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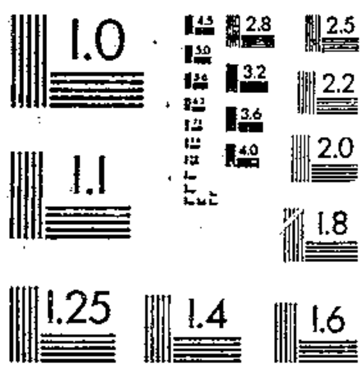

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Economic Research Service

Technical Bulletin Number 1701

A Flexible Rail Rate Policy

Impacts on U.S. Feed Grains

Linwood Hoffman
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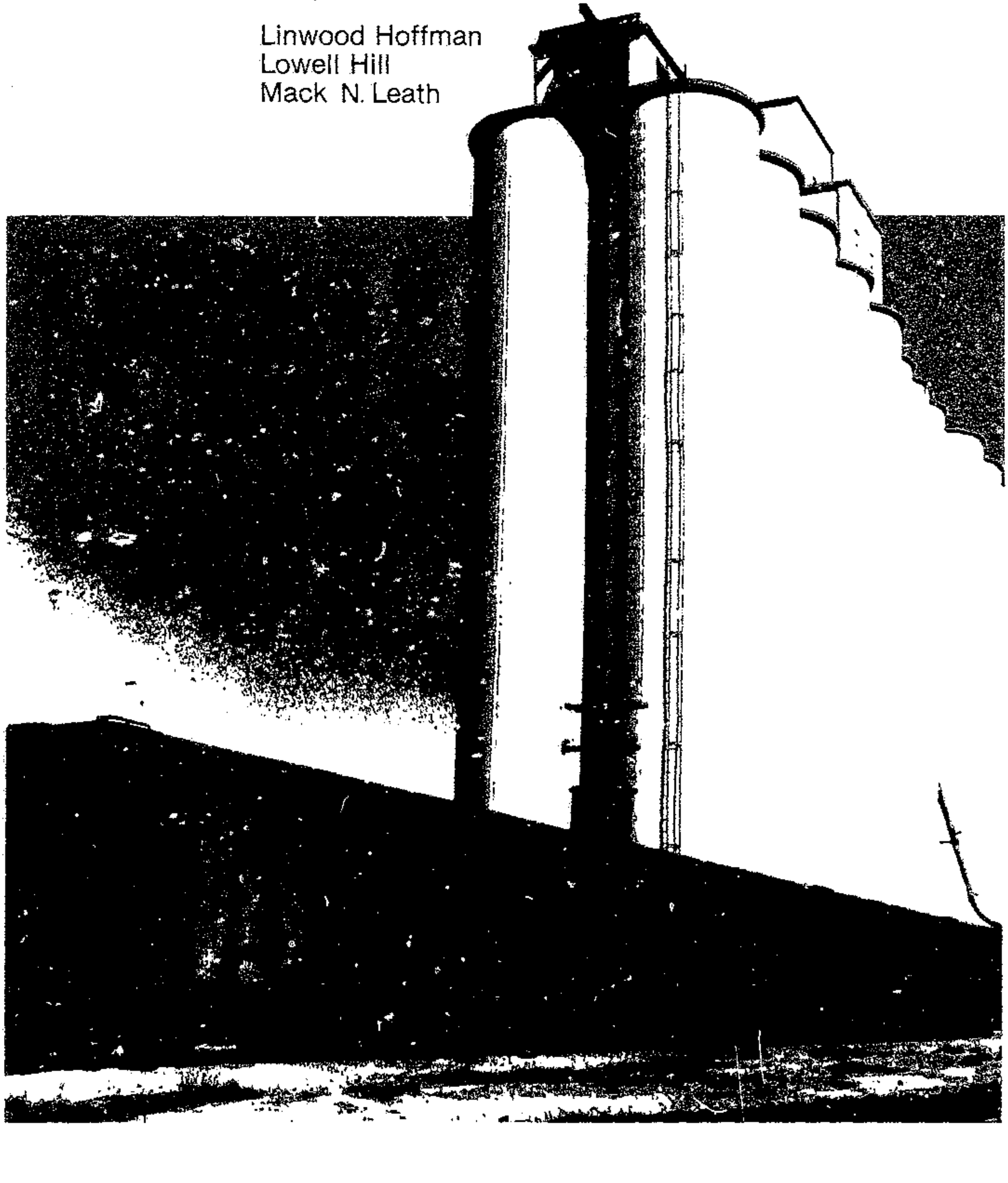
Mack N. Leath



A Flexible Rail Rate Policy: Impacts on U.S. Feed Grains, by Linwood Hoffman, Lowell Hill, and Mack N. Leath. National Economics Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1701.

Abstract

U.S. feed grains could be transported more efficiently by railroads through implementation of a combined peak and off-peak rail rate structure. This study assumes this policy had been in effect during a representative crop year and determines that a 5- to 15-percent change in rail rates would increase rail revenues and volume, reduce seasonal variation of rail demand, and create incentives for producers to store feed grain at country locations and ship at a later date. However, increased costs for storage, transportation, and handling would weaken the overall financial stability of the feed grain market.

Keywords: Feed grains, rail transportation, transportation rates, transportation deregulation, flexible railroad rates, feed grain storage, storage rates.

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Washington, D.C. 20250 April 1985

Contents

Summary

A combined peak and off-peak rail rate policy would result in a more efficient use of U.S. railroads while transporting feed grains, according to this study of flexible rail rates. The study, using a linear programming, time-staged, modified transshipment model, determines what might have happened if flexible rail rates had been in effect during a representative crop year.

Regardless of the rate response scenario examined, a change in railroad rates of 5 to 15 percent increased rail revenue and volume, reduced the seasonality of rail demand, and created incentives to store at country locations and ship at a later date.

However, the overall financial stability of the feed grain market was adversely affected; and total costs of storage, transportation, and handling generally increased. Since total costs increased, prices received by farmers would tend to decline. Regional effects varied as prices received by farmers rose in some feed grain deficit production regions but declined in some surplus regions.

With a flexible rail rate policy, the railroad industry could improve its revenue and lower its costs through improved car utilization (fewer cars needed, lower labor costs). Rail's market share generally increased by two percentage points while truck and barge each lost a percentage point.

An equal percentage rate response by truck and barge would seem most likely because their revenue would generally be greater and thus shipment seasonality would be less than without a rail response.

Higher rates during the peak demand period provide incentives for larger feed grain stocks to be located at the country points during the peak rail demand periods. Sufficient capacity existed to accommodate this added demand. During the slack rail demand periods, inventory levels increased at the domestic and export demand points with the greater increase at the domestic demand points. Feed grain inventories were greater at each location when rates for all transport modes were changed, in contrast to a change in rail rates only.

With a change in rail rates only, the deficit feed grain regions experienced most of the increase in stocks at the domestic demand points during the slack demand periods. However, with an equal percentage rate response by trucks and barges, stocks were greater than the scenario with only a change in rail rates, but most of the increase was located within surplus demand areas.

The longrun demand for new storage capacity increased slightly in the deficit regions as rail rates were progressively changed. However, a simulated 25- to 30-percent change in rates was required before significant increases in capacity expansion occurred, regardless of rate response scenario.

Prices received by deficit region producers tended to rise as rate changes were increased. However, within the surplus areas, simulated prices generally declined, but rose slightly for those producers located close to markets and accessible to competitive modes of transport.

