39	1.09	.87	.90	.83	1.29	1.08	.85	.77	2.38	1.67	3.12	2.43		
Total Costs—\$33,628,998																			
Total Shipments—1,852,367,000 pounds																			

*The U¹ and V¹ are in terms of cents per pound.



sets of price differentials. In general, the equilibrium prices for hogs in this analysis were approximately 10 cents per hundred pounds higher in most regions. The increase in slaughter capacity did not produce any changes in the relative advantage or disadvantage of any region.

Except for Region 8 where the equilibrium pork price was increased by 27 cents per hundred pounds relative to the base region, the equilibrium prices for pork, as derived by the two alternative analyses, were approximately the same for the eastern half of the nation (Regions 1-16). The increase in Region 8 was a result of this region changing from a surplus region in the previous analysis to a deficit region in this analysis. However, in the western part of the U. S., Regions 17-26, slight differences did occur between the two alternative sets of equilibrium prices. In both the surplus and deficit regions, the equilibrium price of pork was increased (approximately 20 cents per hundred pounds) relative to the base region in this analysis as compared to the preceding analysis.

The rents derived for the complete usage of slaughter capacity in this alternative analysis are presented in table 25. These rents varied from a high of 67 cents per hundred pounds in Region 13 to a low of 2 cents in Region 20. As in the preceding analysis, the highest rents were accrued in Region 6 and 13 while the rents in Region 2 were the lowest. The rents accruing in the other regions ranged from a high of 13 cents in Region 16 to 7 cents in Regions 14 and 15.

These two alternative analyses of slaughter hogs and pork for the fourth quarter of 1955, provide a partial explanation to the changes that have been occurring in the location of hog slaughtering facilities in recent years and give an inclination of what might be expected in the future.

In view of the relatively large amount of excess hog slaughter capacity in 1955, the decrease in hog slaughter capacity between 1955 and 1960 would be expected (table 5). In view of possible gains in efficiency (reduced transportation costs) and returns, as indicated by the analysis when slaughter capacities were increased, one would expect increases in the slaughter facilities of those regions in which production exceeded capacity and decreases in the other regions. However, as shown in table 5, only four of the surplus regions (Regions 6, 9, 13, and 15) increased their capacity between 1955 and 1960, while three regions (Regions 11, 14, and 20) sustained decreases, and Region 20 remained approximately the same. Of the other regions in which capacity exceeded production, only 10 regions decreased capacity, while eight had increases in their slaughter capacity.

In view of the results of the analyses derived in this study, it appears questionable as to why hog slaughter capacity should be increased in any regions except those in which production exceeds current capacity. It should be noted, however, that slight increases in slaughter capacities in these regions might be expected in the short run as a result of new facilities being built and put into operation before the old facilities were completely phased out. However, as capacity is increased in regions in which production exceeds capacity, one would expect capacity to be decreased to approximately the level of production.

In view of the possible gains in efficiency and the possible returns indicated by these analyses for the fourth quarter, it appears inconsistent that only four of the surplus producing regions actually increased their slaughter capacity between 1955 and 1960. However, it should be pointed out that on an annual basis, only three regions (Regions 9, 11, and 15) had production in excess of capacity. Of these three regions, both Regions 9 and 15 had increases in capacity between 1955 and 1960, while Region 11 sustained a decrease. Due to the number of old and costly facilities in this region, older facilities were probably phased out at a greater rate than new facilities were constructed.

B. Results Based on Estimated Regional Labor Slaughter Costs.

Two recent spatial equilibrium studies of the livestock-meat market economy by King and Logan³⁴ and Rohdy³⁵ incorporated processing costs into their analyses. King and Logan in their analysis of 34 supply and demand regions in California also included considerations of economies of scale of alternative sized slaughter plants in addition to general assembly and processing costs. Because of this added consideration, an iterative approach was used to solve a non-linear programming problem using linear techniques. Rohdy in his analysis of the U. S. hog and pork industry, assumed that regions in the Southeast had a slaughtering cost advantage of 75 cents per hundred pounds of fresh pork slaughtered over non-southeastern regions.

In the jointly determined analyses of slaughter cattle and beef, 1955 and 1960, and slaughter hogs and pork for the fourth quarter of 1955 presented in this section, only regional labor costs associated with slaughtering were considered. As indicated in the section on labor slaughter costs, the labor requirements were based on synthesized plants; for cattle a

³⁴Gordon A. King and Samuel H. Logan, "Optimum Location, Number and Size of Processing Plants with Raw Product and Final Product Shipment." *Journal of Farm Economics*, Vol. 45, No. 1, February 1964.

³⁵Donald D. Rohdy, "Interregional Competitive Position of the Hog-Pork Industry in Southeast United States." Unpublished Ph.D. dissertation, Iowa State University, Ames, Iowa 1963.

75-head-per-hour, rail system, and for hogs a 300-head-per-hour plant, including pork cut operations. Unlike the study by King and Logan²⁶, in which costs of synthesized alternative sized plants were used, depending on the quantity of cattle slaughtered in any one given region, only one labor cost for a given capacity plant was used in this analysis for all regions. However, with the data given in table 9 on labor slaughtering costs, for alternative size cattle slaughtering plants based on synthesized data and the transportation rates of cattle and beef (Appendix tables 1 and 2), calculations can be made to determine if the costs associated with different size cattle slaughtering plants would affect the optimum flow patterns derived for cattle and beef for 1960. These calculations are made in the following manner:

- a. The transportation cost of shipping dressed beef from 100 pounds of live weight slaughter cattle from Region i to j is added to the labor slaughtering costs for 100 pounds of slaughter cattle for the x , y or z size plant in the i th region.
- b. The transportation costs of shipping 100 pounds of slaughter cattle from Region i to j is added to the labor slaughtering costs for 100 pounds of slaughter cattle for the x , y or z size plant in Region j .

If Region i shipped beef to Region j in the optimum solution, they would continue to do so if the computed cost of " b " was greater than that computed for " a ." However, if the costs derived for " a " are greater than those computed for " b ," total costs could be reduced by shipping cattle from Region i to j for slaughter instead of slaughtering in Region i and shipping beef to Region j . The differences in costs computed for " a " and " b " represent either:

- i. the amount the transportation rates for cattle would have to be reduced relative to beef transportation costs between Regions i and j , or
- ii. the amount labor slaughtering costs would have to be reduced in Region j or increased in Region i before it would be economical to ship slaughter cattle instead of beef from Region i to j .

1. Cattle and Beef, 1955.

a. Estimated flows and costs.

The results of the jointly determined analysis for slaughter cattle and beef in which labor slaughtering costs were included are presented in tables 28 and 29 and figures 19 and 20²⁷.

Only two major changes in the optimum flows of slaughter cattle occurred in this analysis when compared with the previous analysis when labor slaugh-

tering costs were not considered (tables 10 and 28). The changes in the optimum flows indicated by this analysis show increased shipments of slaughter cattle to Regions 6 and 7. In the initial analysis, Region 6 did not receive any shipments of slaughter cattle, while Region 7 received only 95.4 million pounds. However, in this analysis Region 6 imported 191.1 million pounds of slaughter cattle from Region 14 while Region 7 increased its imports by 50.4 million pounds and imported a total of 145.8 million pounds of slaughter cattle from Region 18. The increase in shipments of slaughter cattle to Regions 6 and 7 had corresponding effects on the shipment patterns of slaughter cattle in the other regions. However, the only change of any major significance was that in this analysis, Region 14 was an exporter of slaughter cattle, as compared to an importer of cattle in the previous analysis.

The optimum flows of beef for the jointly determined analysis when labor slaughter costs were considered are presented in table 29 and figure 20. Although there was some change in the shipment patterns because Regions 6 and 7 increased their slaughter, there was no directional change in the optimum shipment patterns. In addition, all regions retained their same surplus-deficit position, except Region 6 which became self-sufficient in this analysis.

The total cost associated with this analysis was \$189.3 million. Of this, \$133.2 million was for transportation, \$32.4 million for slaughter cattle shipments and \$100.8 million for beef shipments while \$56.1 million was for labor slaughtering costs. The total minimum costs for this analysis were only \$50,000 less than the total minimum transportation cost plus the associated labor slaughtering cost for the initial jointly determined analysis (table 30). Although labor slaughtering costs were reduced approximately \$200,000 in this analysis, transportation costs were increased approximately \$150,000 as compared to previous joint analysis in which labor slaughtering costs were not incorporated.

b. Estimated regional slaughter and excess capacity.

