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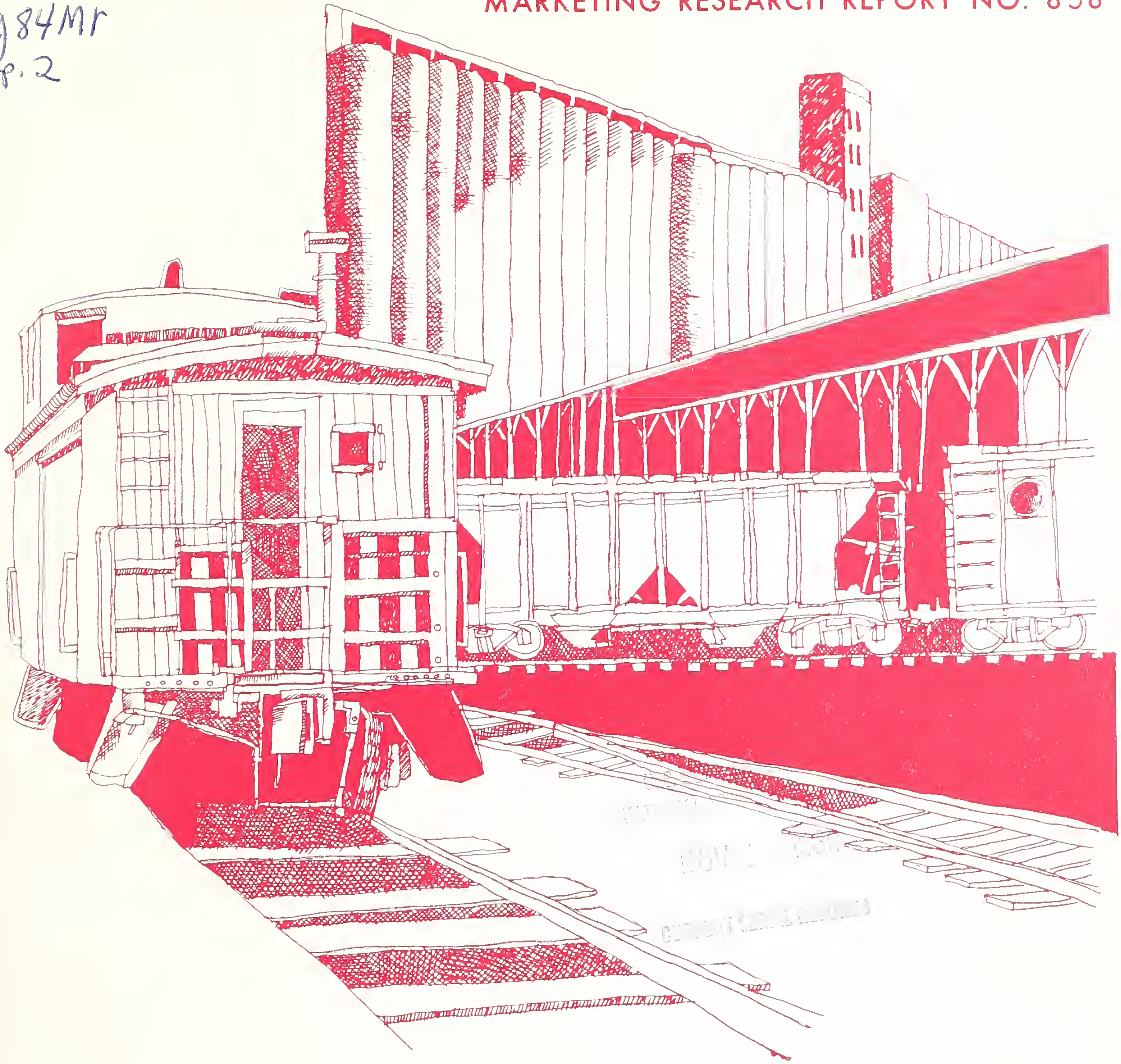

REGIONAL AND SECTORAL ANALYSIS OF THE WHEAT-FLOUR ECONOMY

a transportation study

U.S. DEPARTMENT OF AGRICULTURE   ECONOMIC RESEARCH SERVICE

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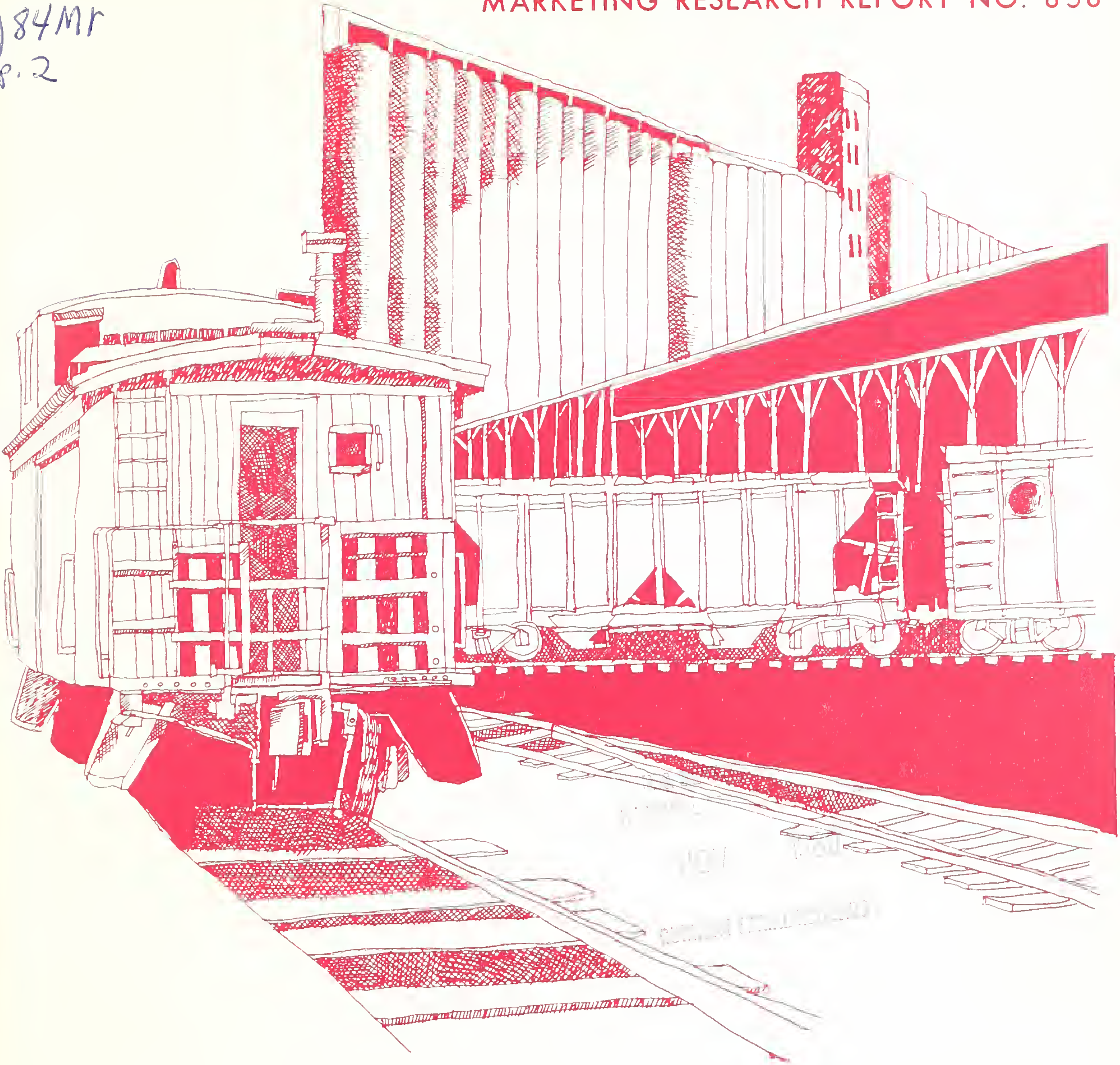

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ACKNOWLEDGMENT

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SUMMARY

Rail rates that are lower for shipping wheat than flour may shift the location of mills from producing or transshipment areas to consumer areas. Analysis of transporting and marketing wheat and flour from 71 major producing areas to 57 major U.S. markets and 10 most active ports for export shows that low rail rates could cause the milling industry to make this shift.

Until the late fifties, rail costs were the same for shipping wheat and flour. To eliminate extra loading and unloading costs, mills were located at transshipment points near producing areas. Truck-barge transportation from some of these points became cheaper than rail. Cost-reducing technology was introduced for bulk wheat shipments, and rail rates were accordingly reduced for wheat. Rates for flour were not changed; this provided millers the incentive to relocate away from producing and transshipping centers to flour market centers.

Two models were developed in the study: model A represents the old system, which is much like that of the early sixties, and model B shows the results of reducing transportation costs for wheat 20 percent--but with no change for flour.

Two limits of the models are:

- They cannot deal with substitutability of different kinds of wheat for each other--wheats are treated as if they were uniform.

- Flour is the only mill product recognized by the models, which do not consider the problem of shipping millfeed back to farm areas.

The models can be used to evaluate the relative magnitude of tradeoffs between those benefiting from and those disadvantaged by relocation of the mills.

REGIONAL AND SECTORAL ANALYSIS OF THE WHEAT-FLOUR ECONOMY

A Transportation Study

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Marketing Economics Division

INTRODUCTION

Rates for hauling wheat have declined relative to those for flour, so the least-cost location pattern of the milling industry has shifted toward a market orientation, moving away from the rail transshipment orientation it exhibited for many years. Industry reorientation (relocation) contains a wide variety of implications pertaining not only to the milling industry itself but also to the different regions and sectors of the wheat-flour economy.

The three main sections of this report serve to fulfill its three main purposes. First, a change in the relationship between rates for hauling wheat and flour is discussed in terms of the effect the change produces in the cost advantage of the present location of the flour milling industry. Second, an analytical framework is developed that identifies relationships between transportation rates and the different sectors and regions of the wheat-flour economy. Implementation of the framework quantifies some of the relationships.

Finally, results obtained under alternative assumptions about transportation rates and valuations of flour are presented and interpreted in terms of implications they contain for the different sectors and regions of the wheat-flour economy.