A change in only rail rates increased total costs slightly, but a change in rates by all modes led to a larger rise in costs. Regardless of rate response scenario, the rise in total costs occurred mostly in surplus feed grain areas rather than deficit areas. The transportation and storage components were mostly responsible for the rise in cost. Total costs of transportation, handling, and storage increased an estimated $19 million or 1 percent with a 10-percent change in only rail rates, but declined by $6.7 million with a 30-percent change. In contrast, a rate response by all modes caused total costs to increase by 3 to 5 percent ($37 to $68 million) for 10- through 30-percent changes in rates, respectively.

A Flexible Rail Rate Policy

Impacts on U.S. Feed Grains

Linwood Hoffman, Lowell Hill, and Mack N. Leath

Introduction

U.S. transportation policy is changing in the 1980's due to greater flexibility and reduced regulation of rates. These changes were initiated by several pieces of legislation passed by Congress in the past decade. The two most important of these legislative actions are 1) the Railroad Revitalization and Regulatory Reform Act (" 4-R Act") of 1976 (*33*) and 2) the Staggers Rail Act of 1980 (*34*).[1]

Both the 1976 and 1980 rail acts attempted to improve the financial position of the railroads by increasing their competitive strength with other modes of transport. Rail rate flexibility was permitted as a means to achieve this goal. The Railroad Revitalization and Regulatory Reform Act of 1976 authorized the Interstate Commerce Commission (ICC) to "establish, by rule, standards and expeditions procedures for the establishment of railroad rates based on seasonal, regional, or peak period demand for rail services." The Staggers Rail Act of 1980 repealed this provision but permitted contract rates, which could include rate provisions with a differential based on seasonal or other demand changes.

The Staggers Act allows for much greater flexibility in ratemaking than allowed previously and in adjusting to different demand conditions. The act permits a carrier to adjust rates for both competitive and inflationary reasons.

Economic research is needed to demonstrate the effect of these adjusted rates on the transportation and agricultural sectors of the economy. This study devises a flexible rail rate policy for feed grains and estimates its effect upon:

(1) Railroad gross revenue and volume transported,
(2) Seasonal nature of rail demand,
(3) Location of storage stocks within the marketing chain,
(4) Feed grain prices at country elevators, and
(5) Total costs of transporting, handling, and storing feed grains.

Effects at both the national and regional level are analyzed.

One function of a pricing system is to allocate resources efficiently. However, inflexible rail rates sometimes prevent equilibrium between the quantity of services demanded and supplied and result in seasonal railcar shortages often followed by periods of surpluses. Although rates for grain hauled by truck and barge vary day to day and season to season, rail rates have tended to be much more static because of alleged regulatory restrictions. Economic shortages of trucks and barges are seldom reported because price is quickly changed to equate demand and supply. Because of static rates, railroads have often been faced with an inadequate car supply to meet the volume of grain that shippers desire to move. Conversely, during off-peak demand periods many railcars remained idle, creating a surplus (*12*). During railcar shortages, railroads may incur additional costs while serving their shippers, but the shipper may also incur additional costs caused by delay or lost sales.

Car shortages and surpluses result from shifts in demand, shifts in supply, or a combination of both. Ex-

[1]Italicized numbers in parentheses refer to literature cited in the bibliography at the end of this report.

amples of demand shifts include increased export volume or seasonal variations in consumption. Examples of supply shifts include poor car turnaround time, cars serving the needs of shippers in the wrong geographic areas, or car rationing.

The problem of peak demands for railcar services involves both time and geography. The overall demand for railcar services may fluctuate widely over time, assuming a given geographic area, or it may fluctuate widely over space, assuming a given time period.

In theory, rail rates which change with demand conditions should improve car use by shifting some peak period traffic to the slack demand periods (*6*). Such shifts in marketing patterns could not be accomplished without concurrent shifts in storage patterns and/or market shares for the competing modes of agricultural transportation. Results of recent studies indicate that the effects of a peak-load rail rate policy on modal split would depend upon the degree of competition from trucks or barges (*5, 11, 26, 50*). Members of the grain marketing industry will also be affected through changes in transportation costs, market prices, and storage requirements (*16*). Finally, total costs of transportation, handling, and storage may change due to the proposed rail rate changes.

Methodology

The authors developed a mathematical model of the storage and transportation system for the U.S. feed grain industry in order to estimate the effects of flexible rail rates. The structure of the model was based on the assumption of a competitive storage and transportation system with a given market structure. Regional price relationships reflect both transfer and storage costs. The objective function minimized the total cost of transporting, handling, and storing feed grains.

Economic Model

The economic function of the national storage and transportation system for feed grains is to match quantities supplied with quantities demanded. Market participants of this system include farmers, country elevators; terminal elevators; domestic millers and processors; export firms; and truck, rail, and barge transportation companies.

Movement of feed grains between production and consumption points is coordinated by relative market price relationships. These relationships are influenced by factors such as supply and demand for feed grains, transportation charges, transportation availability, handling and storage charges, and storage capacity. For any given set of market price relationships, the costs of storage and transportation are important to a marketing firm with the goal of profit maximization. Both functions are necessary in the distribution system of feed grains; and farmers, country elevators, and terminal elevators strive to minimize the costs of storage and transportation to maximize profits. Similarly, transportation firms and consumers of feed grains such as domestic millers, processors, or export firms are assumed to be profit maximizers.