When compared with the previous analyses, the only changes in regional slaughter and excess capacity indicated by this analysis occurred in Regions 6, 7, 14, and 16. With the increased shipments of slaughter cattle to Regions 6 and 7, slaughter was increased from 302.3 million and 508.6 million pounds to 494.4 million and 559.0 million pounds respectively. The percent of excess capacity was reduced from

²⁶King & Logan, *ibid*.

²⁷In the analysis in this section in which labor slaughtering costs were considered, the respective estimated slaughter capacities for slaughter cattle 1955 and 1960, and hogs, fourth quarter, 1955 were also used as a restriction.

47% to 14% in Region 6 and from 46% to 38% in Region 7. Since the shipments to these regions originated in Regions 14 and 18, slaughter in these regions was reduced and capacity utilization was reduced from 100% to 81% in Region 14 and from 94.5% to 93% in Region 18.

c. Price differential and slaughter rents.

The relative equilibrium prices derived for cattle and beef in this analysis were approximately the same as those derived in the previous joint analysis. The greatest difference between the two alternative analyses for both slaughter cattle and beef occurred for slaughter cattle and was 6 cents per hundred pounds, live weight.

The slaughter rent which accrued to regions utilizing the available capacity in this analysis are presented in table 31. These rents varied from a low of 3 cents in Region 21 to a high of \$1.05 per hundred pounds, live weight, in Region 22. Since Region 14 did not utilize its entire capacity, only nine regions received rents in this analysis as compared to 10 regions in the previous analyses. Although there was a slight variation in the rents of this analysis as compared to those of the previous analysis, the relative price advantages or disadvantages of the alternative regions were not altered.

2. Cattle and Beef, 1960.

Since the results of this analysis are virtually the same as for the previous jointly determined analyses (tables 16 and 17 and figures 9 and 10), the flow tables and diagrams will not be repeated. The only change indicated by this analysis in which labor slaughtering costs were considered was that the shipment of 17.7 million pounds of slaughter cattle from Region 18 to Region 7 in the previous analysis was shipped into Region 6 in this analysis.

3. Hogs and Pork, Fourth Quarter, 1955.

The results in which labor slaughtering costs were a factor in the jointly determined analysis for hogs and pork for the fourth quarter of 1955 are presented in tables 32 and 33 and figures 21 and 22. Although the total shipments of slaughter hogs were increased only 19.9 million pounds when labor slaughtering costs were considered as a factor in the jointly determined analyses, several changes occurred in the optimum flow patterns. In total, four regions increased imports of slaughter hogs, four decreased imports, and Region 9, which in the previous analyses neither exported nor imported hogs, became an exporter of slaughter hogs.

Of the regions increasing their inshipments of slaughter hogs in this analysis (Regions 3, 5, 17 and

Table 28. Supplies, Price Differentials, Optimum Levels of Slaughter and Flows of Cattle for Slaughter, Based on Estimated Slaughtering Costs (Labor) and Available Slaughter Capacities, 26 Regions of the U. S., 1955

Destination	Origin and quantities of shipments (1,000 pounds)								Supply of slaughter cattle	Optimum slaughter demand	U†
	14	15	18	19	20	21	22	23			
1*									185,009	185,009	0
2*									908,525	908,525	-.22
3*									477,842	477,842	-.19
4*									128,746	128,746	-.04
5*									159,238	159,238	-.51
6	191,105								302,272	493,377	-.68
7			145,802						413,153	558,955	-.81
8		661,562	201,364						616,576	1,479,502	-.74
9*									760,531	760,531	-1.07
10		530,646							435,937	966,583	-.79
11				307,061					1,938,503	2,245,564	-1.22
12					18,830				569,464	588,294	-1.20
13			86,087						304,453	390,540	-.87
16					140,002				1,227,056	1,367,058	-1.66
17						22,694			1,849,662	1,872,356	-1.13
24									444,017	444,017	-1.93
25							301,153	246,605	1,659,797	2,207,555	-.91
26					225,577		127,120		426,062	778,759	-1.04
Supply	1,156,322	3,192,487	1,768,275	2,376,275	934,374	943,134	565,261	457,850	24,200,821		
Slaughter	965,217	2,000,279	1,335,022	2,069,214	549,965	920,440	136,988	211,245		24,200,821	
U†	-1.46	-1.70	-1.75	-1.99	-2.40	-2.16	-2.40	-1.89			

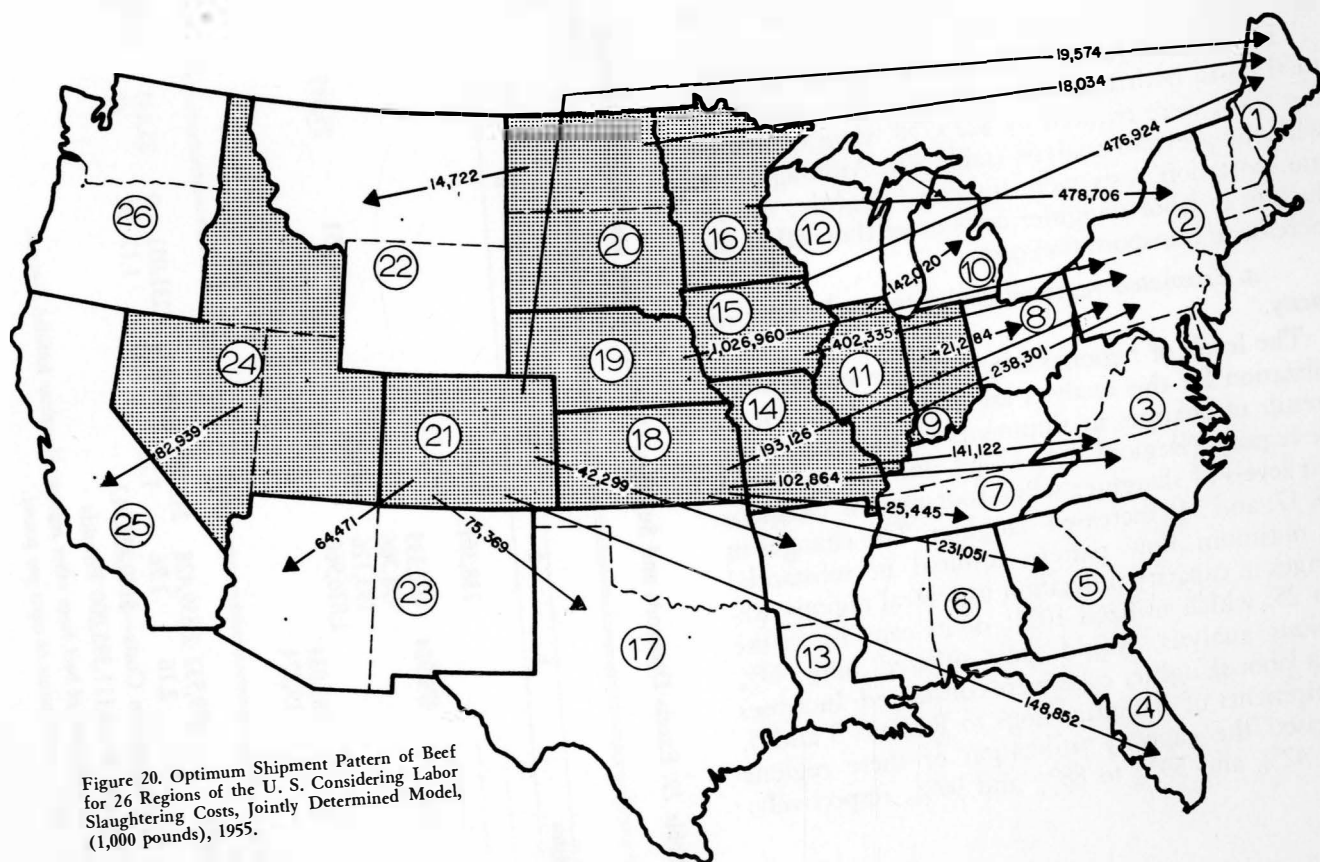
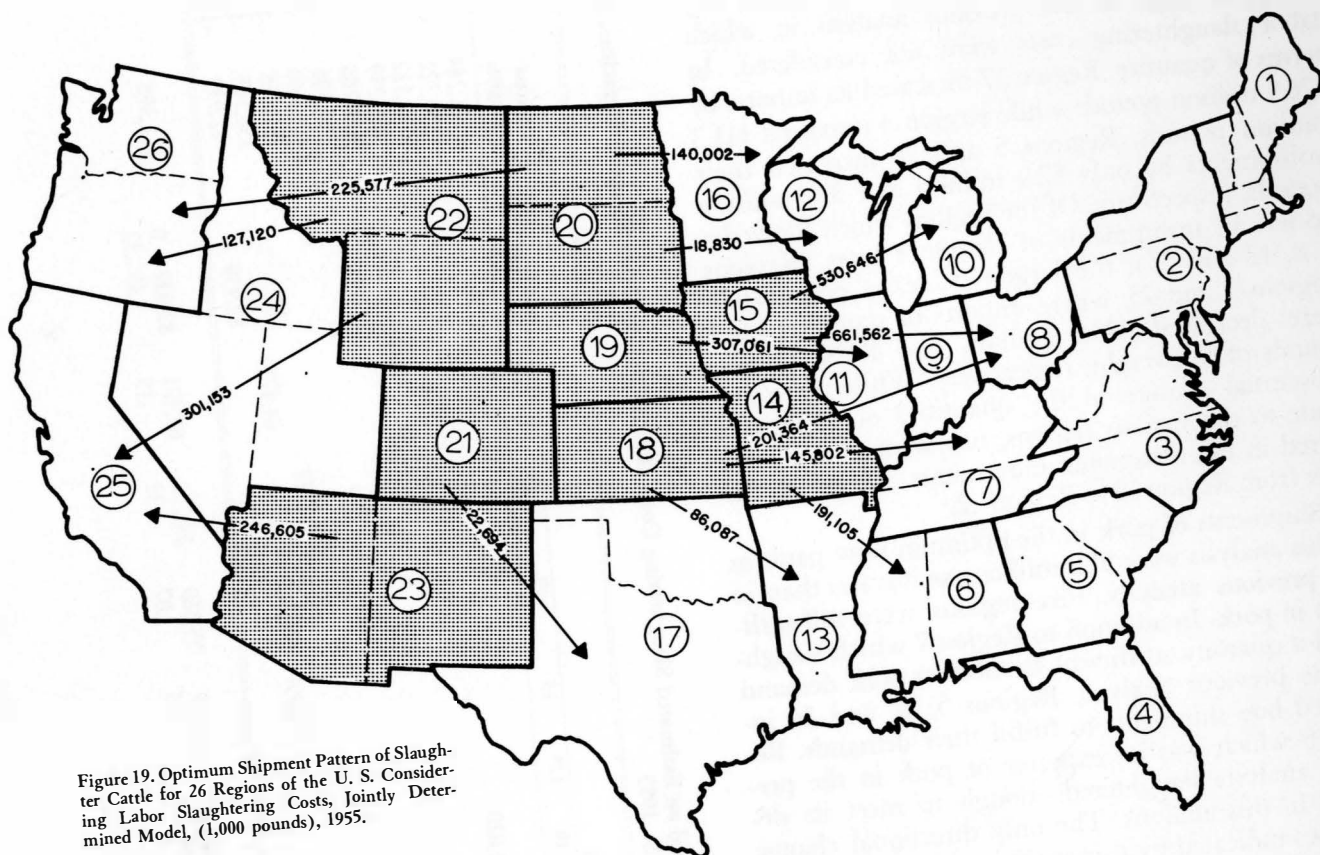
Labor Slaughter Costs—\$56,108,556