TRANSPORTATION COSTS AND LOCATION OF FLOUR MILLING INDUSTRY

Transportation dynamically affects industrial location. When firms consider alternative plant sites, they take into account, among total costs, transportation costs for obtaining raw materials and distributing products. Transportation costs are therefore a major factor in the location decision. The total of these decisions determines the location of the whole industry.

When firms seek new locations for their plants, they are attempting to improve their profit position by minimizing costs. Even though transportation costs are only one component of total costs in an accounting sense, they are inextricably involved in the total cost that is to be minimized by the location decision. Relationships of primary importance exist between outlays for transportation and accessibility to sufficient supplies of raw materials and markets for products that will enable efficient operation of the plant to be built.

Traditionally, industries have been classified as (a) resource-oriented, (b) market-oriented, or (c) intermediate-point-oriented. In addition, some industries have no particularly dominant orientation (4, pp. 27-46; 21, pp. 76-86). 1/ Examples of the three orientations can be taken from the wheat-flour economy, which is the industry examined in this study. Wheat production is resource-oriented. Because the main resource, land, is immobile, wheat must be grown where suitable land is available. The baking industry is market-oriented because the product is perishable--consumers have a high preference for freshly baked bread. The flour milling industry has been oriented toward intermediate points.

At least three factors have influenced the intermediate location of flour milling plants:

. . . intermediate points historically were closer to cheaper power to operate the mill, particularly when water was the dominant source of power for milling;

. . . some intermediate points served as transshipment points; thus, loading and unloading costs could be reduced if the milling took place together with a change in transport equipment or mode:

. from cars used to haul wheat to ones used to haul flour;
. from rail to barge;
. from truck to rail;

. . . closely related to and partly because of the first two factors, railroads tailored to increase their share of the outbound traffic over competing modes.

Stable industry location patterns can occur through a combination of (a) geographically fixed raw material supplies, (b) immobile markets (relatively stable geographical dispersion of population), or (c) transportation charges that are stable over time. Naturally, least-cost industry location patterns can be affected substantially by changes in any of these factors.

Typically, industry location patterns that are dominantly resource- or market-oriented also are highly stable. That is to say, immobile resources remain immobile and major metropolitan centers experience increases or decreases in population, but not general migration of centers in total. In contrast, intermediate orientations based on input-price advantages, mobile resources, or transport-pricing practices are not necessarily of long duration. An industrial site may become competitive, although previously inputs could be supplied only at a high cost or not at all, because, for example, new sources of power could become available or electricity could replace less mobile sources of power such as water.

Advances in transport technology also frequently alter the cost structure of the transportation industry. Changes in the cost structure of carriers are

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1/ Underscored numbers in parentheses refer to items in the Literature Cited, p. 29.

often reflected in their pricing policies. Pricing policies resulting from such changes or from reallocation of high fixed costs may significantly affect the best industry relocation patterns, especially when transportation rates are lower for the raw material, grain, than they are for the product, flour. In other words, if the new technology results in revision of pricing policies that changes the relationships between rates for transporting raw materials and products, measures of accessibility of alternate sites to sources of raw materials and markets will be affected; the net result is a shift in the optimum location of the mobile industry, or the creation of an incentive for new entry in the case of a nonmobile industry. The wheat-flour economy and the flour milling industry in particular have experienced such a phenomenon.

In the late 1950's and early 1960's, introduction of huge covered hopper cars for hauling wheat led to increased intermodal competition between railroads, trucks, and barges that resulted in decreased rail rates for shipping wheat. Knowledge of truck and barge rate trends is not publicly available. Trucks and barges apparently did not compete vigorously to haul flour; consequently, there was no corresponding decrease in rail rates for moving flour. The new competitive rail rates for wheat were based on cost of service criteria and allegedly upset long-established merchandising and processing relationships in the grain marketing industry. Scarce information about truck and barge rate trends makes evaluation of prior intermodal competition difficult.

This report develops a framework for evaluating the potential of this change in transportation rates on the least-cost location of the flour milling industry and the consequent potential impact on different sectors and regions of the wheat-flour economy.

DEVELOPMENT AND IMPLEMENTATION OF ANALYTICAL FRAMEWORK

Development of the Basic Model

Analysis of the interaction between transportation rates for wheat and flour and the location of the flour milling industry requires the formulation of a system that incorporates transport activity as a variable. In contrast, wheat available for shipment from producing areas and flour requirements at centers of population must remain constant in a formulation aimed solely at isolating the interaction between transportation rates and the location of flour milling. These two characteristics of the problem facilitate the adaptation of the transshipment formulation. 2/ Modification of the transshipment formulation focuses on the acquisition of wheat and distribution of flour by mills. Additional activities are included to represent the transport of wheat from producing areas to ports for export. Thus, the formulation presented in figure 1 encompasses the required characteristics for four wheat

2/ The transshipment model developed by Orden in 1956 (20) was a modification of the original transportation model set down by Koopmans in 1947 (12). Further development of the transshipment model has been by King and Logan (11), Hurt and Tramel (5), and Leath and Martin (14).

TRANSSHIPMENT FORMULATION OF THE WHEAT-FLOUR ECONOMY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	0			A					B						
2		0						Wheat: Supply to Export							WS
3			0												
4				0											
1	0			C			D								
2		0				Wheat: Supply to Milling									WS
3			0												
4				0											
5					0		E					Flour: Milling to Consumption		F	
6						0									MC
7							0								
			WS			MC		EX				FC			

Figure 1

supply areas (1, 2, 3, 4), three flour milling centers (5, 6, 7), two wheat export markets (8, 9), and five flour markets (10, 11, 12, 13, 14). Furthermore, it is solvable by the computationally convenient transportation algorithm.

Entries in the cost matrix are interpreted as:

Submatrix A: Zeroes on main diagonal, ∞ elsewhere.
Submatrix B: Wheat transport costs from supply points to ports.
Submatrix C: Zeroes on main diagonal, ∞ elsewhere.
Submatrix D: Wheat transport costs from supply points to mill centers.
Submatrix E: Zeroes on main diagonal, ∞ elsewhere.
Submatrix F: Flour transport costs from mill centers to consumption areas.

Entries in the boundary row and column are interpreted as:

WS: Wheat supply.
MC: Milling capacity.
EX: Export requirements.
FC: Flour consumption.

A primal solution to the formulation will have entries in the submatrices that exhibit the following characteristics:

A (wheat for milling) + B (wheat for export) = wheat supply
A (wheat for milling) + C (wheat for export) = wheat supply
D (wheat for milling) + C (wheat for export) = wheat supply
D (wheat for milling) + E (excess milling capacity) = milling capacity
F (flour consumption) + E (excess milling capacity) = milling capacity

A dual solution to the formulation contains a set of values that when interpreted as prices and multiplied by corresponding quantities indicates the value of wheat and flour in different production and market areas.

Two problems are developed and a solution to each is obtained to analyze the interaction between transportation rates for wheat and flour in different regions and sectors of the wheat-flour economy. A prototype of each, involving four wheat supply areas, three flour milling centers, two export markets, and five flour markets, is presented in appendix A. Wheat supplies, export requirements and flour consumption, milling capacities, and transportation rates are hypothetical, but reflect the nature of the alternate formulations of the models described in this report.

Model A represents the situation where rail rates for transporting wheat and flour are assumed to be the same. Milling capacity at all locations is not constrained at current levels, but to the extent that existing capacity was optimally located, little difference, if any, would be expected between a solution to model A and currently existing capacity.

Model B is designed to evaluate the consequences of reducing transportation rates 20 percent for wheat but not reducing them for flour.

Differences between the two solutions are interpreted as the incentive for longrun adjustments in the orientation of the industry, that is, new mills may be built in locations favored by the new relationship between transportation rates for wheat and flour.

Limitations of the Analysis

Evaluation of the results obtained and their implications for different sectors of the wheat-flour economy should be considered in terms of the model's limitations.

The basic model used in this study does not deal with two characteristics of the wheat-flour economy.

First, wheat is treated as a homogeneous commodity in this study. In reality, there are several different kinds of wheat that produce different kinds of flour. In the production of some flours, different kinds of wheat can substitute, within limits, for each other. The basic model can incorporate the different kinds of wheat as completely independent commodities or as perfect substitutes, but it cannot deal with limited substitutability.

Second, milling wheat produces joint products, flour and millfeed. The model used in this study cannot consider joint products. Flour is the only product recognized in this study. Flour has long represented 90 percent of the value of the two products, though in terms of volume, it represents only 74 percent. Millfeed is a bulky, relatively low-value product used as an ingredient by the mixed feed industry. The geographical location of the feed industry is not the same as that of the Nation's population. Major concentrations of population exist on both the east and west coasts. Livestock production and the mixed feed industry are further inland. Consequently, locating flour mills in population centers would require additional transportation to move millfeed back to feed mixing plants in livestock producing areas. The extent to which the additional transportation costs for millfeed would impede the reorientation of the flour milling industry cannot be determined by the model and data used in this study.

Finally, the model used in this analysis does not answer the related questions of whether the industry will relocate, nor if it does, how fast it will take place.

The main obstacle to an immediate and complete reorientation is the existing milling capacity that would be idled in the process of relocation. If the capacity in question is obsolete or nearly worn out, it may only slightly impede the reorientation. In contrast, the savings provided by the lower transportation rates must be substantially greater if the capacity destined for retirement is technologically efficient and in good repair.

Existing methodology could be adapted to evaluate all three problems, but the collection of relevant data would be difficult and its analysis costly.

Implementing Model of Wheat-Flour Economy

The two prototype models in the appendix indicate the kinds of data needed to examine the spatial interaction between the transportation rates and the wheat-flour economy. Data requirements relate to the separate economic activities of production, consumption, transportation and processing. Development of data to represent each activity is presented after the basic problem of regional demarcation is discussed. Availability of data and ability to answer the questions posed are factors underlying regional demarcation (3 and 10). Obviously, if relevant data do not exist for a particular set of regions, the set cannot be used in an analysis of the problem.

Similarly, results of an analysis are applicable to the set of regions used to obtain them. That is to say, an analysis using highly aggregated data (for example, States as regions) cannot be used to provide completely valid conclusions for regions exhibiting less aggregation (such as counties). Thus, analysis of State data cannot be used to answer all questions pertaining to activity in different areas within the State. Consequently, more than one region is needed to represent a State when areas within it have typically been oriented to various markets, none of which has the same geographical relationship to all areas within the State. Analysis of the interaction between the transportation rates and the wheat-flour economy requires a demarcation of regions that facilitates accurate measurement of shipping costs between regions that ship to or receive from each other.