Specification of Model

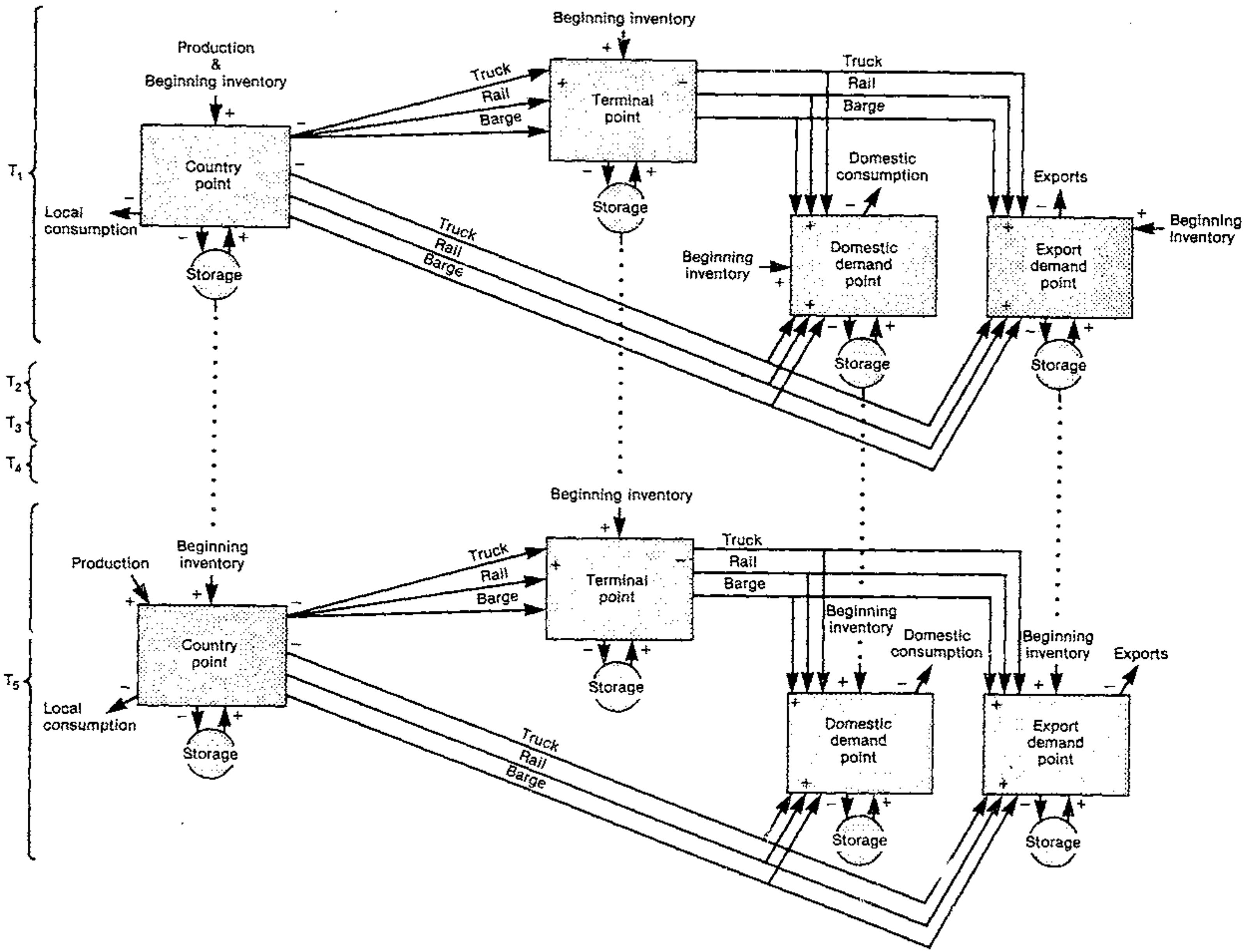
The storage and transportation system represented by the model included a segment of the market chain from production area to initial point of domestic consumption or to port of export (fig. 1). Four activity centers were built into the model. First was the country point, providing a supply of feed grains. Feed grains were stored at the country point or transferred to the domestic and/or export demand points.[2] Local consumption such as seed or onfarm feed was transferred from these supplies at no cost. Transportation between the country point and terminal elevators, domestic millers, processors, and port areas was provided by truck, rail, and barge.

The terminal elevator point was the second activity center and could receive, store, and ship feed grains. Transport to domestic and export demand points was also possible by truck, rail, and barge.

The domestic (millers and processors) and export (port areas) demand points were the third and fourth activity centers, respectively. Each center could receive, store,

[2]Storage capacity for farms and country elevators was aggregated into one storage center for each production region and was called the country point. This aggregation was made for two reasons. First, it permitted a reduction in model size. Second, rail transportation was a primary focus of this study. Trucks and/or farm wagons were the primary means of transportation between the farm and country elevator. Thus, the storage and transportation system for this model began at the country point where rail transportation is an alternative means of transportation.

Feed Grain Storage and Transportation Model



and consume feed grains. Storage stocks provided a source of supply for later time periods. Beginning and ending inventories were assigned to each storage facility (country, terminal, domestic demand, and export demand).

The study ranged from October 1, 1974, through December 31, 1975.[3] This span was divided into five time periods which capture specific transportation demand characteristics. The time periods and their transport demand characteristics were as follows:

(1) T_1: October through December 1974. The fall harvest quarter requires substantial transportation capacity.
(2) T_2: January through March 1975. Off-farm sales increase during the winter quarter but rail and barge transportation can be limited due to snow and ice conditions.
(3) T_3: April through May 1975. Generally, there is a slack demand for feed grain transportation services which coincides with the spring pasture season and planting activities.
(4) T_4: June through September 1975. During the summer period, barley and oats are harvested, requiring an average amount of transportation service.
(5) T_5: October through December 1975. The fall harvest quarter requires substantial transportation capacity.

A five-period model was used because a typical four-quarter model would not capture the potential effects of the oncoming harvest period (T_5)—accompanied by higher transportation rates—on previous periods' storage and distribution activities.

Feed grain transportation was permitted both within and between the domestic production and consumption regions. Transportation modes were allowed to transport between selected origin and destination pairs, and these pairs were selected on the basis of historical trading patterns. For example, rather than allow Colorado to ship feed grains to every terminal elevator and demand location, its origin and destination pairs were reduced to actual and most likely shipment patterns. Data sources for these shipment patterns included results from a 1970 Southern U.S. Grain Flow Survey (*27*), *Carload Waybill Statistics* (*47*), and researchers' judgment. Eliminating illogical transfer possibilities reduced model size without altering results.

Delineation of Activity Centers

Many regions followed State borders, but several included multistate and substate areas (fig. 2). Regions were delineated mostly on the basis of feed grain production characteristics. For some regions, transport demand characteristics were also used to establish regions.

Each region was assigned a base point to represent the location of its production and domestic demand. In some cases, a single point represented production and demand. The base point was used to compute transportation rates between regions.

Terminal storage centers were identified from (*37*). Eleven terminal points were selected. In some cases, terminal points shared the same base point with a particular region's production and domestic demand point.

Port areas were aggregated into 10 export demand points. Each point represented a major port in a geographic area. (See appendix A for name and number of domestic producing and consuming regions and ports of export. Appendix B lists the name of each base point location by activity center. Appendix C lists the mathematical representation of the model.)

Delineation and Description of Transportation Regions

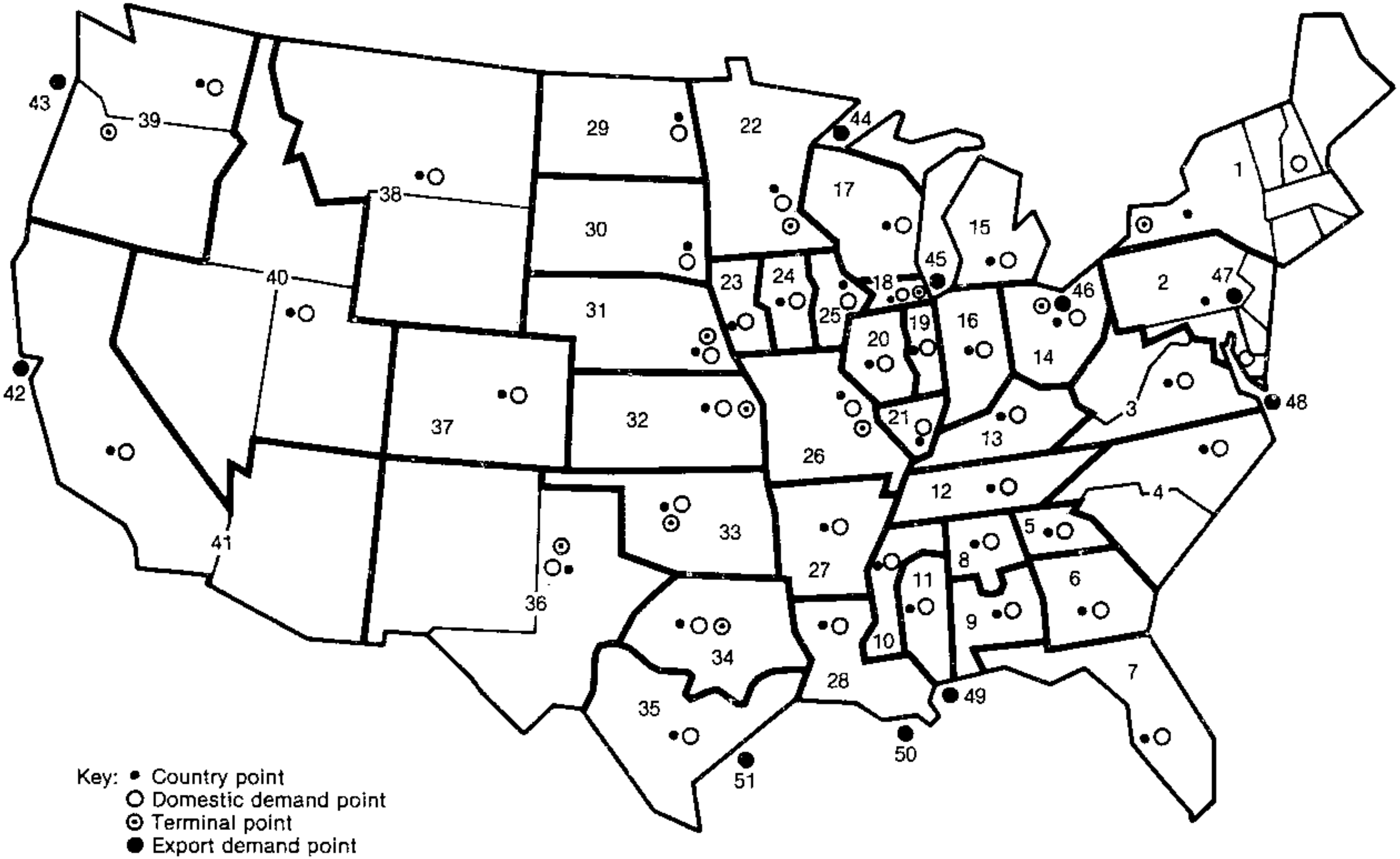
Transportation regions were established for two reasons. First, they facilitated the identification of seasonal shipments across space. Second, they permitted the use of transport capacity constraints by region. Location of production, time of harvest, and railroad rate territories were primary factors used in delineation of these regions. The eight regions selected are shown in figure 3.