Total Shipments—3,205,608,000 pounds

Total Transportation Costs—\$32,393,057

*Received no shipments of slaughter cattle from other regions. Slaughter composed of production from within the region.

†The U and V are in terms of cents per pound.



24), neither Region 3 nor Region 24 imported any slaughter hogs in the previous analysis in which labor slaughtering costs were not considered. In terms of quantity, Region 17 increased its imports by 126.5 million pounds while Region 3 imported 111.3 million pounds. Regions 5 and 24 increased their inshipments by only 82.0 million and 39.3 million pounds, respectively. Of the regions which showed a decline in inshipments of slaughter hogs (Regions 2, 8, 12 and 25), the largest decreases occurred in Regions 2 and 25, where imports of slaughter hogs were decreased 124.5 million and 178.4 million pounds of liveweight, respectively. While there was substantial change in the quantities of shipments made to the various regions, no major changes occurred in the directional movements, except for the flow from Region 19 to Region 22.

Shipments of pork in the optimum flow patterns of this analysis were 31.9 million pounds less than in the previous analysis. Five regions were self-sufficient in pork. In addition to Region 7 which slaughtered a quantity sufficient to meet its pork demand in the previous analysis, Regions 5, 17 and 24 increased hog shipments to fulfill their demands. Region 8 which was an exporter of pork in the previous analysis slaughtered enough to meet its demand in this analysis. The only directional change in flows indicated by this analysis consists of Region 18 shipping to Region 23 as well as to Region 13. In terms of total quantity, approximately 30 million more pounds of pork were shipped to the far West due to the decrease in slaughter in Region 25.

In this analysis for the fourth quarter of 1955, total costs, both transportation and labor slaughtering costs, were reduced by \$223,758 when compared with the previous analysis (table 30). Although total transportation costs were increased slightly, the reduction in labor slaughter costs more than offset the increase in transportation costs.

a. Estimated regional slaughter and excess capacity.

The levels of regional hog slaughter and capacity utilization for this analysis are given in table 34. As a result of changes in shipments of slaughter hogs, five regions (Regions 2, 8, 12, 19, and 25) decreased their levels of slaughter while four regions (Regions 3, 5, 17, and 24) increased slaughter. The changes in the optimum flow pattern resulted in substantial changes in capacity utilization in several regions. Region 25, which utilized 100% of its capacity in the previous analysis, would have utilized only 40% when labor slaughter costs were considered. Increases in shipments of slaughter hogs to Regions 3 and 5, increased the capacity utilization of these regions from 42% and 59% to 88% and 99%, respectively.

Table 29. Excess Demands and Supplies, Optimum Flows and Price Differentials of Beef Based on Estimated Slaughtering Costs (Labor) and Available Slaughter Capacities, 26 Regions of the U. S., 1955

Origins	1	2	3	4	5	6*	7	8	10	12*	13	17	22	23	25	26*	Excess supplies	U†
9								21,284									21,284	.27
11		238,301															380,321	0
14			141,122						142,020								141,122	-.44
15	476,924	402,335															879,259	-.64
16		478,706															478,706	-.74
18		193,126	102,864		231,051		25,445										552,486	-.60
19		1,026,960															1,026,960	-.90
20	183,034												14,722				197,756	-1.46
21	19,574			148,852							42,299	75,369		64,471			350,565	-1.69
24															82,939		82,939	-1.34
Excess Demands	679,532	2,339,428	243,986	148,852	231,051	0	25,445	21,284	142,020	0	42,299	75,369	14,722	64,471	82,939	0	4,111,398	
U†	2.16	1.76	1.71	1.97	1.17	.81	.68	.83	.83	.04	.70	.07	-.32	.19	.39	.32		
Total Transportation Costs—\$100,826,912																		
Total Shipments—4,111,398,000 Pounds																		

*Received no shipments of beef from other regions. Slaughter fulfilled demand.

†The U† and U† are in terms of cents per pound.

Table 30. Total Cost Associated with Alternatively Derived Analyses, Slaughter Cattle and Beef, 1955 and 1960, and Slaughter Hogs and Pork, Fourth Quarter, 1955*

	Independently Derived Analyses	Jointly Derived Analyses	Jointly Derived Analyses (Labor Slaughter Costs Included)
(dollars)			
CATTLE AND BEEF, 1955			
Cattle Shipments	58,017,930	30,545,269	32,393,057
Beef Shipments	86,000,000	102,528,633	100,826,912
Total Transportation Costs	144,017,930	133,073,902	133,219,969
Labor Slaughter Costs	56,257,510	56,303,290	56,108,556
Total Costs	200,275,440	189,377,192	189,327,525
CATTLE AND BEEF, 1960			
Cattle Shipments	58,454,120	30,075,946	30,102,577
Beef Shipments	86,000,000	98,039,392	98,023,112
Total Transportation Costs	144,454,120	128,115,338	128,125,689
Labor Slaughter Costs	76,485,230	76,289,140	76,278,348
Total Costs	220,939,350	204,404,478	204,404,037
HOGS AND PORK, FOURTH QUARTER 1955			
Hog Shipments		12,917,864	11,641,870
Pork Shipments		29,410,492	80,960,609
Total Transportation Costs	†	42,328,356	42,602,479
Labor Slaughter Costs		31,264,744	30,766,863
Total Costs		73,593,100	73,369,342

*Labor slaughtering costs for the independently derived and the initial jointly determined analyses were obtained by multiplying the regional labor slaughtering costs by the optimum quantity of regional slaughter derived for these analyses.