Delineating a different region for each point with a different transportation cost could not be implemented. Even if data were available, such a regional demarcation would not be feasible computationally. Recognizing differences in transportation costs to or from other areas, however, was the primary factor considered in conjunction with availability of data during the process of regional demarcation.

Wheat Supply

The analysis requires estimates of the quantities of wheat available at different geographical locations. The location of wheat production is largely fixed because of climatic and geological conditions. Abnormal climatic conditions may substantially affect the geographical distribution of production from a single crop, but such incidents tend to cancel one another over longer periods.

A data bank maintained by the Center for Agricultural and Economic Development, Iowa State University, contains annual estimates of the agricultural production of 144 regions in the United States. The bank provided 10-year average (1951-60) yield and acreage data as estimates of wheat production (adjusted to reflect requirements for seed) for each of the 144 areas (29). Some of the 144 regions have little or no wheat production--several of the 144 regions represent cotton-producing areas. Other regions are too large or irregularly shaped for use in an analysis focusing on transportation. Consequently, to obtain production estimates for this analysis, the 144 regions are regrouped into 71 regions according to the demarcation indicated in figure 2 and in appendix tables 1 and 2.

Flour Milling Centers

A comprehensive historical description of the location of the flour milling industry appears in a series of articles by Fred Lukerman in the Northwestern Miller (15, 16, 17, and 18).

Lukerman identifies factors that influenced the development of major milling centers. The evolution of the industry's location is graphically presented and its 1966 geographical distribution described.

Consideration of relevant location factors (discussed in the articles) as they relate to transportation costs involved in wheat procurement and flour distribution was given in the delineation of the 28 milling centers presented in figure 3. Capacity at each mill center is specified to be in excess of total U.S. flour requirements so that milling can and will occur at least-cost locations in the models.

REGIONAL DELINEATION OF WHEAT SUPPLY AREAS

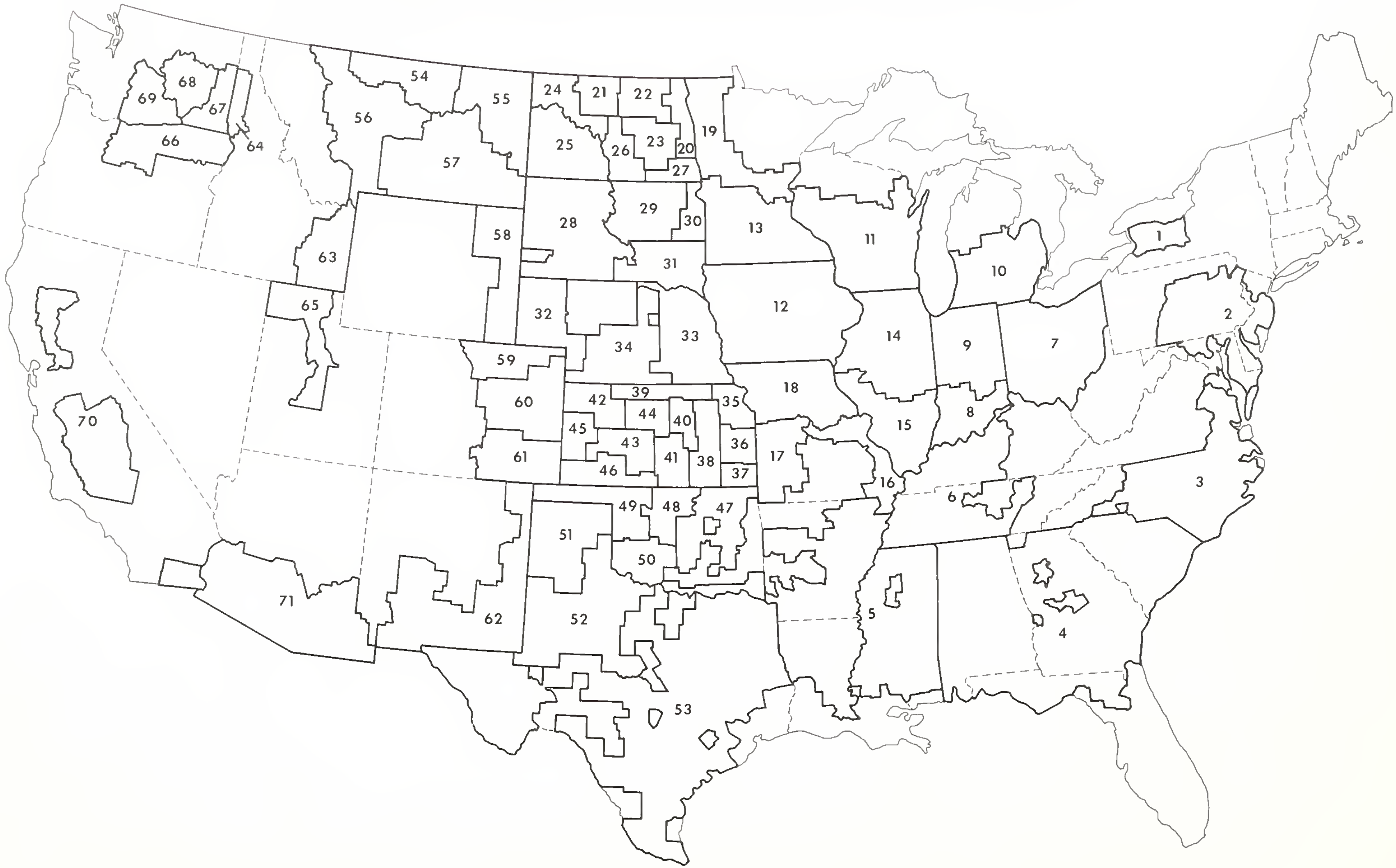

Figure 2

LOCATION OF MILLING CENTERS USED IN THE ANALYSIS

Figure 3

Wheat Exports

The models as formulated require estimates of wheat moving into foreign markets. Since this analysis focuses on relationships between domestic transportation rates for wheat and flour, the location of the flour milling industry, and the different regions and sectors of the U.S. wheat-flour economy, disappearance of U.S. wheat into foreign markets is measured at the U.S. port of export. Different producing areas are tributary to individual ports on each of the four coastal areas; 10 ports represent the four coastal areas. Exports were allocated to 10 ports on the basis of 1966 and 1967 shipments (25 and 27) and adjusted to satisfy a basic constraint (supply equals demand) of the formulation (appendix table 3).

Flour Consumption

Domestic flour consumption is another component of the models. Patterns of per capita flour consumption are relatively stable over time (24). Consequently, population is used to estimate the geographical distribution of flour consumption. The 1960 Census of Population data are published according to various levels of geographic aggregation--county, State economic area, economic subregion, State, and region.

The 501 State economic areas in the census of population, ranging in size from single counties to the State of Alaska, are aggregated into 57 market areas to represent the flow of flour from mills to final markets (fig. 4). The flour consumption associated with each market area is based on U.S. per capita annual consumption and the population data in appendix tables 4 and 5.

Transportation Costs

The cost-of-service criterion apparently underlies the transportation pricing policy used to support most of the current changes in transportation rates. Transportation rates based on this criterion largely reflect the distance the product travels. In fact, some new rates are directly related to distance (6, p. 6). Existing rate structures contain, to some extent, value of service and public utility concepts. Consequently, existing rates were not used for this analysis; instead, I used a rate structure that is more directly related to the cost of service, based on distance. Thus, elements in the transportation cost matrix are the rail mileages appearing in the most recent complete rail atlas (22). This assumes charges for truck and barge transportation correspond to rail distances. Strong intermodal competition supports this assumption. Exceptions involve circuitous rail routes to avoid mountainous conditions. In most such cases, truck charges are also higher.

In evaluating a solution to the dual system, a monetary value is applied to the distances used as transportation costs. The values used in this analysis were: 1 mile equal to 0.1 cent, 10 miles to 1 cent, and so on. Primary support for using these values was the high degree of correlation between the solution obtained from these models and solutions obtained from identical formulations using existing transportation rates as the elements in

REGIONAL DELINEATION OF FLOUR MARKETS

Figure 4

the cost matrix. Only slight discrepancies were evident and in most cases appeared to be a result of specific characteristics of the existing rate structure.

Wheat Prices

A solution to the dual system acquires economic meaning when values of the dual variables are interpreted as prices. Values for all the dual variables represent the geographical price differentials associated with the solution. Because there is one more equation (m+n) than there are unknowns (m+n-1), one dual variable is assigned an arbitrary value. If such an assignment is based on real prices, the price differentials, multiplied by the quantity associated with each, determine the value of wheat in producing areas and of wheat and flour in market areas.

The price of wheat is determined by a variety of forces. In recent years, international markets have been a dominant influence. World demand for U.S. wheat is reflected by wheat prices at U.S. ports. In 1966 and 1967, Houston exported more wheat than any other port (appendix table 3). The 1966-67 average price of wheat at Gulf ports was $2.01 per bushel (26). Consequently, the values of wheat and flour in each model are first determined by a set of prices based on a wheat price of $2.01 per bushel at Houston for export. An alternative valuation using a constant average flour price shows the importance of alternate price bases in the computation of sectoral effects. No attempt was made in this study to determine the correct price base.

EMPIRICAL RESULTS AND THEIR INTERPRETATION

A solution to each of the two models contains information in two major categories--one on the location of milling and corresponding shipments of wheat and flour; the other on valuation of wheat and flour in different regions and sectors of the wheat-flour economy. The first is in a primal solution and the second in a solution to the dual problem.

Models A and B contain the same wheat supplies, wheat and flour requirements, and transportation rates for flour, but transportation rates for wheat in model B are 20 percent below their model A level. Thus, the primal solution for model B, compared with the model A solution, indicates the amount of industry relocation that would occur as new milling capacity is built to replace wornout or obsolete mills and as the industry adjusts to the new relationship between wheat and flour transportation rates. The dual solutions indicate the corresponding impact on wheat values in producing areas and on wheat and flour values in market areas.