Each transport region had access to truck, rail, and barge transportation, except the Northeast and Southwest regions, where only transportation by truck and rail was available.

[3]This time period was used because it was representative of shipment seasonality problems. Export demand surges for grains and oilseeds placed peak demands upon all transport capacity: truck, rail, and barge.

Figure 2

Production and Consumption Regions with Ports of Export, Terminal Centers, and Identification Numbers[1]



Production and consumption regions are identified by number in Appendix A. Ports of export and terminal centers are listed in Appendix B.

The transport region had either a surplus (production exceeded consumption) or a shortage (consumption exceeded production) of feed grains. The Midwest, North Central, Middle Central, and South Central regions experienced surpluses in feed grains for all time periods T_1 through T_5. The remaining regions experienced a deficit for only some of the time periods. For example, the Northeast experienced deficits during T_2, T_3, and T_4. The Southeast (T_3 and T_4) and Northwest (T_2 and T_3) regions experienced deficits during two time periods of the crop year.

Data Requirements, Assumptions, and Sources

The model required the following data input: cost coefficients for the objective function, transfer coefficients for each equation, and right-hand side values for each equation. The cost coefficients included transfer and storage costs by activity center. Transfer coefficients included a receipt or withdrawal of storage stocks by activity center, a transfer from country and terminal points, and a receipt at terminal and consuming points. Values for the right-hand side consisted of beginning and ending inventories by storage facility, quantities supplied by region and time period, quantities demanded by consuming points and time period, storage capacities by storage facility, and transportation capacities by mode and transportation region.

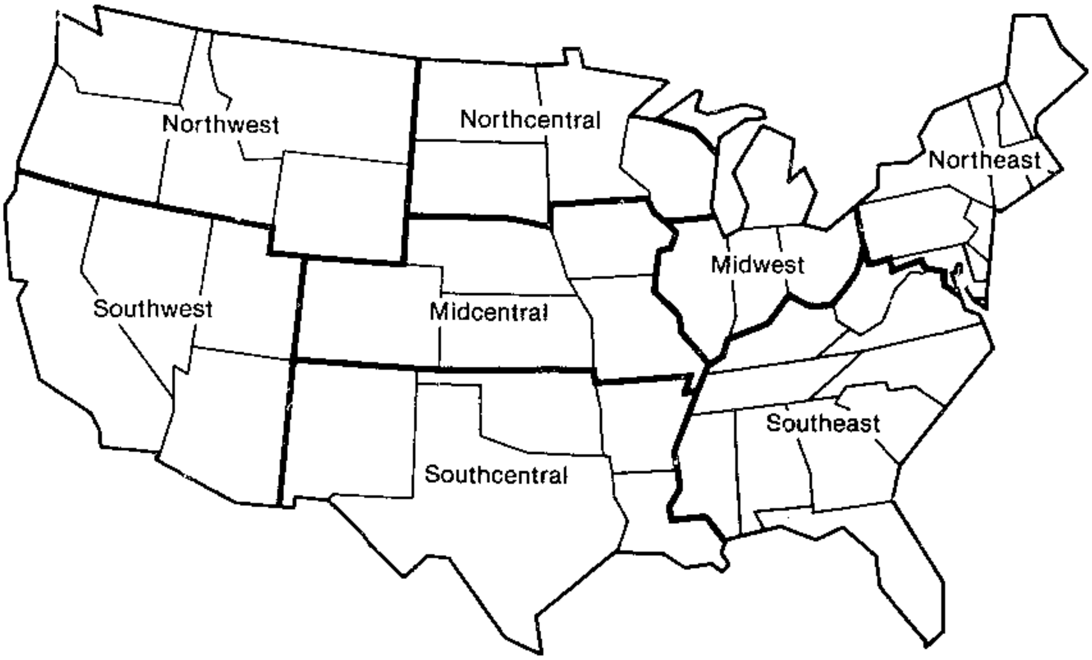
Feed Grains Feed grains were considered a representative commodity because they used a large amount of storage and rail transportation resources. Bulk agricultural commodities such as wheat, soybeans, and dry fertilizer compete for the same trucks, railroad cars, and barges as do feed grains. Feed grains, wheat, and soybeans compete for the same country storage space.[4] However, a limitation of research resources precluded consideration of more than one commodity. Of all grain shipped by rail in the United States during 1972-75, feed grains, wheat, and soybeans accounted for an average of 49, 42, and 9 percent, respectively (*14*).

The four feed grains—corn, sorghum, barley, and oats—were aggregated into one commodity called "feed grains" based on each grain's corn feed value

[4]Transportation and storage capacity was reduced to compensate for the exclusion of these commodities.

Figure 3

U.S. Transportation Regions



equivalent (3). This conversion was made to reduce the size of the model. Conversion factors for each feed grain were as follows:

1 bushel of corn = 1 bushel of feed grain,
1.0526 bushels of sorghum = 1 bushel of feed grain,
1.2962 bushels of barley = 1 bushel of feed grain,
1.9444 bushels of oats = 1 bushel of feed grain.

A conversion to corn feed value equivalents was made because corn is an important feed ingredient and a majority of each grain's domestic disappearance was consumed by livestock. Such a conversion assumed feed grains were perfect substitutes. This assumption may not always hold, but the consequences were considered to be minor. Regional shipment distortions may occur, but the total U.S. shipment pattern was not expected to change significantly. One example of distortion is that barley demand by maltsters in Wisconsin could be met in the model by corn shipments from Wisconsin or northern Illinois as a least cost alternative that would obviously not be acceptable to maltsters. Storage requirements also change when barley, oats, and sorghum are converted to a corn feed equivalent. Appropriate adjustments were made to storage capacity to compensate for this change. (See section on storage capacity.)