†Not available.

Table 31. Slaughter Rents in Cents per Hundred Pounds, Live Weight, Slaughter Cattle 1955 and 1960, and Hogs, Fourth Quarter, 1955 for Estimated Actual Capacity Levels when Labor Slaughtering Costs were Included in the Analyses

Region	Cattle		Hogs 1955
	1955	1960	
	(dollars)		
1 -----			.02
6 -----			.45
9 -----			.09
10 -----	.04	.05	.11
11 -----		.21	.09
13 -----	.14		.72
14 -----		.10	.02
15 -----	.13	.35	.14
16 -----		.29	.11
18 -----	.17	.37	
19 -----	.27		
20 -----	.38	.20	.02
21 -----	.03	.33	
22 -----	1.05	1.01	
23 -----	.84	.88	.16

b. Price differentials and rents.

The relative equilibrium prices derived in this analysis for hogs and pork are presented in the last columns and rows of tables 32 and 33. As shown in table 32, only slight differences occurred in the price differentials for slaughter hogs between the two analyses. The equilibrium prices of pork for the two

analyses were approximately the same for Regions 1-18. However, the equilibrium prices for pork in Regions 19-26 in this analysis were increased approximately 15 cents per hundred pounds. This resulted from a smaller quantity of slaughter hogs being shipped in the western regions, which increased the pork deficit in these regions.

The slaughter rents accrued by these regions which employed their total available capacity in this analysis are given in table 31. With the exception of Region 25, which did not receive a rent in this analysis, the regions accruing rents were the same as in the previous analysis. Although the relative positions of various regions enjoying slaughter rents remained the same, the inclusion of labor slaughtering costs did affect the magnitude of the returns. For example, the rents accrued in the central Corn Belt were reduced slightly when compared with those of the previous analysis, while those in Regions 6 and 13 were increased. This is attributable to the higher labor costs in the central Corn Belt as compared to those in the Southeast.

4. General Effects of Consideration of Labor Slaughtering Costs.

As indicated in the results presented in the previous section, consideration of labor slaughtering costs had little or no effect on the jointly determined

Table 32. Supplies, Price Differentials, Optimum Levels of Slaughter and Flows of Hogs for Slaughter, Based on Estimated Slaughter Costs (Labor) and Available Slaughter Capacities, 26 Regions of the U. S., Fourth Quarter (Oct.-Dec.), 1955

Destination	Origins and quantities of shipments (1,000 pounds)									Supply of slaughter hogs	Optimum slaughter demand	V _i †
	6	9	11	13	14	15	16	19	20			
1			84,398							14,920	99,318	0
2			37,695							84,000	121,695	-.21
3		77,821				33,459				99,150	210,430	-.10
4	7,495			3,070						24,100	34,665	.21
5					2,381	81,986				116,630	200,997	-.37
7						60,504				151,320	211,824	-.77
8						81,007				267,780	348,787	-.83
10						62,249	4,450			66,310	133,009	-.86
12*										224,880	224,880	-1.39
17						189,728				132,610	322,338	-.66
18*										110,130	110,130	-1.42
21*										13,350	13,350	-.79
22*										11,540	11,540	-.75
23								19,889		4,600	24,489	.05
24						39,302				11,680	50,982	-.31
25						90,300				29,090	119,390	.44
26									22,497	26,870	49,367	.10
Supply	92,530	446,210	686,400	41,500	434,840	1,436,590	458,670	334,230	242,120	5,562,050		
Slaughter	85,035	368,389	564,307	38,430	432,459	798,055	454,220	314,341	219,623		5,562,050	
U _i †	-.88	-1.23	-1.36	-1.01	-1.43	-1.77	-1.88	-1.53	-1.51			
Labor Slaughter Costs — \$30,766,863												
Total Shipments — 898,231,000 pounds												
Total Transportation Costs — \$11,641,870												

*Received no shipments of slaughter hogs from other regions. Slaughter composed of production from within the region.

†The U_i and V_i are in terms of cents per pound.

spatial analyses of cattle and beef for 1955 and 1960 and only moderate effects on the analysis of hogs and pork. The deviations that did occur in optimum flow patterns only affected those regions which were importers in the analyses which did not consider labor slaughtering costs. Each of the surplus cattle and hog producing regions of the initial analyses continued to slaughter at their capacity level in this analysis.

These analyses indicate that under the transportation and labor cost structures considered, major producing regions will continue to slaughter at their capacity level, even though labor slaughtering costs are lower in other regions such as the Southeast. A factor not considered in these analyses that would tend to strengthen this conclusion is that the plants in the central Corn Belt and other major producing regions because of a greater density of livestock, tend to have larger rated capacities than those in other regions. In view of the economies of scale depicted by Logan and King³⁸ and others the differentials in labor slaughter costs would be reduced between the Corn Belt and regions in the Southeast, giving further emphasis to slaughtering at the point of production.

Although consideration of labor slaughtering costs in the jointly determined analyses had little or no effect on major producing regions, it did affect the flow patterns of the regions importing the sur-

plus live animals. In general, slaughter tended to increase in the southeastern regions which are characterized by lower wage rates, at the expense of regions in the West, Northeast, and regions adjacent to the central Corn Belt.

V. SUMMARY AND CONCLUSIONS

In this study minimum cost flows of live slaughter animals from regions of production to slaughter and meat flows from points of slaughter to regions of consumption were estimated for slaughter cattle and beef and for slaughter hogs and pork. A linear programming model was developed which permits estimating minimum cost flows of live slaughter animals and meat simultaneously. This model was used to determine regional levels of livestock slaughter and the directions and levels of interregional slaughter livestock and meat flows which satisfy regional production, consumption, and slaughter capacity constraints and yield a minimum total transportation cost for the live slaughter animals and meat. Required data such as regional production for slaughter, regional consumption of meats, regional slaughter capacities, and transportation costs of live slaughter animals and meats were estimated for 26 regions of the U. S. for cattle and hogs. Alternative regional slaughter capacity restrictions and regional differ-