Location Analysis

A solution to each model determines the quantity of flour milled at each milling center and indicates the geographical pattern of each center's wheat procurement and flour disposition. The flow pattern of wheat moving to ports for export is also given. These two closely related aspects of the solutions pertaining to flour milling are presented separately. The location of milling in the eight regions is shown in table 1. The wheat procurement and flour disposition of mill centers is discussed in conjunction with the results pertaining to the flow of wheat into export markets.

Location of Milling

The expected location of the industry (model B) is compared with its current location as well as with its model A location for the following reason. The structure of rates used in model A results, as expected, in a locational pattern of the industry that is not unique--mill centers in and between particular production and market areas each faced with the same transportation costs can and do share in the relevant milling. 3/

In model A, existing flour milling capacity is fully utilized in two (North Atlantic and Mountain) of the country's eight regions (table 1). In fact, the solution indicates milling exceeds currently existing capacity by a third in each of the two regions. 4/

The West North Central Region with two-fifths of the Nation's milling capacity has more than 2 1/2 times as much as any other region (table 1). The North Atlantic, East North Central, and Pacific Regions each account for an additional 10 to 15 percent. Remaining capacity is evenly distributed among the other 4 regions.

Of the six regions with excess capacity in model A, the West North Central region has the most on an absolute basis, but the least in percentage. Even though the West North Central Region has the most unused capacity, it also mills more flour than any other two regions combined.

In model B, the quantity of flour milled in two regions, 61,000 hundredweight in the North Atlantic and 29,000 hundredweight in the South Atlantic, exceeds currently available capacities by 19,000 and 12,000

3/ Four interregional examples of this phenomenon in model A are: (1) Mills in the East North Central (Detroit, Fostoria, Chicago, Minneapolis, Winona, and Davenport) and North Atlantic (New York, Buffalo, and Lancaster) Regions share the North Atlantic (Boston, New York, Syracuse, Buffalo, Philadelphia, and Pittsburgh) market for flour. (2) Mills in the West North Central Region (Omaha, Kansas City, and St. Louis) share the South Atlantic market (Columbia, Atlanta, Jacksonville, Orlando, and Miami) with mills in 3 other regions (East North Central-Evansville, East South Central-Chattanooga, and South Atlantic-Jacksonville). (3) West North Central (Wichita) and West South Central (Enid and Dallas) mills share markets in 2 regions (East South Central-New Orleans and West South Central-Dallas, Houston, and San Antonio). (4) Mountain (Ogden) and Pacific (San Francisco and Los Angeles) mills share Pacific markets (San Francisco and Los Angeles) for flour.

4/ A solution to the same problem with capacity constrained at current levels however indicated less than a 1-percent increase in total transportation costs. Consequently, little incentive exists for the industry to reorient from its current location to the one indicated in the model A solution.

Table 1.--Flour: existing, used, and excess milling capacity, by region, models A and B

Region	Existing capacity 1/	Model A		Model B	
		Used	Excess	Used	Excess
	1,000 hundredweight				
North Atlantic	41,818	57,434	2/15,616	60,731	2/18,913
South Atlantic	17,490	11,730	5,760	29,265	2/11,775
East North Central	51,771	37,079	14,692	46,182	5,589
West North Central	128,934	105,916	23,018	65,119	63,815
East South Central	14,229	---	14,229	9,127	5,102
West South Central	24,961	17,652	7,309	19,387	5,574
Mountain	15,096	20,227	2/5,131	9,922	5,174
Pacific	34,371	22,136	12,335	32,441	2,030
United States	328,770	272,174	77,343	272,174	87,284

1/ (19).
2/ Indicates usage over currently available capacity, rather than excess capacity.

hundredweight, respectively. This deficit capacity represents about 16 new mills with capacity of 5,000 cwt. per day: 10 in the North Atlantic Region, 6 in the South Atlantic. All regions except the West North Central and Mountain mill more flour in model B than they did in model A.

The West North Central Region milled 65,000 hundredweight in model B, 40 percent of the 106,000 hundredweight milled in the initial situation (model A). Excess capacity as a percentage of the total available in the region increased from less than a fifth in model A to nearly a half in model B. In terms of 5,000 cwt. per day, mills' excess capacity increased from 13 mills in model A to 37 mills in model B.

The least-cost location of the industry is changed considerably when it is oriented towards the new structure of transportation rates (model B rates for wheat are decreased 20 percent, while those for flour are not). The West North Central Region mills only one-fifth of the Nation's flour--utilizing only half of its share of existing capacity. Producing-area mill locations faced with high-cost flour transportation are now less economically located, except for fulfilling local flour requirements.

In four regions--North Atlantic, South Atlantic, East North Central, and Pacific--the regions' shares of milling exceed their shares of capacity (comparison of capacity used in model B with existing capacity). No incentive for new mills exists in two regions (East North Central and Pacific), however, because capacity already available exceeds that required.

Even though the model B solution indicates a substantial shift in the optimum location of the industry over the longer run, one should not expect the new mills to be put into operation in the near future. For discussion of factors deterring relocation see "Limitations of the Analysis," p. 5.

Wheat and Flour Shipments

Wheat flows from producing areas to either flour mill centers for milling or to ports for export. Thus, the relationship between transportation rates for wheat and flour that affects the spatial pattern of wheat moving to mills also affects the flow of wheat to ports. Consequently, the three separate components of the complete flow pattern associated with one model (wheat to ports, wheat to mills, and flour from mills) are presented as a unit and briefly described.

Model A.--In model A, as in model B, 57 percent of the wheat supply moves to ports for export (table 2). Gulf ports account for over half of all exports and draw wheat from major producing areas, the West North Central and West South Central Regions. About a third of the wheat exports are from West Coast ports, which draw wheat from the nearby Pacific and Mountain Regions. The other two port areas, Atlantic and Great Lakes, draw wheat from nearby producing areas, the North and South Atlantic Regions and the East and West North Central Regions, respectively. In addition, the Atlantic ports draw half of their requirements from the East North Central Region.

Mill centers also tend to draw wheat from nearby producing areas (table 3). The main interregional wheat shipment involves the North Atlantic mills which obtain nearly 95 percent of their requirements from the two North Central Regions--45,000 hundredweight from the East North Central Region, and an additional 8,000 hundredweight from the West North Central Region. Over four-fifths of the Mountain Region's wheat moves to mills outside the region, primarily to the Pacific and West South Central Regions.

Flour shipments are predominantly intraregional (table 4), but they also duplicate interregional wheat shipments. The East North Central Region ships sizable quantities of both wheat and flour to the North Atlantic Region. Other instances of shipping both wheat and flour from the same originating region to the same destination include: the West North Central Region to the East South Central and the Mountain to the Pacific Region. Duplicate interregional shipments of wheat and flour are primarily a result of the relationship between the transportation rates for wheat and flour in model A. Between any two points, the rate for shipping wheat is the same as the rate for shipping flour. Consequently, mills in different regions have the same relative advantage or disadvantage with respect to transportation costs.

Table 2.--Wheat: shipments for export, model A

Region of origin	Total shipments of region	Destination of shipments for export				Total for export	Percentage of total shipments for export
		Atlantic	Great Lakes	Gulf	Pacific		
	1,000 hundredweight						Percent
North Atlantic	17,023	12,990				12,990	76.3
South Atlantic	11,179	8,048				8,048	72.0
East North Central	97,989	21,133	6,090			27,223	27.8
West North Central	277,087		16,978	124,672		141,650	51.1
East South Central	7,514			2,620		2,620	34.9
West South Central	65,913			63,020		63,020	95.6
Mountain	92,046				50,375	50,375	54.7
Pacific	63,862				54,513	54,513	85.4
United States	632,613	42,171	23,068	190,312	104,888	360,439	57.0

Table 3.--Wheat: shipments to mills, model A

Region of origin	Total shipments of region	Destination of shipments to mills								Total to mills	Percentage of total shipments to mills
		North Atlantic	South Atlantic	East North Central	West North Central	East South Central	West South Central	Mountain	Pacific		
	1,000 hundredweight										Percent
North Atlantic	17,023	4,033								4,033	23.7
South Atlantic	11,179		3,131							3,131	28.0
East North Central	97,989	45,180		25,586						70,766	72.2
West North Central	277,087	8,221	3,705	11,493	99,548			12,470		135,437	49.9
East South Central	7,514		4,894							4,894	65.1
West South Central	65,913						2,893			2,893	4.4
Mountain	92,046				6,368		14,759	7,757	12,303	41,187	45.3
Pacific	63,862								9,833	9,833	14.6
United States	632,613	57,434	11,730	37,079	105,916	---	17,652	20,227	22,136	272,174	43.0

Table 4.--Flour: shipments from mills, model A

Region of origin	Total shipments of region	Destination of shipments from mills							
		North Atlantic	South Atlantic	East North Central	West North Central	East South Central	West South Central	Mountain	Pacific
	1,000 hundredweight								
North Atlantic	57,434	57,434							
South Atlantic	11,730		11,730						
East North Central	38,385	10,037	8,656	14,078		5,614			
West North Central	104,610		16,780	36,388	28,851	14,643	7,948		
East South Central	---								
West South Central	17,652						17,652		
Mountain	20,227							9,922	10,305
Pacific	22,136								22,136
United States	272,174	67,471	37,166	50,466	28,851	20,257	25,600	9,922	32,441

Model B.--The flow of wheat to ports in model B is basically unchanged from the model A solution (table 5). The decrease in transportation rates for wheat however does have a significant effect on the patterns of wheat shipments to and flour shipments from mills (tables 6 and 7).

Surplus wheat areas ship wheat to mills in and near major flour markets. Costly flour transportation is eliminated wherever possible. The South Atlantic Region mills 17,000 hundredweight more in model B than in model A. Additional wheat requirements are fulfilled by the East and West North Central Regions (13,000 and 4,000 hundredweight).

Sectoral Valuation of Wheat and Flour

Two sectors of the wheat-flour economy are identified for analysis in this study: the producing (wheat supply) and consuming (export wheat and domestic flour) sectors. The processing sector (flour milling) is not considered in the valuation of wheat and flour in producing areas and markets.