Transportation Rates Transportation rates were part of the objective function's cost coefficient and were used as a row coefficient to record each mode's transportation revenue derived from each shipment. Transportation rates, rather than costs, were used because they reflect charges on which shippers base their decisions and because they were expected to generate commodity flows that better approximate the shipment patterns of the real world.

Rail. A representative least cost rate was selected for each interregional origin and destination pair included in the model. Rail rates were obtained for the major feed grain shipped from each area. For example, rail rates for barley were specified for shipments from North Dakota, while corn rates were specified for shipments from east central Illinois.

Rail rates were obtained from three data sources. Most rates were derived from (9) which were in effect as of January 30, 1974. A second rate source was the Tennessee Valley Authority, Navigation Branch personnel. All rates were updated to the level of April 27, 1975. Although updating rates may cause distortions in rate relationships due to new tariffs, holddowns, or flag-outs, the general rate relationships were assumed to remain relatively constant in this relatively short time span.

The third data source provided estimates of intra-regional rail rates (47). An average rate per 1,000 bushels was computed for the major feed grain shipped within each region. These rates were used for intra-regional rail shipments between country and terminal points or country and demand points.

Transit rates were not incorporated into the rail rate structure used in this study because these rates are not used extensively for feed grains. Study results could be slightly biased due to this exclusion.

Truck. Truck rates are not published at the national or regional levels because transportation of grain by truck is exempt from interstate regulation. These rates vary according to supply and demand conditions, such as backhaul opportunities or seasonality of demand. Consequently, these rates may vary within or between regions. Regional rate differences due to costs were estimated from the Interstate Commerce Commission's (ICC) regional data on truck costs. Rate variability due to equipment backhaul effects or seasonality of demand was not considered because of lack of information.

Truck rates for the Central region only were obtained from the Mid-West Truckers Association (20). Members of this association hauled agricultural products throughout Illinois. These truck rates for grain were in effect throughout the study period and compared favorably with other nonmember rates being charged shippers throughout Illinois. They were similar to Midwest truck rates as reported in (9). The rates published by the Mid-West Truckers Association represented three discrete linear rate equations. The standard equation is as follows:

$$Y = a + bX$$

where:

Y = total truck charge per mile for moving 1,000 bushels of feed grains

a = fixed charge
b = rate per mile for 1,000 bushels
X = miles

(1) Y = \$40 + \$1.00X (X = 1 to 200 miles)
(2 Y = \$140 + \$0.50X (X = 201 to 300 miles)
(3) Y = \$180 + \$0.40X (X = 301 to 1,000 miles)

Distances between origins and destinations were required in order to compute the respective truck rates. Interregional distances were computed from (23). A proxy was used for the interregional distances and was based on the average length of rail shipment within each domestic region. These distances were compared to the results of a 1970 grain flow survey completed by the Southern Regional Marketing Research Committee (27) and were found to be reasonable.

Rates for other regions were derived from rates for the Central region by use of line haul costs. These costs were used to adjust rates because they account for most of variable truck costs. Variable costs represent nearly 95 percent of total truck costs; therefore, truck rates are believed to be close to total costs because of their competitive economic environment. Line-haul costs for regulated and exempt for-hire trucking were assumed to be approximately equal.

Line-haul truck costs are reported to the ICC (15) by regulated trucking firms. The ICC publishes these costs on a regional basis. There are eight such regions: Central, New England, Middle Atlantic, Southern, Middle West, Southwest, Rocky Mountain, and Pacific.

The equations for estimating truck rates in the Central region were adjusted to reflect differences in line haul costs for the remaining seven regions. Line haul costs for the Central region, as reported by the ICC, were used as a base. Costs for 30,000 pounds or greater were used with 19 different mileage blocks ranging from 0 to greater than 1,000 miles. Similar costs from the other regions were expressed as a percentage of this base. These percentages were used to adjust rates from the Central region to each of the remaining regions.

Barge. Barge shipments of feed grains were not regulated by ratemaking guidelines. Thus, barge rates were free to vary with supply and demand conditions. Representative rates were obtained from (4 and 7). The Arrow Barge Tariff (Supplement #3) was applicable to the Mississippi River System (4). The Federal Trade Commission prohibited the use of this tariff by the barge trade, but this restriction occurred after this study's time period.

A seasonal nature was built into these rates based on rate discounts or premiums as reported in (46). The weighted average rates reported in this study varied less than spot rates reported by the industry. The range for the weighted average rate was from 75 to 111 percent of tariff, in contrast to spot rate variation of 50 to 100 percent. This finding suggests that much of the grain shipped via barge is moving under contract rates.

Barge rates from (7) were used for the Columbia River and varied little seasonally.

Handling Charges The handling activities included loading and unloading of transportation vehicles for each shipment. Rates for these services were not available, so shortrun average costs were used as a proxy. Each transfer activity was assigned the loading cost at origin and unloading cost at destination. These costs were added to the transportation rates. The transfer cost for each shipment was a combination of handling and transportation charges.

Handling costs were obtained from (24), which provided both replacement and standardized book handling costs for country elevators, inland terminal elevators, and port terminal elevators by region and mode of transport. Standardized book handling costs for the country elevators were applied to the country and domestic demand point activity centers. Similar handling costs for the inland and port terminal elevators were assigned to the terminal and export demand activity centers.

Storage Charges Storage rates charged by grain facilities were desired but unavailable. Rates paid by the Commodity Credit Corporation (CCC) were considered unacceptable because there was very little storage activity by the CCC during the 1974/75 crop year, the period on which this study is based. Therefore, shortrun average costs were used as a proxy for storage rates. These costs may tend to be less than the actual storage rates because a 1973 survey found that storage rates were slightly higher than actual costs (*19*). However, this bias was considered insignificant.

Storage costs were obtained from the same publication used for handling costs. Storage cost estimates for country elevators were applied to the country point storage facilities. Storage facilities for the domestic demand point were assigned those storage costs estimated for inland terminal elevators. Storage cost estimates for the inland and port terminal elevators were assigned to the terminal and export storage facilities, respectively. Costs differed by storage facility and region (*12*).

Construction Costs for Storage Capacity The model permitted additional storage capacity to be constructed at each storage location. Construction costs were derived from (*25*), which provided estimates for both replacement and standardized book costs for country, inland terminal, and port terminal elevators. Each additional unit of storage capacity at each location was assigned a cost equal to the annual replacement cost.

Beginning Inventory Beginning inventories as of October 1, 1974, were determined for each storage facility within each domestic region. Three steps were followed to arrive at the beginning inventories. First, old-stock farm inventories of feed grains were allocated by region and assigned entirely to the country point storage facility (*38*). Substate allocations were based on production by substate area. Second, production which took place before October 1, 1974, and not included in old-stock inventory, was assigned to the beginning inventory of country point storage facilities. Third, off-farm storage stocks in each region were allocated among country elevators, terminal elevators, and domestic processors in direct proportion to their respective storage capacities reported for each region (*38*).

Quantities Supplied Production by time period was determined on the basis of average harvesting dates (*35*). Quantities of grain supplied by region and time period were determined and assumed to be available at each region's country elevator point. Data sources include *Agricultural Statistics* (*39*) for the multistate and State regions and State statistical series (*1, 10, 13, 17, 22, 28, 29, 30, 31*).