³⁸Logan and King, *ibid.*

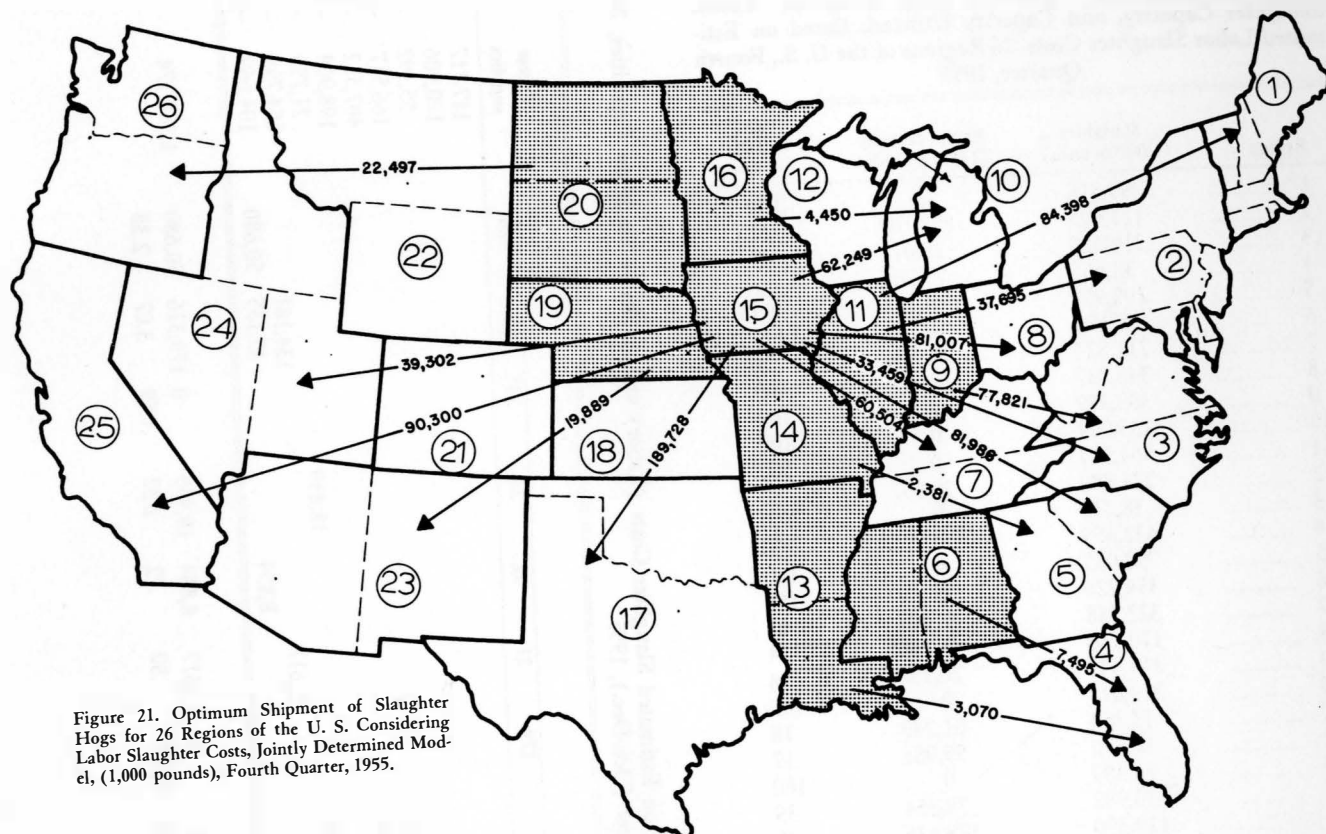


Figure 21. Optimum Shipment of Slaughter Hogs for 26 Regions of the U. S. Considering Labor Slaughter Costs, Jointly Determined Model, (1,000 pounds), Fourth Quarter, 1955.

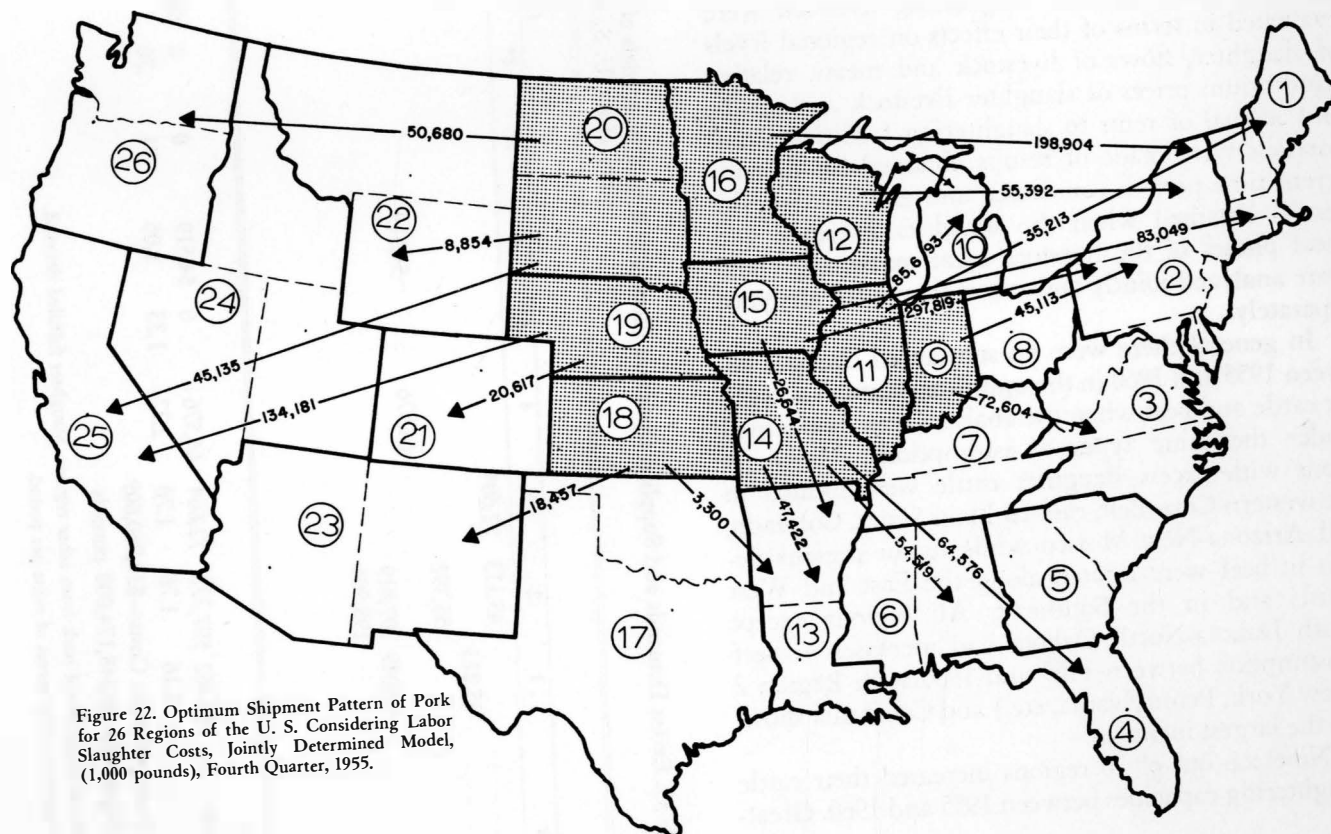


Figure 22. Optimum Shipment Pattern of Pork for 26 Regions of the U. S. Considering Labor Slaughter Costs, Jointly Determined Model, (1,000 pounds), Fourth Quarter, 1955.

Table 34. Estimated Optimum Hog Slaughter, Excess Slaughter Capacity, and Capacity Utilized, Based on Estimated Labor Slaughter Costs, 26 Regions of the U. S., Fourth Quarter, 1955

Region	Slaughter (1,000 pounds)	Excess capacity (1,000 pounds)	Capacity utilized (percent)
1	99,318	0	100
2	121,695	858,109	12
3	210,430	28,011	88
4	34,665	25,761	57
5	200,997	1,155	99
6	85,035	0	100
7	211,824	74,296	74
8	348,787	179,704	66
9	368,389	0	100
10	133,009	0	100
11	564,307	0	100
12	224,880	30,837	88
13	38,430	0	100
14	432,459	0	100
15	798,055	0	100
16	454,220	0	100
17	322,338	66,804	83
18	110,130	94,708	54
19	314,341	20,150	94
20	219,623	0	100
21	13,350	61,249	18
22	11,540	55,088	17
23	24,489	0	100
24	50,982	78,354	39
25	119,390	178,435	40
26	49,367	166,567	23
Total	5,562,050	1,919,228	74

ences in labor costs of slaughtering livestock were evaluated in terms of their effects on regional levels of slaughter, flows of livestock and meats, relative equilibrium prices of slaughter livestock and meats, and accrual of rents to slaughtering facilities. Comparisons were made of results obtained for the different time periods considered and also between the results obtained when the slaughter livestock and meat phases of the livestock-meat marketing chain were analyzed jointly and when they were analyzed separately.

In general there were no substantial changes between 1955 and 1960 in the optimum flows of slaughter cattle and beef when the analyses were performed under the same types of assumptions. Major regions with excess slaughter cattle were located in the western Corn Belt, eastern Plain States, Colorado, and Arizona-New Mexico while major regions deficit in beef were located along the East and West Coasts and in the Southeast. All regions except South Dakota-North Dakota had increases in beef consumption between 1955 and 1960 with Region 2 (New York, Pennsylvania, etc.) and California showing the largest increases.

Nineteen out of 26 regions increased their cattle slaughtering capacities between 1955 and 1960. Great-

Table 33. Excess Demands and Supplies, Optimum Flows and Price Differentials of Pork, Based on Estimated Slaughter Costs (Labor) and Available Slaughter Capacities, 26 Regions of the U. S., Fourth Quarter (Oct.-Dec.), 1955

Origin	Destination (1,000 pounds)																Excess supplies	U†	
	1	2	3	4	5*	6	7*	8*	10	13	17*	21	22	23	24*	25			26
9																		117,717	.22
11		35,213							85,693									120,906	0
12																		55,392	-.17
14						54,519				47,422								166,517	-.28
15		83,049	297,819							26,644								407,512	-.64
16			198,904															198,904	-.74
18										3,300				18,459				21,759	-.32
19												20,617					134,181	154,798	-.44
20													8,854			45,135	50,680	104,669	-.42
Excess																			
Demands	118,262	597,228	72,604	64,576	0	54,519	0	0	85,693	77,366	0	20,617	8,854	18,459	0	179,316	50,680	1,348,174	
V†	2.16	1.76	1.70	2.22	1.33	1.06	.71	.70	.83	1.29	.87	.80	.72	2.32	1.59	3.07	2.38		
Total Transportation Costs—\$30,960,609																			
Total Shipments—1,348,174,000 pounds																			

*Received no shipments of pork from other regions. Slaughter fulfilled demand.