Results pertaining to the valuation of wheat and flour in producing areas and at markets are presented on two price bases. First, results are presented on an export base; that is, on the assumption that the critical factor determining the U.S. price of wheat is export demand. The price of wheat for export at Houston therefore serves as a benchmark for valuing wheat and flour throughout the United States. The second set of results is presented on a flour base--on the assumption that benefits accruing through decreased expenditures for transportation are, in fact, not attained by domestic consumers but rather are transferred by the distribution system to wheat producers or foreign consumers. Setting the average U.S. price of flour in the solution to model B equal to its model A level produces an alternate valuation of wheat and flour in producing areas and markets.

Transportation cost for moving grain and flour to ports, mills, and markets depends on transportation rates and milling location--which depends on the relationship between transportation rates for wheat and flour. The magnitude of the transport cost savings reflected in model B below costs of model A are unaffected by the particular price base selected for valuation. Consequently, discussion of the expenditures for transportation (total transportation costs) precedes the discussion of the impact total transportation costs have on the producing or consuming sectors of the wheat-flour economy.

The model A formulation resulted in a total transportation cost of $438 million (table 8); the comparable total for model B is $362 million.

Decreasing the rates for shipping wheat results in a substantial shift from flour transportation to wheat transportation. The regional pattern of this shift was discussed in an earlier part of this section. Here the shift is viewed in terms of expenditures for transportation. In model A, $123 million was spent to move wheat to mills and $88 million to move flour from mills. Even though wheat transportation is relatively cheaper in model B, expenditures for moving wheat to mills increased 10 percent as costly flour

Table 5.--Wheat: shipments for export, model B

Region of origin	Total shipments of region	Destination of shipments for export				Total for export	Percentage of total shipments for export
		Atlantic	Great Lakes	Gulf	Pacific		
	1,000 hundredweight						Percent
North Atlantic	17,023	12,990				12,990	76.3
South Atlantic	11,179	8,048				8,048	72.0
East North Central	97,989	21,133	5,260			26,393	26.9
West North Central	277,087		17,808	121,779		139,587	50.4
East South Central	7,514			2,620		2,620	34.9
West South Central	65,913			65,913		65,913	100.0
Mountain	92,046				51,634	51,634	56.1
Pacific	63,862				53,254	53,254	83.4
United States	632,613	42,171	23,068	190,312	104,888	360,439	57.0

Table 6.--Wheat: shipments to mills, model B

Region of origin	Total shipments of region	Destination of shipments to mills								Total to mills	Percentage of total shipments to mills
		North Atlantic	South Atlantic	East North Central	West North Central	East South Central	West South Central	Mountain	Pacific		
	1,000 hundredweight										Percent
North Atlantic	17,023	4,033								4,033	23.7
South Atlantic	11,179		3,131							3,131	28.0
East North Central	97,989	36,420	13,173	22,003						71,596	73.1
West North Central	277,087	20,278	8,067	24,179	65,119	9,127	4,810		5,920	137,500	49.6
East South Central	7,514		4,894							4,894	65.1
West South Central	65,913									---	---
Mountain	92,046						14,577	9,922	15,913	40,412	43.9
Pacific	63,862								10,608	10,608	17.6
United States	632,613	60,731	29,265	46,182	65,119	9,127	19,387	9,922	32,441	272,174	43.0

Table 7.--Flour: shipments from mills, model B

Region of origin	Total shipments of region	Destination of shipments from mills							
		North Atlantic	South Atlantic	East North Central	West North Central	East South Central	West South Central	Mountain	Pacific
	1,000 hundredweight								
North Atlantic	60,713	60,731							
South Atlantic	29,265		29,265						
East North Central	46,182	6,740		33,828		5,614			
West North Central	65,119		2,968	16,638	28,851	10,449	6,213		
East South Central	9,127		4,933			4,194			
West South Central	19,387						19,387		
Mountain	9,922							9,922	
Pacific	32,441								32,441
United States	272,174	67,471	37,166	50,466	28,851	20,257	25,600	9,922	32,441

Table 8.--Transportation costs, models A and B

Item	Model A	Model B
	Million dollars	
Total	438	362
Wheat to ports	227	187
Wheat to mills	123	134
Flour from mills	88	41

transportation was eliminated and expenditures decreased to less than half their model A level.

Transportation costs for moving wheat to ports were $187 million in model B--$40 million (18 percent) below the $227 million of model A.

The lower rates for transporting wheat favor market-oriented mills that require less high-cost flour transportation. Expenditures for transporting flour from mills in model B are $41 million--$47 million (55 percent) below the model A level of $88 million. The substantial reduction in relatively high-cost activity (flour transportation) is associated with an increase in the relatively low-cost activity. Consequently, as indicated, expenditures for transporting wheat to mills are $134 million--$11 million (10 percent) above the $123 million level of model A.

Export Base

Basing the model A solution on the price of wheat for export at Houston resulted in a producing-area wheat value of $1,721 million. The value of wheat at ports and flour at markets was $1,228 million and $931 million. Decreased transportation costs in model B ($76 million) raised the value of wheat in producing areas $63 million (3.7 percent) and decreased values of wheat at ports $9 million (0.7 percent) and of flour at market $4 million (0.4 percent) (table 9).

The individual producing areas or market areas do not share equally, either absolutely or proportionately, in the benefits that accrue to the two sectors in the aggregate.

Producing Areas.--In two regions in this analysis the value of wheat in producing areas actually decreased--5 and 8 cents per bushel--in the North and South Atlantic Regions (table 10). The decreases result from decreases in market prices in the two regions that are determined by prices in producing areas that the regions draw from plus transportation costs from the relevant surplus producing regions. In each case, the decrease in transportation cost exceeds the increase in wheat price in the producing area, lowering the market price in both of the deficit regions (North and South Atlantic).

Table 9.--Sectoral valuation, models A and B, export base

Sector	Model A	Model B	Change: Value	Change: Percentage
	Mil. dol.	Mil. dol.	Mil.	Pct.
Producing area value	1,721	1,784	+63	+3.7
Transportation costs	438	362	-76	-17.3
Market area value	2,159	2,146	-13	-0.6
Wheat	1,228	1,219	-9	-0.7
Flour	931	927	-4	-0.4

Table 10.--Wheat: production area valuation, by region, models A and B, export base

Region	Quantity	Model A: Value	Model A: Price per bu.	Model B: Value	Model B: Price per bu.	Change: Value	Change: Price per bu.
	Mil. bu.	Mil. dol.	Dol.	Mil. dol.	Dol.	Mil. dol.	Dol.
North Atlantic	28	63	2.23	62	2.18	-1	-.05
South Atlantic	19	42	2.24	41	2.16	-1	-.08
East North Central	163	307	1.88	308	1.89	+1	+.01
West North Central	462	687	1.49	727	1.57	+40	+.08
East South Central	13	24	1.94	24	1.94	---	---
West South Central	110	183	1.66	190	1.73	+7	+.07
Mountain	153	217	1.42	234	1.52	+17	+.10
Pacific	106	198	1.86	198	1.86	---	---
United States	1,054	1,721	1.63	1,784	1.69	+63	+.06

The price increase in surplus producing areas (8, 7, and 10 cents per bushel in the West North Central, West South Central, and Mountain Regions) results directly from the decrease in transportation rates to Houston to which each of the regions ship in both models.

Market Areas.--In three market areas (North and South Atlantic and Pacific), the value of flour decreases; in two more (East and West South Central) it remains unchanged, while it increases in the remaining three regions (East and West North Central and Mountain) (table 11). The three increases result from the lower transportation charges being more than offset by the increased price of wheat in producing areas. Markets in the North and South Atlantic and Pacific Regions draw wheat or flour from distant surplus areas; thus, the absolute decrease in transportation rates is sufficient to offset increases in producing area wheat prices. In addition, the North and South Atlantic flour requirements are in part filled by lower priced local wheat.

Table 11.--Flour and wheat: market area valuation, by region, models A and B, export base

Commodity and region	Model A	Model B	Change: Value	Change: Percentage
	1,000 dollars	1,000 dollars	1,000 dollars	Percent
Flour:				
North Atlantic	260	254	-6	-2.3
South Atlantic	141	138	-3	-2.2
East North Central	161	163	+2	+1.2
West North Central	78	81	+3	+3.8
East South Central	68	68	--	---
West South Central	82	82	--	---
Mountain	28	30	+2	+7.1
Pacific	113	111	-2	-1.8
United States	931	927	-4	-0.4
Wheat:				
Coastal Areas				
Atlantic	164	158	-6	-3.7
Great Lakes	65	67	+2	+3.1
Gulf	651	648	-3	-0.5
Pacific	348	346	-2	-0.6
United States	1,228	1,219	-9	-0.7

Three (Atlantic, Gulf, and Pacific) of the four coastal areas contribute to the $9 million decrease in the value of wheat at ports. An increase in the value of wheat at Great Lakes ports of $2 million is indicated, however, because the decreased transportation costs failed to offset the increase in the price (and value) of wheat in the West North Central Region, the main source of wheat exported via the Great Lakes ports.

Flour Base

The results discussed in the last section indicated a $4 million (0.4 percent) reduction in the value of flour in market areas. The results in this section are predicated on the notion that no decrease would appear in flour prices, but rather that the average U.S. price of flour would remain unchanged. Model A still represents the initial situation and the regional and sectoral valuation of wheat and flour remains unchanged for the first set of results. The average flour price of the model B solution was set equal to its model A level and the regional and sectoral values recomputed.

The model A problem, solution, and valuation is not affected by changing from an export base to a flour base (the first column of table 12 is same as the first column of table 9). In the model B solution, however, changing to the base of average flour prices of model A resulted in a producing area value of $1,794 million--an increase of $73 million above the model A level. The $73 million increase is $10 million more than the corresponding increase in the first set of results (export base).

Table 12.--Sectoral valuation, models A and B, flour base

Sector	Model A	Model B	Change: Value	Change: Percentage
	Mil. dol.	Mil. dol.	Mil.	Pct.
Producing area value	1,721	1,794	+73	+4.2
Transportation costs	438	362	-76	-17.3
Market area value	2,159	2,156	-3	-0.1
Wheat	1,228	1,225	-3	-0.2
Flour	931	931	0	0

The value of wheat at ports decreased $3 million--$6 million less than the $9 million decrease in the first set of results (export base). The aggregate value of flour in market areas was unchanged, being set equal to its previous level for use as a benchmark.

Changing from an export to a flour base also affected the regional composition of wheat and flour values.