Quantities Demanded Quantities demanded by demand point within each region were determined by time period. During the study's time frame, feed grains were used for the following: feed, 67 percent; export, 23 percent; food, 6 percent; alcoholic beverages, 3 percent; and seed, 1 percent. These uses were allocated within the model to three demand points: local consumption (country point), domestic demand, and export demand.

A local consumption demand point was attached to each region's country point activity center. This demand point accounted for all onfarm feed and all seed (commercial and onfarm) consumed by the region. Two publications were used to determine local consumption by region and time period (*42, 39*).

The domestic demand point accounted for feed grains used for commercial feed, food, and alcoholic beverage production in each region. Commercial feed was derived by subtracting onfarm feed use from total feed use. Commercial feed use was allocated to each region based on the region's proportion of total grain-consuming animal units (*2*).

Feed grains used for food products were utilized by three major industries: wet processing, dry milling, and breakfast cereal (*41, 42*). Utilization of feed grains by the wet-processing industry was allocated to each region's domestic demand point on the basis of its proportion of the total U.S. wet-milling capacity (*21*). Use by the dry-milling industry was allocated on the basis of each region's proportion of the total U.S. dry-milling sales in 1975 (*43*). Regional employment by breakfast cereal manufacturing plants was used to allocate feed grain use by breakfast cereal manufacturers (*44*). Feed grains used by these industries were allocated by time period based on disappearance by quarter as shown in (*41*).

The alcoholic beverage demand involved three major industries: distilled liquors, fermented malt liquors, and barley malting (*41, 42*). Consumption by each industry was allocated to each region by time period. Feed grains for use in distilled liquors and fermented malt liquors were allocated to each region on the basis of data found in (*48*). Feed grains for use in barley malt were allocated to each region on the basis of its proportion of the total U.S. employment by barley malt plants (*44*). These allocations were distributed by time period based on statistics found in (*42*).

Demand for feed grains at export points during each time period was based on inspections for export published in (*36*).

Storage Capacity Storage capacity was determined by activity center for each production and consumption region. The model included four storage facilities per region. The country point storage facility included farm and country elevator storage capacity for each region. Onfarm storage capacity was derived from the 1974 agricultural census (*45*). Country elevator storage capacity was estimated from (*38*). Regional storage capacity for country elevators was derived by identifying regional off-farm storage capacity and subtracting the storage capacities of the following: soybean processor, wheat flour miller, terminal elevators, export elevators, and feed grain millers and processors. Data sources were as follows:

(1) Soybean processor storage (*8*).
(2) Wheat flour milling storage (*21*).
(3) Export elevator storage (*21*).
(4) Terminal elevator storage (*21*).
(5) Storage capacity at feed grain millers and processors was the sum of storage capacity at feed grain processing plants and grain storage capacity at formula feed manufacturers. Storage capacity at feed manufacturers was calculated from data on daily feed production capacity by region and the average inventory of grains held by feed manufacturers. The inventory of average number of working days held by feed manufacturers was multiplied by the daily feed production capacity converted to grain requirements (*49*). The result was an estimate of the average volume of grain inventory held by feed manufacturers and represents the lower limit of available storage capacity.

Regional storage capacity for all grains and soybeans, at country and terminal points, was converted to feed grain storage capacity on the basis of the ratio between feed grains and all grain and soybean production in the region. Storage at port areas was adjusted by the proportion of total grain exports accounted for by feed grains. A second adjustment to storage capacity was required to account for volume differences created when barley, oats, and sorghum were converted to a corn feed value equivalent. Each region's country storage capacity was reduced based on the proportion of these three feed grains per region and based on each grain's conversion factor to corn equivalents. The third adjustment reduced storage capacity because of working space. Working space estimates for the country, terminal, and export storage facilities were obtained from (*25*).

Transportation Capacity Transportation capacity by mode and region was nonexistent from published secondary data sources. Therefore, capacity was estimated by two different methods. The first method used secondary data to estimate rail and barge capacity. The second method estimated peak rail quantities demanded and used this quantity as a capacity estimate. This approach was used because the first method—a historical allocation of rail capacity—would not allow expansion in rail transportation because of the rigidities imposed by regulation. The method which generated the greatest capacity was used to set the upper limit on each mode's transport capacity (table 1).

The first method used secondary data sources to compute rail and barge capacity constraints. Past shipment levels were identified by time period, mode, and region or river segment. Rail transportation capacity was computed in the following three steps:

(1) Annual feed grain transportation from 1972 through 1975 was determined from (*14*).

(2) Each yearly total was allocated to each transportation region by time period based upon each region's proportion of total rail shipments as derived from (*47*).

(3) The largest tonnage shipped by period and region for the 4-year period was selected as the rail capacity for that region and period. This capacity figure was applied to each of the remaining time periods.

Barge transportation capacity was computed in the following three steps:

(1) River segments were identified as follows: (*36*).[5]
  (a) Mississippi River
    (i) Minnesota-Wisconsin (south to Iowa)

[5]Regions having access to barge transportation are listed in appendix D.

Table 1—Computation of transportation capacity constraints by transportation region or river segment for a 3-month time period

Transportation region or river segment	Method I[1]			Method II[2]			Constraints		
	Truck	Rail	Barge	Truck	Rail	Barge	Truck	Rail	Barge
	Million bushels								
Northeast	79.6	3.0	NA	62.9	28.6	NA	79.6	28.6	NA
Southeast	178.8	32.4	NA	148.1	83.8	NA	178.8	83.8	NA
Ohio River	NA	NA	24.5	NA	NA	74.9	NA	NA	74.9
Midwest	136.3	165.7	NA	74.2	378.6	NA	136.3	378.6	NA
Illinois River	NA	NA	137.9	NA	NA	137.9	NA	NA	137.9
North Central	157.8	99.4	NA	157.8	98.5	NA	157.8	99.4	NA
North Mississippi River	NA	NA	77.5	NA	NA	77.5	NA	NA	77.5
Mid Central	242.6	194.9	NA	256.4	194.9	NA	256.4	194.9	NA
Mid-Mississippi River	NA	NA	57.2	NA	NA	57.2	NA	NA	57.2
South Central	91.9	46.8	NA	202.4	37.9	NA	202.4	46.8	NA
South Central Mississippi River	NA	NA	22.6	NA	NA	118.1	NA	NA	118.1
Northwest	19.6	17.9	NA	24.8	20.6	NA	24.8	20.6	NA
Snake & Columbia Rivers	NA	NA	.4	NA	NA	16.4	NA	NA	16.4
Southwest	69.0	1.4	NA	62.2	4.2	NA	69.0	4.2	NA
Missouri River	NA	NA	8.4	NA	NA	63.3	NA	NA	63.3
Southern Mississippi & Arkansas River	NA	NA	2.0	NA	NA	7.1	NA	NA	7.1

NA = not applicable.

[1]Transportation capacity constraints for rail and barge were derived from secondary data. Capacity constraints for truck transportation were derived from the model's base solution I. This solution used the computed capacity constraints for rail and barge. Truck shipments were unconstrained and peak shipments were used to compute truck capacity constraints.

[2]Transportation capacity constraints for all three modes were computed from the model's base solution II. Capacity constraints were not imposed on each mode, but, instead, each mode was permitted to ship an unrestricted amount. Each mode's peak shipment was used to compute its capacity constraint.