†The U_i and V_i are in terms of cents per pound.

est increases occurred in Iowa and Nebraska while Illinois had the largest reduction in slaughtering capacity. Regions 12 and 17 and regions along the East and West Coasts had the largest amounts of excess slaughter capacity for cattle in both 1955 and 1960.

When labor slaughtering costs were incorporated in the analyses some minor changes occurred in the quantities of shipments but there was no directional change in the optimum shipment pattern. There were some slight increases in shipments of slaughter cattle into regions in the Southeast resulting in decreases in excess slaughter capacities of regions which received these cattle. The relative equilibrium prices derived for cattle and beef were approximately the same as those occurring when labor slaughtering costs were not explicitly considered. Although the amount and distribution of rents which accrue to slaughter facilities changed when labor slaughtering costs were considered, the differences were not large enough to alter the relative price advantages or disadvantages of the various regions.

The analyses in which increased slaughter capacities were assumed in the major cattle producing regions indicated that total transportation costs could be reduced by locating slaughter in areas of production. Slaughter tended to take place at the point of production and resulted in a high utilization of slaughter facilities in these regions while excess capacities of regions in the South and on the East and West Coasts increased. Changes in the relative equilibrium prices of cattle and beef were minor in most cases and in general the equilibrium prices of slaughter cattle in the major producing regions were increased relative to the base region while relative beef prices declined in deficit beef regions. Rents accruing to slaughter facilities ranged from 1 to 60 cents per hundred pounds with the greatest returns occurring in regions in the Corn Belt, particularly the western part, and regions adjacent to the western Corn Belt. This suggests that in the future, expansion of slaughter facilities and the location of new slaughter facilities are likely to occur in these regions. As slaughter facilities expand and develop in the major cattle producing regions, regions in the South and on the East and West Coasts will incur contractions in the slaughtering of cattle and will have more excess slaughter capacity than currently exists.

On an annual basis production of slaughter hogs exceeded hog slaughter capacity only in Indiana, Illinois, and Iowa in 1955 and in no regions in 1960. On a quarterly basis hog production for slaughter exceeded slaughter capacity in eight regions in the fourth quarter of 1955. These were regions in the central Corn Belt plus Regions 16 and 20 to the north and Regions 6 and 13 to the south. In optimum

flow pattern, shipments of live slaughter hogs originating from these regions went east except all of the hogs from the Dakotas and part of Iowa's slaughter hogs went west. Regions along the East Coast and in the West and Southwest, except for California and New Mexico-Arizona regions, had the greatest estimated excess slaughter capacities. Surplus hog producing regions in the South (Regions 6 and 13) had the greatest comparative price advantage for slaughter hogs while Iowa and Minnesota also had the least comparative price advantage for pork while Indiana and Ohio had the greatest price advantage. Of the major surplus producing regions of slaughter hogs, the highest returns for complete usage of slaughter facilities accrued in Iowa and Indiana.

Incorporating regional labor slaughter costs into the analysis of slaughter hogs and pork resulted in substantial changes in the quantities of shipments made to various regions, however, very little change occurred in the directional movement of slaughter hogs. In the optimum solution, consideration of labor slaughter costs resulted in higher levels of slaughter in some regions of the Southeast and Southwest. Relative equilibrium prices of pork were unchanged in regions of the eastern part of the U. S. and increased slightly in regions of the western part of the U. S. because of fewer slaughter hogs moving into the western regions. Although inclusion of labor slaughtering costs did affect the magnitude of accrued rents, the relative positions of regions receiving these rents remained about the same.

When increased slaughter capacities were assumed in the major hog producing regions, slaughtering tended to concentrate in these regions. Slaughter decreased in all regions in the East and in some regions in the Mountain States and the West. There was very little change in the directions of flows of slaughter hogs but the quantities of interregional shipments were reduced substantially while the quantity of pork moved interregionally increased considerably. Relative equilibrium prices of slaughter hogs were higher in most regions when increased slaughter capacities were assumed in major producing regions, however, this had little effect on the relative advantage or disadvantage of any region. Regional equilibrium pork prices were approximately the same for regions in the eastern half of the U. S. but slight increases occurred in regions located in the western part of the U. S. Rents derived for the complete usage of slaughter capacity ranged from a low of 2 cents to a high of 67 cents per hundred pounds with Iowa and Indiana accruing the highest rents. The relative positions of regions earning these rents remained about the same. The large decrease in estimated total transportation costs indicates that with the present transportation structure it is more economical to

ship pork than live hogs. This suggests that expansion of slaughter is likely to occur in major slaughter hog producing regions which are primarily located in the Corn Belt. Such a change in the location of slaughter facilities would reduce the quantities of slaughter hogs and increase the quantities of pork entering interregional trade. Regions in the East, Southeast, and the West would incur even greater excess slaughter capacities.

Since the analyses in this study are based on limited data and all factors affecting production, slaughter, and interregional trade of live slaughter animals and meats could not be considered, some caution needs to be exercised in evaluating the results and implications. The analyses of slaughter cattle and beef and slaughter hogs and pork provide a partial explanation of changes which have been

occurring in the location of slaughter facilities in recent years and suggest probable directions of change which might occur in the future.

From a methodological point of view the more general models that consider a number of marketing activities simultaneously appear to be superior in the characteristics of output information. The type of model used in this study is operational and applicable to a wide variety of applied economic problems.

The three studies in this series have been concerned with the spatial characteristics of the livestock industry in 1955 and 1960. Given this base, new research should be concerned with the future spatial characteristics of the livestock industry so that additional information can be gleaned relative to the geographical structure of consumption and the time path of the optimum geographical level of production and slaughter.

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APPENDIX

Appendix Table 1. Estimated Minimum Meat Transportation Costs, Truck and Rail in Cents per Pound or Dollars per Hundred Pounds, Between Specified Points, 26 Regions of the United States, 1960