Producing Areas.--Wheat values (and prices) in producing areas increased more (decreased less in the North and South Atlantic Regions) when flour values instead of exports were used as a benchmark to evaluate the impact of decreased transportation costs (table 13). The changes were uniform--1 cent per bushel in each region.

Table 13.--Wheat: production area valuation, by region, models A and B, flour base

Region	Quantity	Model A Value	Model A Price per bu.	Model B Value	Model B Price per bu.	Change Value	Change Price per bu.
	Mil. bu.	Mil. dol.	Dol.	Mil. dol.	Dol.	Mil. dol.	Dol.
North Atlantic	28	63	2.23	62	2.19	-1	-.04
South Atlantic	19	42	2.24	40	2.17	-2	-.07
East North Central	163	307	1.88	310	1.90	+3	+.02
West North Central	462	687	1.49	731	1.58	+44	+.09
East South Central	13	24	1.94	24	1.95	---	+.01
West South Central	110	183	1.66	191	1.74	+8	+.08
Mountain	153	217	1.42	235	1.53	+18	+.11
Pacific	106	198	1.86	201	1.87	+3	+.01
United States	1,054	1,721	1.63	1,794	1.70	+73	+.07

Market Areas.--Using flour value as a benchmark somewhat nullifies the impact of decreased transportation costs on regional flour values (changes for flour in table 14 are equal to or less than corresponding changes in table 11). Decreases in major flour markets (North and South Atlantic and Pacific Regions) are still evident, however, as are increases in surplus wheat producing areas.

Using flour value as a benchmark leaves the value of wheat at two major coastal areas (Gulf and Pacific) unchanged when wheat transportation rates were lowered (table 14). The $2 million increase in value at Great Lakes ports is still indicated, but more than offset by the $5 million decline at Atlantic ports.

Table 14.--Flour and wheat: market area valuation, by region, models A and B, flour base

Commodity and region	Model A	Model B	Change	
			Value	Percentage
	1,000 dollars			Percent
Flour:				
North Atlantic	260	256	-4	-1.5
South Atlantic	142	139	-3	-2.1
East North Central	161	163	+2	+1.2
West North Central	78	81	+3	+3.8
East South Central	68	69	+1	+1.5
West South Central	82	82	--	---
Mountain	28	30	+2	+7.1
Pacific	112	111	-1	-0.9
United States	931	931	--	---
Wheat:				
Coastal Areas				
Atlantic	164	159	-5	-3.0
Great Lakes	65	67	+2	+3.1
Gulf	651	651	--	---
Pacific	348	348	--	---
United States	1,228	1,225	-3	-0.2

CONCLUSIONS

Generally, the foregoing analysis is based on the assumption that railroads will continue to price services for transporting wheat below those for transporting flour, so that they can compete with barges and trucks for the wheat traffic. The appearance and continued existence of a differential between transportation rates for wheat and flour will have a variety of long-lasting ramifications for different sectors and regions of the wheat-flour economy.

The results of the analysis support two main conclusions:

(1) The structure of transportation rates (relationship between the transportation rates for wheat and flour) influences the regional location (orientation) of the flour milling industry, and consequently the geographical pattern of wheat and flour shipments, and

(2) the general level of transportation rates influences the value of wheat in producing areas and ports and the value of flour in market areas.

Transportation rates for wheat that are below the corresponding rates for flour will cause the economic location of the milling industry to shift towards major population centers (flour markets). A complete relocation will be conditioned by the limited opportunity for millfeed disposal in urban areas and delayed by the continued operation of existing capacity in nonoptimum locations. Mills may relocate in intermediate locations adjacent to population centers where they can gain most of the benefits of the lower wheat rates and yet avoid backhauling of millfeed.

Savings in transportation costs will be shared by the producing and consuming sectors of the wheat-flour economy. Regional participation in the benefits accruing to the producing and consuming sectors will not be uniform. Valuing the wheat and flour alternately on an export and flour basis, however, did not affect the relative regional participation in transportation savings. Changing from an export to a flour base affected the absolute but not the relative distribution of benefits among producers and consumers in different regions. Generally, decreasing transportation costs in this analysis produced the following impacts on producers and consumers in different regions: producers in surplus areas receive more for their wheat because of the lower transportation charges it incurs. Consumers in wheat surplus areas pay more for flour because it is made from higher priced wheat. Consumers in wheat deficit areas pay less for flour because of lower transportation costs involved in moving needed supplies from surplus areas. Producers in deficit areas receive less for their wheat because its value is based on the lower price in the market area resulting from the decreased cost of obtaining wheat from surplus areas.

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1. Model A

In the formulation of model A (fig. 5), the wheat supplies are:

Rows 1 and 5, column 1	Grand Forks, N. Dak.	20 units
Rows 2 and 6, column 2	Minot, N. Dak.	20 "
Rows 3 and 7, column 3	Hutchinson, Kans.	20 "
Rows 4 and 8, column 4	Leoti, Kans.	20 "

$$\sum_{i=1}^{4} a_i = \sum_{i=5}^{8} a_i = \sum_{j=1}^{4} b_j \qquad = \qquad 80 \text{ units}$$

ILLUSTRATIVE EXAMPLE, MODEL A

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	0			A				45	23 B						20
2		0						55	33						20
3			0					44	52						20
4				0				54	62						20
5	0			C	20	31	84 D								20
6		0			30	41	94								20
7			0		29	17	86								20
8				0	39	27	96								20
9					0		E			0	11	21	27	107 F	50
10						0				12	0	12	32	112	50
11							0			66	71	59	39	41	50
	20	20	20	20	50	50	50	20	10	5	5	5	10	25	310

Figure 5

Capacities of milling centers are:

Row 9, column 5	Minneapolis, Minn.	50 units
Row 10, column 6	Kansas City, Mo.	50 "
Row 11, column 7	Buffalo, N.Y.	50 "

$$\sum_{i=9}^{11} a_i = \sum_{j=5}^{7} b_j = 150 \text{ units}$$

Export requirements are:

Column 8	New Orleans, La.	20 units
Column 9	Duluth, Minn.	10 "

$$\sum_{j=8}^{9} b_j = 30 \text{ units}$$

Flour requirements are:

Column 10	Minneapolis, Minn.	5 units
Column 11	Kansas City, Mo.	5 "
Column 12	St. Louis, Mo.	5 "
Column 13	Chicago, Ill.	10 "
Column 14	New York, N.Y.	25 "

$$\sum_{j=10}^{14} b_j = 50 \text{ units}$$

Transportation costs are the c_{ij} shown in figure 5. In model A, milling capacity ($\sum_{i=9}^{11} a_i = \sum_{j=5}^{7} b_j = 150$) exceeds flour requirements ($\sum_{j=10}^{14} b_j = 50$). Furthermore, supply ($\sum_{i=1}^{4} a_i = 80$) equals export requirements ($\sum_{j=8}^{9} b_j = 30$) plus flour requirements ($\sum_{j=10}^{14} b_j = 50$). Since all milling conceivably could occur at one center, the capacity of each mill center in model A is set equal to total flour requirements (fig. 5). Thus, in model A, $a_9 = a_{10} = a_{11} = b_5 = b_6 = b_7 = 50$. Total milling capacity in model A is 150 units or 100 units more than that required. Thus, a solution to model A will have entries in submatrix E that total 100.

A solution to model A is given in figure 6. Ten units of North Dakota wheat go to Duluth for export, 15 to Minneapolis for milling and the remaining 15 to Buffalo for milling. Flour milled at Minneapolis fills flour requirements at Minneapolis (5 units) and Chicago (10 units). The 25 units of flour milled at Buffalo fill the New York requirement. Twenty units of Kansas wheat go to New Orleans for export, 10 to Kansas City for milling, and the remaining 10 to Buffalo for milling. Kansas City milled flour fills requirements at Kansas City (5 units) and St. Louis (5 units). The 10 units of Kansas wheat milled at Buffalo fulfill the remaining New York requirement. The 100 units of excess milling capacity are divided between Minneapolis ($X_{9,5}$ = 35 units), Kansas City ($X_{10,6}$ = 40 units), and Buffalo ($X_{11,7}$ = 25 units).

A SOLUTION TO ILLUSTRATIVE EXAMPLE, MODEL A

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	15			A					5 B						20
2		15							5						20
3			10					10							20
4				10				10							20
5	5			C			15 D								20
6		5			15										20
7			10				10								20
8				10		10									20
9					35		E			5			10	F	50
10						40					5	5			50
11							25							25	50
	20	20	20	20	50	50	50	20	10	5	5	5	10	25	310

Figure 6

With respect to the dual problem, the i,j pairs in the solution are:

$u_1 - v_1 = 0$	$u_7 - v_3 = 0$
$u_1 - v_9 = 23$	$u_7 - v_7 = 36$
$u_2 - v_2 = 0$	$u_8 - v_4 = 0$
$u_2 - v_9 = 33$	$u_8 - v_6 = 27$
$u_3 - v_3 = 0$	$u_9 - v_5 = 0$
$u_3 - v_8 = 44$	$u_9 - v_{10} = 0$
$u_4 - v_4 = 0$	$u_9 - v_{13} = 27$
$u_4 - v_8 = 54$	$u_{10} - v_6 = 0$
$u_5 - v_1 = 0$	$u_{10} - v_{11} = 0$
$u_5 - v_7 = 84$	$u_{10} - v_{12} = 12$
$u_6 - v_2 = 0$	$u_{11} - v_7 = 0$
$u_6 - v_5 = 30$	$u_{11} - v_{14} = 41$

Setting v_8 = 2.00 (price at New Orleans at $2 per unit) gives the following values for the other dual variables:

$u_1 = 1.58$	$v_1 = 1.58$
$u_2 = 1.48$	$v_2 = 1.48$
$u_3 = 1.56$	$v_3 = 1.56$
$u_4 = 1.46$	$v_4 = 1.46$
$u_5 = 1.58$	$v_5 = 1.78$
$u_6 = 1.48$	$v_6 = 1.73$
$u_7 = 1.56$	$v_7 = 2.42$
$u_8 = 1.46$	$v_8 = 2.00$
$u_9 = 1.78$	$v_9 = 1.81$
$u_{10} = 1.73$	$v_{10} = 1.78$
$u_{11} = 2.42$	$v_{11} = 1.73$
	$v_{12} = 1.85$
	$v_{13} = 2.05$
	$v_{14} = 2.83$

The value of wheat in producing areas is \$121.60. Transportation costs are \$54.55. Consequently, the value in market areas is \$176.15. The value of flour in 5 market areas accounts for \$118.05 of the \$176.15, and the value of wheat at ports for the remaining \$58.10. In solving a single problem of this type, values in the various sectors are unaffected by the choice of price base. However, the meaningful comparison of values obtained from two or more problems requires that the same price base be used in all problems.