(ii) Iowa and northern Illinois (along Iowa-Wisconsin and Iowa-Illinois lines)
(iii) St. Louis area (along Missouri-Illinois line)
(iv) Memphis area (Arkansas-Missouri line south to Greenville including Arkansas River).

(b) Missouri River
(i) Nebraska-Iowa (south to Kansas line)
(ii) Kansas City area (Kansas-Nebraska border to St. Louis)

(c) Illinois River (all points including Chicago)

(d) Ohio River (all points including the Tennessee River)

(e) Snake and Columbia Rivers (all points east of Bonneville).

(2) Feed grains transported by barge were identified for 1972 through 1975 by river segment and time period. This information was derived from *Grain Market News*.[6]

(3) The largest quantity shipped for that time period was selected as that segment's capacity for that time period. This capacity was used to compute barge capacity for the remaining periods.

[6]Data from the Army Corps of Engineers were used to determine total yearly feed grain shipments on the Columbia River. More recent reports of *Grain Market News* were used to allocate shipments by time period (36).

Truck transportation capacity was computed from the model's base solution I in which the previously determined rail and barge constraints were included. The peak truck shipments by time period and region were assumed to represent truck capacity for that region in all five time periods.

The second method used the model's base solution II to estimate transportation capacity. This solution excluded all previously estimated transportation capacity constraints. The peak shipment quantity from one of the four time periods was selected from each region or river segment and for each mode to represent a peak demand (table 1). This peak was subsequently used to compute capacity for each remaining time period.

Demand-Sensitive Rail Rate Policy

Estimates of rail service demanded were derived by region and time period from the model's base solution. This information was used to formulate a rail rate policy.

A seasonal index was constructed to provide comparisons of fluctuations in quantities demanded among regions. The formula for this index was:

$$\text{Seasonal index} = \frac{\text{Actual quantities demanded by time period}}{\text{Average quantities demanded by time period}}$$

An index value of 1 represented an average (normal) demand for that period and region. An index value of less than 1 indicated a below average (slack) demand. An index value of greater than 1 indicated an above average (peak) demand.

A combined peak and off-peak rail rate policy was instituted within each transport region. Two rate change scenarios were analyzed. The first scenario assumed truck and barge rates did not change, and the second assumed rates for all three modes changed by an equal percentage. Changes in rail rates were based upon the relative magnitude of each region's seasonal demand index and upon each rate's expected contribution to the reduction of seasonal demand. Rail rates were increased for those regions and time periods that exhibited a peak demand and were simultaneously reduced by an equal amount during the slack demand period (table 2). During the average demand periods, rates were generally unchanged. Rates for either scenario were changed in increments of 5 percent with a new model solution generated for each incremental change. The maximum rate change was 30 percent.

Results

A model with five time periods was developed and analyzed. A four-quarter model, covering one marketing year (October through September), was desired, but such a model did not reflect the potential effects of the oncoming harvest period (October through December) accompanied with peak rail rates. Results will be discussed in terms of one marketing year, T_1 through T_4.

Since this study was conducted, rates and rate relationships changed. However, the grain marketing system and major flows have changed very little with the exception of export flows through ports. The methodology and procedures are still appropriate and the changes that have occurred in rates should not invalidate the study because the emphasis is on the effect of shortrun rate changes rather than long-term trends. Although the rate data are not current, the major conclusions are still valid.

The Staggers Rail Act of 1980 has had minimal effects on the organizational structure of the railroad industry up to this point, although this could change. Therefore, the basic conclusions should hold for the post-Staggers period. The 1980 legislation did grant railroads more ratemaking freedom, but this would essen-

Table 2—Time periods during which rail rates were changed by transportation region

Transportation regions	Simultaneous rate changes: Increases	Simultaneous rate changes: Decreases
	Time periods	
Northeast	T_1, T_5	T_3
Southeast	T_1, T_5	T_3
Midwest	T_1, T_2, T_5	T_3, T_4
North Central	T_1, T_5	T_3
Middle Central	T_1, T_2, T_5	T_3, T_4
South Central	T_1, T_2, T_5	T_3, T_4
Northwest	T_4, T_5	T_3
Southwest	T_2, T_3	T_4, T_1

tially allow the railroads to engage in the type of pricing evaluated in this study, and not change the underlying assumptions.

Rail Revenue and Volume Transported

Based on results from the base solution, the transport sector generated an estimated $868 million in revenue from shipping 4.6 billion bushels of feed grain during the 1974/75 crop year (T_1—T_4). Rail revenue was estimated to be $446 million and rail volume shipped was estimated to be 1.9 billion bushels, for a market share of 42 percent. Rail revenue and traffic volume were hypothesized to increase relative to the base solution as a result of instituting a combined peak and off-peak rail rate policy, regardless of the rate response by truck and barge (*12*).

National Impact Total U.S. rail revenue increased beyond the base solution for the smaller rate change solutions (5 through 15 percent) regardless of the rate response from trucks and barges, but revenue generally declined from the base for the larger rate change solutions with either scenario (table 3). Revenue ranged from a high of $479 million with a 5-percent change in rail rates to a low of $411 million with a 30-percent change in rail rates. In contrast, variations in rail revenue were less with an equal percentage rate change by all modes. Total revenues ranged from a maximum of $472 million with a 5-percent change in rates to a minimum of $443 million with a 25-percent change. However, for the smaller rate changes, truck and barge revenue tended to decline when only rail rates were changed, but truck and barge revenue tended to increase when transport rates were changed for all modes.

Total U.S. rail revenue increased when revenue losses during the peak demand periods, T_1 and T_2, were more than offset by revenue gains of the off-peak periods, T_3 and T_4. Rail revenue declined in the peak periods because the percentage rate increase was less than the percentage decline in quantity shipped (table 4). For example, a 5-percent increase in rail rates during the peak demand periods caused 29- and 55-percent declines in traffic volume during T_1 and T_2, respectively.

During the peak periods, rail volume and revenue declined with each successive simulated change in rail rates because some rail traffic was diverted to country storage facilities and to truck and barge competitors. However, with an equal percentage rate change by all modes, such a decline in traffic volume was less. For example, a 5-percent increase in all rates during the peak demand periods caused declines in rail traffic volume by 7 and 29 percent during T_1 and T_2, respectively.[7] The decline in rail traffic during the peak periods represented both a leftward movement along the demand curve for rail service (created by increased rail rates) and a leftward shift of the demand curve (created by higher rail rates relative to the off-peak periods, T_3 and T_4).

Rail revenue increased during the off-peak periods because the percentage decline in rail rates was less than the percentage increase in quantity shipped. For example, a 5-percent decrease in rail rates caused 147- and 152-percent increases in traffic volume during T_3 and T_4, respectively. While this response may seem large, railroads are essentially regaining traffic lost in the peak periods to trucks and barges. Also, some of the T_4 rail shipments are being made in advance of the T_5 peak rail rate period. During T_3 and T_4, rail revenue and volume increased with each additional decrease in rail rates because of an incentive to shift stocks from country storage facilities in producing regions to storage facilities located at demand points and because some truck and barge traffic was diverted to rail. However, with an equal percentage rate change by all modes, the increase in rail traffic was less. For example, a 5-percent decrease in all rates during the slack demand periods caused increases in rail traffic volume by 104 and 53 percent during T_3 and T_4, respectively. The increase in rail traffic represented a rightward movement along the demand curve for rail services (created by decreased rail rates) and a rightward shift of the demand curve (created by lower rail rates relative to the peak periods, T_1 and T_2).