Region		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
		Shipments West																									
1			.94	1.52	2.50	2.21	2.48	2.31	1.83	2.05	1.74	2.09	2.19	2.80	2.44	2.47	2.53	2.98	2.62	2.67	2.95	3.11	3.32	3.66	3.44	4.02	3.97
2		.76		.74	2.17	1.84	2.15	1.91	1.38	1.67	1.58	1.83	1.94	2.55	2.12	2.24	2.31	2.72	2.68	2.41	2.76	2.92	3.12	3.41	3.27	3.82	3.81
3		1.22	.61		1.87	1.49	1.91	1.64	1.36	1.62	1.63	1.87	1.98	2.51	2.09	2.28	2.35	2.53	2.24	2.40	2.79	2.95	3.14	3.38	3.30	3.77	3.84
4		2.23	1.90	1.59		1.37	1.65	1.77	2.16	2.12	2.24	2.31	2.41	1.91	2.31	2.54	2.71	2.27	2.42	2.64	3.11	2.98	3.41	3.33	3.39	3.66	3.99
5		1.94	1.56	1.19	1.08		.90	.79	1.23	1.46	1.86	1.75	1.87	1.62	1.74	2.00	2.22	1.96	1.89	2.18	2.68	2.57	3.04	2.97	3.05	3.41	3.66
6		2.21	1.88	1.63	1.35	.73		.62	1.39	1.21	1.59	1.68	1.79	1.20	1.52	1.83	2.09	1.58	1.66	1.95	2.57	2.38	2.87	2.73	2.87	3.19	3.52
7	S	2.04	1.63	1.35	1.49	.65	.97		.96	.74	1.21	1.33	1.50	1.55	1.32	1.65	1.94	1.79	1.54	1.87	2.42	2.30	2.81	2.83	2.81	3.28	3.45
8	h	1.55	1.09	1.07	1.88	1.53	1.67	1.28		.48	.53	1.10	1.33	2.06	1.50	1.75	1.83	2.24	1.69	1.87	2.35	2.39	2.73	3.01	2.85	3.47	3.48
9	i	1.77	1.37	1.33	1.85	1.16	1.51	1.08	.42		.69	.53	.84	1.87	1.09	1.37	1.59	2.04	1.43	1.64	2.16	2.20	2.60	2.86	2.69	3.32	3.35
10	p	1.45	1.28	1.33	2.07	1.59	1.87	1.51	.46	.85		.94	1.25	2.20	1.64	1.65	1.74	2.35	1.85	1.88	2.28	2.47	2.69	3.11	2.86	3.54	3.46
11	m	1.82	1.54	1.58	2.04	1.46	1.39	1.05	.88	.46	.78		.35	2.00	1.16	1.04	1.24	2.10	1.46	1.51	1.95	2.14	2.42	2.87	2.58	3.34	3.22
12	e	1.92	1.66	1.70	2.14	1.59	1.51	1.20	1.05	.68	.92	.24		2.09	1.34	1.09	1.02	2.19	1.54	1.54	1.84	2.13	2.33	2.92	2.62	3.35	3.16
13	n	2.53	2.28	2.03	1.63	1.33	.87	1.25	1.78	1.59	1.93	1.72	1.82		1.69	1.94	2.24	1.06	1.71	1.97	2.58	2.23	2.81	2.51	2.71	3.02	3.41
14	t	2.16	1.85	1.82	2.04	1.45	1.21	1.04	1.20	.87	1.34	.92	1.06	1.39		.75	1.41	1.64	.32	1.07	2.01	1.80	2.37	2.59	2.40	3.04	3.11
15	s	2.20	1.97	2.00	2.27	1.72	1.55	1.35	1.46	1.08	1.36	.84	.87	1.66	.62		.64	1.79	.63	.59	1.71	1.71	2.13	2.60	2.22	3.05	2.97
16		2.26	2.04	2.07	2.44	1.94	1.82	1.66	1.55	1.29	1.45	.98	.82	1.97	1.11	.78		2.11	1.36	1.21	1.29	1.94	1.94	2.80	2.38	3.18	2.86
17	E	2.70	2.45	2.26	2.00	1.69	1.28	1.50	1.97	1.76	2.08	1.83	1.91	.85	1.34	1.51	1.84		1.19	1.36	2.30	1.83	2.48	2.14	2.37	2.71	3.14
18	a	2.34	2.00	1.96	2.15	1.61	1.36	1.24	1.40	1.13	1.57	1.16	1.23	1.42	.30	.53	1.08	1.50		.66	1.86	1.60	2.23	2.37	2.24	2.92	2.98
19	s	2.40	2.14	2.12	2.37	1.90	1.67	1.58	1.59	1.35	1.60	1.21	1.24	1.69	.86	.50	.96	1.65	.56		1.60	1.43	1.97	2.45	2.03	2.88	2.81
20	t	2.67	2.49	2.51	2.83	2.41	2.30	2.15	2.08	1.89	2.01	1.67	1.56	2.31	1.73	1.42	1.02	2.03	1.57	1.30		1.72	1.31	2.66	2.07	2.87	2.47
21		2.83	2.65	2.67	2.71	2.30	2.10	2.03	2.12	1.92	2.20	1.86	1.85	1.96	1.52	1.42	1.66	1.54	1.31	1.13	1.43		1.58	1.90	1.46	2.45	2.44
22		3.03	2.84	2.85	3.11	2.76	2.59	2.54	2.45	2.33	2.42	2.15	2.06	2.54	2.10	1.86	1.66	2.21	1.95	1.70	1.04	1.28		2.45	1.56	2.44	2.05
23		3.35	3.11	3.08	2.94	2.69	2.45	2.56	2.73	2.58	2.83	2.60	2.64	2.24	2.32	2.33	2.53	1.86	2.10	2.18	2.38	1.62	2.18		1.43	1.61	2.43
24		3.14	2.98	3.00	3.10	2.77	2.59	2.54	2.58	2.42	2.59	2.31	2.34	2.44	2.13	1.95	2.11	2.10	1.97	1.75	1.79	1.15	1.26	1.72		1.28	1.89
25		3.68	3.49	3.45	3.35	3.11	2.90	2.99	3.16	3.03	3.24	3.04	3.05	2.74	2.76	2.77	2.89	2.44	2.64	2.61	2.59	2.17	2.16	1.32	1.01		1.56
26		3.63	3.49	3.51	3.65	3.35	3.22	3.15	3.18	3.06	3.16	2.93	2.87	3.12	2.83	2.69	2.58	2.85	2.71	2.54	2.20	2.17	1.78	2.16	1.60	1.84	

Appendix Table 2. Estimates of Truck Transport Rates for Slaughter Cattle, between Specified Points, 26 Regions of the U. S., 1960.

Region	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	(Cents per pound or dollars per 100 pounds)																									
1	0																									
2	.72	0																								
3	1.05	.49	0																							
4	2.70	2.07	1.77	0																						
5	2.14	1.51	1.24	1.04	0																					
6	2.68	2.03	1.77	1.46	.73	0																				
7	2.24	1.61	1.42	1.53	.66	.77	0																			
8	1.50	1.05	.92	2.06	1.16	1.40	.79	0																		
9	1.86	1.34	1.19	1.89	1.02	1.20	.57	.45	0																	
10	1.46	1.23	1.16	2.29	1.40	1.68	1.02	.40	.67	0																
11	1.94	1.56	1.53	2.28	1.39	1.24	.88	.74	.48	.65	0															
12	2.14	1.70	1.70	2.49	1.59	1.49	1.05	.90	.66	.82	.28	0														
13	3.41	2.74	1.03	1.62	1.22	.77	1.17	1.49	1.31	2.23	1.42	1.99	0													
14	1.86	2.48	1.91	2.26	1.31	.89	.82	.98	.64	1.13	.62	.80	.96	0												
15	2.55	2.01	2.19	2.72	1.80	1.53	1.22	1.09	.85	1.04	.59	.61	1.23	.49	0											
16	2.76	2.22	2.41	3.13	2.19	2.02	1.63	1.27	1.03	1.19	.70	.57	2.22	.80	.52	0										
17	3.61	3.06	2.66	2.29	1.70	1.16	1.41	1.64	1.43	2.31	1.48	2.00	.58	1.03	1.17	1.84	0									
18	2.75	2.15	2.22	2.52	1.58	1.22	1.07	1.15	.83	1.33	.87	.96	1.00	.34	.46	.76	.89	0								
19	2.92	2.44	2.62	2.78	2.03	1.67	1.56	1.46	1.22	1.46	.88	.92	1.33	.81	.43	.75	1.01	.48	0							
20	3.57	3.12	3.29	4.00	3.09	2.82	2.48	2.26	1.87	2.04	1.45	1.36	2.97	1.60	1.17	.86	2.24	1.31	1.16	0						
21	2.96	2.59	3.50	3.89	2.95	2.46	2.40	2.11	1.90	2.09	1.74	1.85	1.55	1.71	1.31	1.54	1.20	1.20	1.01	1.12	0					
22	3.20	2.96	4.32	4.93	4.12	3.59	3.53	2.46	2.27	2.28	1.96	1.85	2.29	2.07	1.64	1.42	2.17	1.91	1.39	.78	1.09	0				
23	3.74	4.78	5.00	4.53	3.90	3.17	3.53	3.77	3.40	3.98	3.48	3.60	1.87	2.87	2.87	3.24	1.52	2.44	2.43	2.90	1.56	1.83	0			
24	4.82	4.30	4.63	8.13	4.11	3.53	3.49	3.32	2.77	3.30	2.76	2.81	2.12	2.36	2.09	2.36	1.80	2.11	1.69	1.81	1.10	1.16	1.23	0		
25	6.43	5.82	6.83	7.83	5.40	4.57	4.76	4.77	4.37	4.99	4.41	4.48	2.44	3.66	3.73	4.08	2.08	3.39	3.37	3.40	2.02	1.70	1.12	1.54	0	
26	3.60	2.15	7.00	8.15	6.00	5.42	5.21	3.33	3.17	3.33	3.07	3.00	5.19	2.96	2.70	2.36	2.96	2.71	2.61	1.54	1.91	1.55	2.60	1.45	1.41	0

Appendix Table 3. Estimated Optimum Slaughter, Excess Capacity, and Capacity Utilized with Increased Capacity Levels, Cattle 1955 and 1960, and Hogs, Fourth Quarter, 1955, 26 Regions of the U. S.