2. Model B

Model B is identical to model A, except that wheat transportation rates are 20 percent lower than in model A. All c_{ij} elements in submatrices B and D are reduced to 80 percent of their model A level. Milling capacity is not constrained. The complete formulation is given in figure 7.

A solution is given in figure 8. The shipment pattern is substantially unaffected by the decrease in transportation charges for wheat. Total transportation costs in model A were \$54.55. In model B they are \$46.30, a decrease of \$8.25.

In the dual system the values of other dual variables are (v_8 = \$2.00):

u_1 = \$1.67	v_1 = \$1.67
u_2 = 1.59	v_2 = 1.59
u_3 = 1.64	v_3 = 1.64
u_4 = 1.57	v_4 = 1.57
u_5 = 1.67	v_5 = 1.83
u_6 = 1.59	v_6 = 1.79
u_7 = 1.65	v_7 = 2.34
u_8 = 1.57	v_8 = 2.00
u_9 = 1.83	v_9 = 1.85
u_{10} = 1.79	v_{10} = 1.83
u_{11} = 2.34	v_{11} = 1.79
	v_{12} = 1.91
	v_{13} = 2.10
	v_{14} = 2.75

ILLUSTRATIVE EXAMPLE, MODEL B

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	0			A				36	18						20
2		0						45	26						20
3			0					36	42						20
4				0				43	50						20
5	0			C	16	25	67 D								20
6		0			24	33	75								20
7			0		23	14	69								20
8				0	31	22	77								20
9					0		E			0	11	21	27	107 F	50
10						0				12	0	12	32	112	50
11							0			66	71	59	39	41	50
	20	20	20	20	50	50	50	20	10	5	5	5	10	25	310

Figure 7

A SOLUTION TO ILLUSTRATIVE EXAMPLE, MODEL B

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	15			A					5 B						20
2		15							5						20
3			20												20
4				0				20							20
5	5			C			15 D								20
6		5			15										20
7						10	10								20
8				20											20
9					35		E			5			10	F	50
10						40					5	5			50
11							25							25	50
	20	20	20	20	50	50	50	20	10	5	5	5	10	25	310

Figure 8

Applying the relevant model B prices to available supplies, the value in producing areas is:

Grand Forks, N. Dak.	20 units	@ 1.67	=	$33.40
Minot, N. Dak.	20 "	@ 1.59	=	31.80
Hutchinson, Kans.	20 "	@ 1.65	=	33.00
Leoti, Kans.	20 "	@ 1.57	=	31.40
				129.60

The value in market areas is:

Export					
New Orleans, La.	20 units	@ 2.00	=	$40.00	
Duluth, Minn.	10 "	@ 1.85	=	18.50	
					58.50
Flour					
Minneapolis, Minn.	5 units	@ 1.83	=	$9.15	
Kansas City, Mo.	5 "	@ 1.79	=	8.95	
St. Louis, Mo.	5 "	@ 1.91	=	9.55	
Chicago, Ill.	10 "	@ 2.10	=	21.00	
New York, N.Y.	25 "	@ 2.75	=	68.75	
					117.40
					175.90

The value in producing areas is $129.60, $8.00 above model A. The value in market areas, however, is $175.90, or $.25 below the model A level of $176.15.

In conclusion, these examples demonstrate that the 20-percent reduction in wheat rates affects both the location of milling (and the associated shipping patterns of wheat and flour) and the value of wheat and flour in producing and market areas. By assuming other models of price determination (this illustration assumes U.S. price level is determined by world prices for wheat as reflected at the port of Houston), different distributions of wheat and flour values would be shown, but these do not alter the transportation cost and shipping pattern comparisons.

Appendix table 1.--Regional supply of wheat (1951-60 average)

	Region	(1,000 cwt.)		Region	(1,000 cwt.)
1	Rochester, N.Y.	4,314	37	Parsons, Kans.	7,971
2	Lancaster, Pa.	12,709	38	Emporia, Kans.	14,449
3	Rocky Mount, N.C.	8,048	39	Mankato, Kans.	14,777
4	Augusta, Ga.	3,131	40	Salina, Kans.	8,771
5	Greenville, Miss.	2,620	41	Hutchinson, Kans.	24,092
6	Clarksville, Tenn.	4,894	42	Colby, Kans.	12,394
7	Findlay, Ohio	28,144	43	Larned, Kans.	19,261
8	Jasper, Ind.	4,630	44	Downs, Kans.	10,217
9	Logansport, Ind.	17,036	45	Leoti, Kans.	4,622
10	Battle Creek, Mich.	19,908	46	Meade, Kans.	10,484
11	Watertown, Wis.	1,033	47	Guthrie, Okla.	7,510
12	Corning, Iowa	1,406	48	Enid, Okla.	16,347
13	Granite Falls, Minn.	3,946	49	Hooker, Okla.	12,095
14	Decatur, Ill.	8,361	50	Altus, Okla.	7,777
15	Centralia, Ill.	18,877	51	Amarillo, Tex.	12,575
16	Cape Girardeau, Mo.	4,804	52	Sweetwater, Tex.	5,566
17	Lamar, Mo.	5,260	53	Corsicana, Tex.	4,043
18	Macon, Mo.	8,213	54	Havre, Mont.	12,527
19	Crookston, Minn.	6,177	55	Wolf Point, Mont.	20,044
20	Grand Forks, N. Dak.	4,508	56	Great Falls, Mont.	6,789
21	Minot, N. Dak.	2,378	57	Billings, Mont.	6,373
22	Devils Lake, N. Dak.	3,377	58	Torrington, Wyo.	3,306
23	Jamestown, N. Dak.	4,753	59	Sterling, Colo.	6,368
24	Tioga, N. Dak.	7,385	60	Limon, Colo.	14,172
25	Dickinson, N. Dak.	8,922	61	La Junta, Colo.	3,475
26	Bismarck, N. Dak.	4,080	62	Tucumcari, N. Mex.	587
27	Wyndmere, N. Dak.	3,705	63	Pocatello, Idaho	9,483
28	Lemmon, S. Dak.	5,297	64	Plummer, Idaho	5,671
29	Redfield, S. Dak.	9,612	65	Ogden, Utah	2,767
30	Milbank, S. Dak.	2,025	66	Pendleton, Oreg.	22,229
31	Mitchell, S. Dak.	3,557	67	Colfax, Wash.	13,995
32	Sidney, Nebr.	13,940	68	Lind, Wash.	17,030
33	Lincoln, Nebr.	17,017	69	Prosser, Wash.	3,839
34	McCook, Nebr.	17,943	70	Stockton, Calif.	6,769
35	Atchinson, Kans.	5,277	71	Picacho, Ariz.	484
36	Garnett, Kans.	6,467			

Source: Appendix table 2.

Appendix table 2.--Regional supply of wheat, 1951-60 average

Region		Area included	Production
			1,000 bu.
1	Rochester, N.Y.	1	7,190
2	Lancaster, Pa.	2-3-4	21,182
3	Rocky Mount, N.C.	5-6-7-8-9-13	13,414
4	Augusta, Ga.	10-11-12-14-15 16-17-18-19-20 122-123-124	5,218
5	Greenville, Miss.	21-24-25-125-126 127-128-129-130 131-144	4,367
6	Clarksville, Tenn.	22-23-27-28-29-35	8,157
7	Findlay, Ohio	30-31-32-33	46,907
8	Jasper, Ind.	34-37	7,716
9	Logansport, Ind.	38-39	28,393
10	Battle Creek, Mich.	40-41	33,180
11	Watertown, Wis.	42-43-44-59	1,721
12	Corning, Iowa	46-54-55-57	2,344
13	Granite Falls, Minn.	56-58-60-61	6,576
14	Decatur, Ill.	45-47	13,935
15	Centralia, Ill.	36-48-49-53	31,462
16	Cape Girardeau, Mo.	26-50	8,006
17	Lamar, Mo.	51	8,767
18	Macon, Mo.	52	13,688
19	Crookston, Minn.	62-63	12,869
20	Grand Forks, N. Dak.	64	18,784
21	Minot, N. Dak.	1/65-A	9,909
22	Devils Lake, N. Dak.	1/65-B	14,069
23	Jamestown, N. Dak.	1/65-C	12,188
24	Tioga, N. Dak.	66	17,583
25	Dickinson, N. Dak.	2/67-A	18,588
26	Bismarck, N. Dak.	2/67-B	7,556
27	Wyndmere, N. Dak.	68	8,233
28	Lemon, S. Dak.	69	8,829

Region		Area included	Production
			1,000 bu.
29	Redfield, S. Dak.	70	16,020
30	Milbank, S. Dak.	71	4,219
31	Mitchell, S. Dak.	72-73	5,928
32	Sidney, Nebr.	75-76	23,234
33	Lincoln, Nebr.	74-80	28,361
34	McCook, Nebr.	78-79	29,905
35	Atchinson, Kans.	81	8,795
36	Garnett, Kans.	82	10,779
37	Parsons, Kans.	83	13,285
38	Emporia, Kans.	84	24,082
39	Mankato, Kans.	85	24,629
40	Salina, Kans.	86	14,618
41	Hutchinson, Kans.	87	40,153
42	Colby, Kans.	3/88-A	20,656
43	Larned, Kans.	3/88-B	32,101
44	Downs, Kans.	3/88-C	17,028
45	Leoti, Kans.	4/89-A	7,704
46	Meade, Kans.	4/89-B	17,474
47	Guthrie, Okla.	90-93-134-135	12,517
48	Enid, Okla.	91	27,245
49	Hooker, Okla.	92	20,159
50	Altus, Okla.	94	12,962
51	Amarillo, Tex.	95	20,958
52	Sweetwater, Tex.	96-97	9,277
53	Corsicana, Tex.	98-99-100-101 102-103-132 133-136-137 138-139-140	6,738
54	Havre, Mont.	5/104-A	20,879
55	Wolf Point, Mont.	5/104-B	37,119
56	Great Falls, Mont.	105	11,315

See footnotes at end of table.

Continued

Appendix table 2.--Regional supply of wheat, 1951-60 average--Continued

Region	Area included	Production	Region	Area included	Production
		1,000 bu.			1,000 bu.
57 Billings, Mont.	106-107	10,622	65 Ogden, Utah	114	4,611
58 Torrington, Wyo.	108	5,510	66 Pendleton, Oreg.	116	37,048
59 Sterling, Colo.	77	10,613	67 Colfax, Wash.	117	23,325
60 Limon, Colo.	109	23,620	68 Lind, Wash.	118	28,384
61 La Junta, Colo.	110-111	5,791	69 Prosser, Wash.	119	6,398
62 Tucumcari, N. Mex.	112-141	978	70 Stockton, Calif.	120-121-143	11,281
63 Pocatello, Idaho	113	15,805	71 Picacho, Ariz.	142	806
64 Plummer, Idaho	115	9,452			

1/ Area 65 divided into 3 regions as follows:
A. Bottineau, McHenry, Renville, Ward
B. Benson, Cavalier, Nelson, Pierce, Ramson, Rolette, Towner
C. Barnes, Eddy, Foster, Griggs, La Moure, Steele, Stutsman, Wells.

2/ Area 67 divided into 2 regions as follows:
A. Adams, Billings, Bowman, Dunn, Golden Valley, Grant, Hettinger, McKenzie, Mercer, Morton, Oliver, Sioux, Slope, Stark
B. Burleigh, Emmons, Kidder, Logan, McIntosh, Sheridan.

3/ Area 88 divided into 3 regions as follows:
A. Cheyenne, Decatur, Gove, Graham, Rawlins, Sheridan, Sherman, Thomas, Trego
B. Barton, Edwards, Finney, Hodgeman, Kiowa, Lane, Ness, Pawnee, Pratt, Rush, Stafford
C. Ellis, Ellsworth, Lincoln, Mitchell, Osborne, Rooks, Russell.

4/ Area 89 divided into 2 areas as follows:
A. Greeley, Hamilton, Kearny, Logan, Scott, Wallace, Wichita
B. Barber, Clark, Comanche, Ford, Grant, Gray, Haskell, Meade, Morton, Seward, Stanton, Stevens.

5/ Area 104 divided into 2 areas as follows:
A. Blaine, Hill, Liberty, Phillips, Toole
B. Daniels, Dawson, Fallon, McCone, Prairie, Richland, Roosevelt, Sheridan, Valley, Wibaux.

Source: Reproduced from (29).

Appendix table 3.--Export requirements by port (1,000 hundredweight)

Atlantic	42,171	
New York, N. Y.		12,990
Baltimore, Md.		16,741
Norfolk, Va.		12,440
Great Lakes	23,068	
Toledo, Ohio		5,260
Chicago, Ill.		830
Duluth, Minn.-Superior, Wis.		16,978
Gulf	190,312	
New Orleans, La.		58,616
Houston, Tex.		131,696
Pacific	104,888	
San Francisco, Calif.		1,259
Portland, Oreg.		103,629
	360,439	

Source: (25 and 27)

Appendix table 4.--Regional disposition of flour, 1960

Area	Market	Hundred-weight	Area	Market	Hundred-weight
		(wheat equiv.) 1/			(wheat equiv.) 1/
1	Boston	15,871	30	St. Louis	6,190
2	New York	24,311	31	Minneapolis	7,115
3	Syracuse	3,637	32	Des Moines	2,419
4	Buffalo	5,258	33	Omaha	2,915
5	Philadelphia	11,654	34	Kansas City	3,810
6	Pittsburgh	6,740	35	Fargo	954
7	Baltimore	7,240	36	Sioux Falls	1,028
8	Richmond	4,517	37	Wichita	2,147
9	Charleston	2,968	38	Little Rock	2,697
10	Raleigh	5,998	39	New Orleans	4,919
11	Knoxville	4,194	40	Oklahoma City	3,516
12	Louisville	3,457	41	Dallas	7,409
13	Nashville	2,157	42	Houston	3,371
14	Memphis	1,636	43	San Antonio	3,688
15	Columbia	3,599	44	Great Falls	1,019
16	Atlanta	4,933	45	Cheyenne	499
17	Jacksonville	2,407	46	Denver	2,649
18	Orlando	2,773	47	Albuquerque	1,436
19	Miami	2,731	48	Boise	1,007
20	Birmingham	3,768	49	Salt Lake City	1,346
21	Mobile	2,229	50	Phoenix	1,966
22	Jackson	2,816	51	Spokane	1,228
23	Cleveland	8,252	52	Seattle	2,697
24	Cincinnati	7,769	53	Portland	3,055
25	Detroit	11,351	54	San Francisco	9,902
26	Indianapolis	4,583	55	Los Angeles	14,264
27	Milwaukee	4,286	56	Anchorage	341
28	Chicago	14,225	57	Honolulu	954
29	Davenport	2,273			

1/ Per capita flour consumption of 116 pounds.

Source: Appendix table 5.

Appendix table 5.--Population, by market, 1960

	Market	Area included 1/	Population (000)
1	Boston	Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island	10,509
2	New York	New York (9,G), New Jersey (1,B,C,G,H)	16,098
3	Syracuse	New York (4,5,6,7,8,C,D,F)	2,408
4	Buffalo	New York (A,B,E,1,2,3), Pennsylvania (A,2)	3,482
5	Philadelphia	Pennsylvania (B,C,G,H,J,K,L,M,6,7) New Jersey (A,D,E,F,2)	7,717
6	Pittsburgh	Pennsylvania (1,3,4,5,D,E,F)	4,463
7	Baltimore	Maryland (2,3,4,A,B,C), Delaware Virginia (B,9), District of Columbia (A)	4,794
8	Richmond	Virginia (A,C,D,E,F,3,4,5,6,7,8,10)	2,991
9	Charleston	West Virginia, Maryland (1)	1,965
10	Raleigh	North Carolina (B,C,D,E,F,3,4,5,6,7, 8,9,10,11)	3,972
11	Knoxville	North Carolina (A,1,2), Virginia (1,2) Kentucky (9), Tennessee (7,8,C,D)	2,777
12	Louisville	Kentucky (1,2,3,6,7,8,A,B,C,D,E)	2,289
13	Nashville	Kentucky (4,5), Tennessee (3,4,5,6,B)	1,428
14	Memphis	Tennessee (A,1,2)	1,083
15	Columbia	South Carolina	2,383
16	Atlanta	Georgia (A,B,C,D,F,G,1,2,3,4,5,6,7)	3,266
17	Jacksonville	Georgia (8,9,E), Florida (2,3,A)	1,594
18	Orlando	Florida (4,5,B,E)	1,836
19	Miami	Florida (6,C,F,G)	1,808

See footnotes at end of table.

Continued

Appendix table 5.--Population, by market, 1960--Continued

	Market	Area included 1/	Population (000)
20	Birmingham	Alabama (A,B,C,E,F,1,2,3,4,5,6)	2,495
21	Mobile	Alabama (7,8,9,D), Florida (D,1), Mississippi (7,8)	1,476
22	Jackson	Mississippi (1,2,3,4,5,6,A)	1,865
23	Cleveland	Ohio (A,E,F,G,H,M,O,1,2,4,5)	5,464
24	Cincinnati	Ohio (B,C,D,J,K,L,3,6,7,8)	4,242
25	Detroit	Michigan (A,B,C,D,E,F,G,H,J,3,4,5,6,7,8,9)	7,516
26	Indianapolis	Indiana (D,E,F,G,H,4,5,6,7,8,9)	3,035
27	Milwaukee	Wisconsin (6,7,8,B,C,D,E,F)	2,838
28	Chicago	Illinois (B,C,D,G,2,5,6), Indiana (1,2, 3,A,B,C)	9,419
29	Davenport	Illinois (A,1,3), Wisconsin (3), Iowa (6,D,F)	1,505
30	St. Louis	Illinois (4,7,8,9,10,11,E,F), Missouri (2,6,8,9,B)	4,099
31	Minneapolis	Minnesota, Wisconsin (A,1,2,4,5), Michigan (1,2)	4,711
32	Des Moines	Iowa (2,3,4,5,C,E)	1,602
33	Omaha	Iowa (1,A,B), Nebraska	1,930
34	Kansas City	Missouri (1,3,4,5,7,A,C), Kansas (6, 7,B,C)	2,523
35	Fargo	North Dakota	632
36	Sioux Falls	South Dakota	681
37	Wichita	Kansas (1,2,3,4,5,8,A)	1,422
38	Little Rock	Arkansas	1,786

See footnotes at end of table. Continued

Appendix table 5.--Population, by market, 1960--Continued

	Market	Area included 1/	Population (000)
39	New Orleans	Louisiana	3,257
40	Oklahoma City	Oklahoma	2,328
41	Dallas	Texas (4,5,6,8,9,B,C,D,E,J,K,L,O,P)	4,906
42	Houston	Texas (13,14,G,H,M)	2,232
43	San Antonio	Texas (A,F,N,1,2,3,10,11,15,16)	2,442
44	Great Falls	Montana	675
45	Cheyenne	Wyoming	330
46	Denver	Colorado	1,754
47	Albuquerque	New Mexico	951
48	Boise	Idaho	667
49	Salt Lake City	Utah	891
50	Phoenix	Arizona	1,302
51	Spokane	Washington (5,6,7,8,D)	813
52	Seattle	Washington (1,2,3,A,B,E)	1,786
53	Portland	Oregon, Washington (4,C)	2,023
54	San Francisco	California (1,2,3,4,5,6,9,A,B,C,D,E), Nevada (1)	6,557
55	Los Angeles	California (7,8,F,G,H,J,K), Nevada (A)	9,445
56	Anchorage	Alaska	226
57	Honolulu	Hawaii	632

1/ Reference is to State if State economic area is not specified.

Source: U.S. Bureau of the Census. Current Population Reports, Series P-23, No. 7, Components of Population Change, 1950 to 1960, for Counties, Standard Metropolitan Statistical Areas, State Economic Areas, and Economic Subregions. November 1962.

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