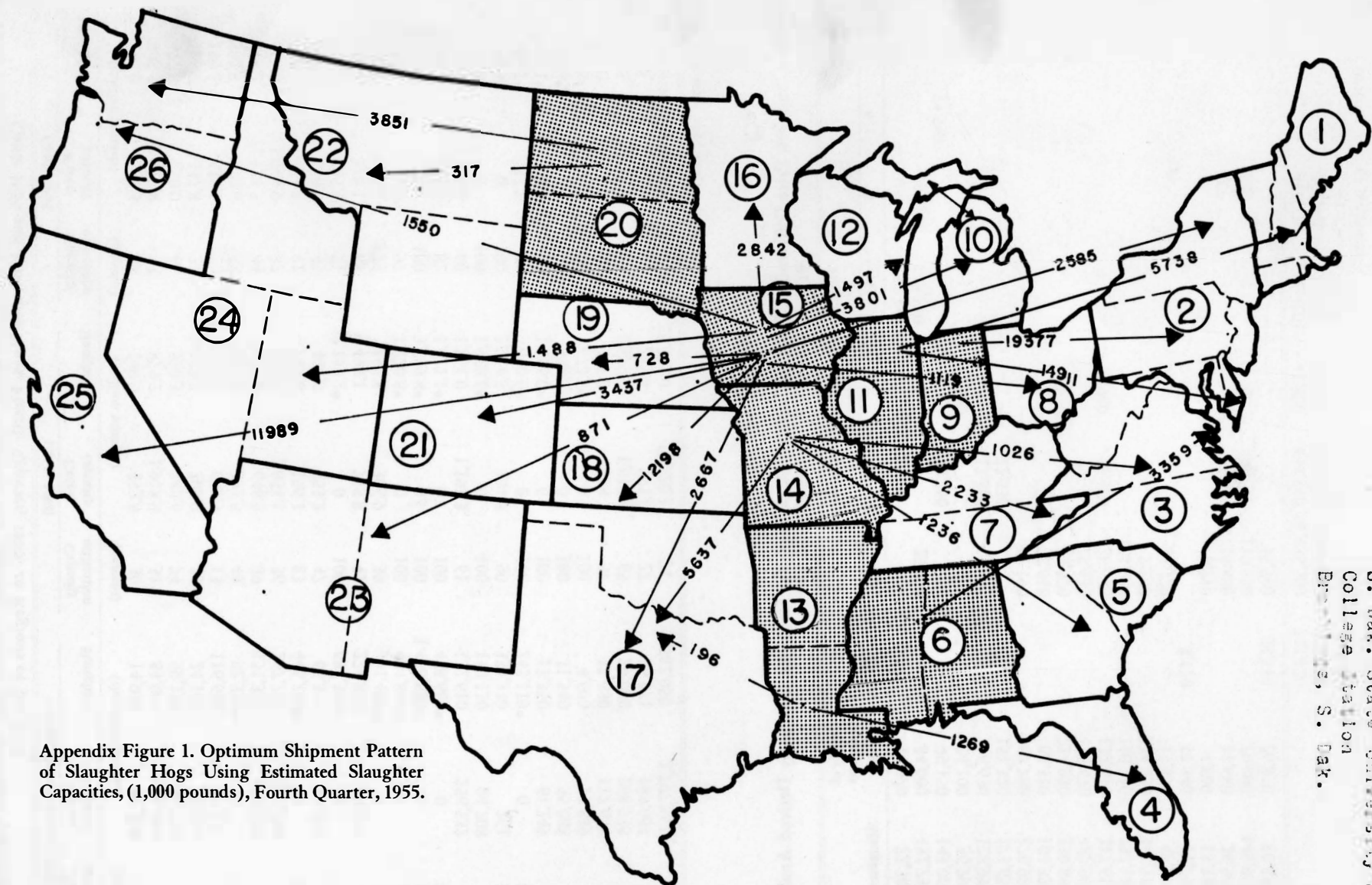
Region	Cattle 1955			Cattle 1960			Hogs, fourth quarter 1955		
	Slaughter	Excess capacity	Capacity utilization	Slaughter	Excess capacity	Capacity utilization	Slaughter	Excess capacity	Capacity utilization
	(million pounds)		(percent)	(million pounds)		(percent)	(thousand pounds)		(percent)
1	185.0	241.3	43	149.9	352.8	30	14,920	84,398	15
2	908.5	1,877.8	33	875.2	1,918.8	31	84,000	895,804	9
3	477.8	250.0	66	520.3	180.6	74	99,150	139,291	42
4	128.7	347.8	27	143.2	305.9	32	24,102	36,324	40
5	159.2	638.1	20	99.2	638.5	13	116,630	85,522	58
6	302.3	270.6	53	281.7	292.5	49	92,529*	0	100
7	413.2	524.5	44	412.6	640.8	39	151,321	134,799	53
8	616.6	1,044.9	37	588.7	1,054.1	36	267,782	260,709	51
9	760.5	74.2	91	745.6	156.1	83	446,209*	0	100
10	435.9	530.6	45	408.6	453.2	47	66,312	66,697	50
11	1,938.5	785.4	71	2,159.2*	0	100	686,399*	0	100
12	588.3	318.1	65	498.1	715.8	41	224,880	30,837	88
13	304.5	86.1	78	192.8	306.9	39	41,499*	0	100
14	1,156.3	31.5	97	1,270.8*	0	100	434,839*	0	100
15	3,192.5*	0	100	3,789.8*	0	100	1,436,589*	0	100
16	1,208.2	258.5	82	1,621.1*	0	100	458,669*	0	100
17	1,849.7	1,244.7	60	1,861.0	1,197.3	61	132,610	256,532	34
18	1,768.3*	0	100	1,978.6*	0	100	110,130	94,708	54
19	2,376.3*	0	100	2,214.3	234.5	90	334,230	261	100
20	901.7*	32.7	96	690.0*	0	100	242,119*	0	100
21	943.1*	0	100	1,216.0*	0	100	13,350	61,249	18
22	565.3*	0	100	402.3*	0	100	11,540	55,088	17
23	457.8*	0	100	670.7*	0	100	4,600	19,889	19
24	444.0	60.9	88	375.8	288.7	57	11,680	117,656	9
25	1,659.8	973.0	63	1,879.7	1,012.6	65	29,000	268,735	10
26	458.8	577.8	44	285.8	771.0	27	26,871	189,063	12
Total	24,200.8	10,168.5	70	25,331.0	10,520.1	71	5,562,050	2,797,562	67

*Regions in which capacity level was increased.

Appendix Table 4. Supplies, Price Differentials, Slaughter and Flows of Hogs for Slaughter, Separately Derived Analysis, 26 Regions of the U. S., Fourth Quarter, 1955

Destination	Origin and quantities of shipments (1,000 pounds)							Supply of hogs	Slaughter	V _i *
	6	9	11	13	14	15	20			
1			57,380					14,920	72,300	0
2		193,770	149,110			25,850		84,000	452,730	-.21
3	33,590				10,260			99,150	143,000	-.16
4				12,690				24,100	36,790	-.22
5					12,360			116,630	128,990	-.59
7					22,330			151,320	173,650	-.94
8						11,190		267,780	278,970	-.85
10						38,010		66,310	104,320	-.88
12						14,970		224,880	239,850	-1.23
16						28,420		458,670	487,090	-1.32
17				1,960	56,370	26,670		132,610	217,610	-.68
18						121,980		110,130	232,110	-1.36
19						7,280		334,230	341,510	-1.38
21						34,370		13,350	47,720	-.74
22							3,170	11,540	14,710	-.52
23						8,710		4,600	13,310	.03
24						14,880		11,680	26,560	-.33
25						119,890		29,090	148,980	.42
26						15,500	38,510	26,870	80,880	.33
Supply	92,530	446,210	686,400	41,500	434,840	1,436,590	242,120			
Slaughter	58,940	252,440	479,910	26,850	333,520	968,870	200,440			
U _i *	-1.21	-1.23	-1.36	-1.44	-1.65	-1.79	-1.28			

*The U_i and V_i are in terms of cents per pound.



Appendix Figure 1. Optimum Shipment Pattern of Slaughter Hogs Using Estimated Slaughter Capacities, (1,000 pounds), Fourth Quarter, 1955.