Regardless of rate response scenario by truck and barge, changes in rail volume and market share generally corresponded to the change in rail revenue. The market shares for truck, rail, and barge were 31, 42, and 17 percent, respectively (base solution). Rail's

[7]These figures cannot be used to compute price elasticities of demand. Such elasticities cannot be computed because all time periods (T_1-T_4) were considered simultaneously; therefore, a rate change in T_1 could affect quantity shipped in T_2, T_3, or T_4, or rate change in T_3 could affect quantity shipped in T_1, T_2, or T_4.

Table 3—Total U.S. truck, rail, and barge revenue derived as a result of the combined peak and off-peak rate policy by time period, crop year 1974-75[1]

Rate response from truck and barge with alternative rate solutions	Time periods														
	T_1 (Oct.-Dec.)			T_2 (Jan.-Mar.)			T_3 (Apr.-May)			T_4 (June-Sept.)			Total[2]		
	Truck	Rail	Barge	Truck	Rail	Barge	Truck	Rail	Barge	Truck	Rail	Barge	Truck	Rail	Barge
	Million dollars														
Scenario 1:[3]															
Base	111	196	25	72	148	14	52	38	21	89	64	39	324	446	99
5 percent	150	127	37	98	56	29	16	130	9	52	166	17	316	479	92
10 percent	166	98	42	94	68	28	12	131	9	49	173	15	321	470	94
15 percent	168	91	43	102	64	28	15	129	9	72	165	14	357	449	93
20 percent	170	89	43	105	61	28	15	122	10	57	171	13	347	443	94
25 percent	176	82	45	112	48	21	15	116	9	58	171	13	361	417	88
30 percent	188	70	48	117	48	28	13	117	8	82	176	13	400	411	97
Scenario 2:[4]															
Base	111	196	25	72	148	14	52	38	21	89	64	39	324	446	99
5 percent	134	162	30	46	128	18	52	91	15	96	91	35	328	472	98
10 percent	140	139	40	44	97	31	53	98	14	103	132	20	340	466	105
15 percent	145	133	39	45	98	32	59	95	12	101	128	39	350	454	122
20 percent	136	139	35	51	99	34	62	91	8	105	117	33	354	446	110
25 percent	130	130	46	58	100	35	59	90	14	111	123	25	358	443	120
30 percent	122	142	49	61	100	36	57	92	13	115	121	24	355	455	122

[1]See table 2 for the combined increase and decrease in rail rates by time period and transportation region.
[2]May not add to total due to rounding.
[3]No rate response from truck and barge modes.
[4]Equal percentage rate response from truck and barge modes.

Table 4—Total U.S. traffic volume generated by truck, rail, and barge as a result of the combined peak and off-peak rail rate policy by time period, crop year 1974-75[1]

Rate response from truck and barge with alternative rate solutions	Time periods																		
	T_1 (Oct.-Dec.)			T_2 (Jan.-Mar.)			T_3 (Apr.-May)			T_4 (June-Sept.)			Total[2]				Market share		
	Truck	Rail	Barge	Truck	Rail	Barge	Truck	Rail	Barge	Truck	Rail	Barge	Truck	Rail	Barge	Total	Truck	Rail	Barge
	Million bushels																*Percent*		
Scenario 1:[3]																			
Base	787	841	171	385	613	124	239	186	153	436	263	302	1,847	1,903	750	4,500	41	42	17
5 percent	919	596	260	423	273	255	131	460	57	377	662	129	1,850	1,991	701	4,541	41	44	15
10 percent	966	470	289	428	292	248	101	489	57	314	713	111	1,809	1,964	705	4,478	40	44	16
15 percent	980	428	293	457	274	246	116	506	58	328	687	98	1,881	1,895	695	4,471	42	42	16
20 percent	999	393	292	446	263	247	120	511	63	298	754	99	1,863	1,921	701	4,485	42	42	16
25 percent	998	352	299	486	208	247	116	502	56	308	820	95	1,908	1,882	697	4,487	42	42	16
30 percent	998	320	326	536	203	236	118	502	55	312	867	97	1,965	1,892	714	4,571	43	41	16
Scenario 2:[4]																			
Base	787	841	171	385	613	124	239	186	153	436	263	302	1,847	1,903	750	4,500	41	42	17
5 percent	798	786	195	301	436	155	281	379	98	470	403	285	1,850	2,005	732	4,587	40	44	16
10 percent	808	681	254	285	273	247	286	451	92	471	622	144	1,850	2,007	737	4,594	40	44	16
15 percent	801	613	253	279	286	249	332	448	79	498	643	204	1,910	1,990	785	4,685	41	42	17
20 percent	733	603	260	292	293	248	386	445	62	555	617	233	1,966	1,958	802	4,726	42	41	17
25 percent	698	524	290	321	306	247	425	447	104	590	679	181	2,034	1,956	821	4,811	42	40	18
30 percent	683	535	292	327	302	247	41[illegible]	469	103	617	696	172	2,045	2,002	814	4,861	42	41	17

[1]See table 2 for the combined increase and decrease in rail rates by time period and transportation region.
[2]May not add to total due to rounding.
[3]No rate response from truck and barge modes.
[4]Equal percentage rate response from truck and barge modes.

market share increased 2 percentage points to 44 percent for most of the smaller rate changes, with a 1-percent loss each in market share for truck and barge.

Of the two rate-response scenarios, an equal percentage rate response from trucks and barges would seem most likely. With such a response, all modes would generally gain revenue. However, with only a change in rail rates, revenue for the barge and truck industry generally declined.

Regional Impact Results from most transportation regions tended to support the findings at the national level (*12*). Most transport regions experienced rail revenue increases with 5- through 15-percent rate changes, regardless of the rate response scenario. Exceptions to this improvement were consistent declines by the Midwest and Northwest regions, assuming only rail rate changes. With an equal rate response from truck and barge, the Northwest and Southwest regions experienced consistent declines in rail revenue. Changes in rail revenue were generally positively correlated with changes in rail traffic volume and market share. Rail revenue and volume declined for those regions that possessed competitive modes of transport but increased where competitive transport was nonexistent or less effective. Thus, regional differences in rail revenue resulted more from transport modal competition than from each region's surplus or deficit feed grain characteristics.

Seasonal Demand for Rail Service

Another goal of demand-sensitive railroad rates was to improve the utilization of railroad cars.[8] Based on results from the base solution, peak demand periods at the national level came during T_1 and T_2 with seasonal index values of 1.77 and 1.29, respectively. Off-peak periods, T_3 and T_4, had seasonal index values of 0.58 and 0.41, respectively (table 5). Excess railcar capacity totaled 1.6 billion bushels or 31,333 covered-hopper cars per year.[9]

National Impact Seasonality was less than the base solution with each incremental rate change solution, although it began to re-intensify because the peak demand period was shifted from T_1 to T_3, regardless of rate-response scenario (table 5). The seasonality index for T_3 steadily increased from a base value of 0.58 to a maximum of 1.60 with a 30-percent change in rail rates, and to a maximum of 1.41 with a percentage change in rates for all modes.

Seasonal variation was generally less when rates were changed for all modes than with a change in rail rates only. A rate response by truck and barge prevented the large shift to these transport modes during T_1 and T_2, and thus seasonal variation declined. If only rail rates were changed, rail seasonal variation would decline but would increase for truck and barge. A 5-percent change in rail rates minimized rail seasonal variation of all incremental rate change solutions 5 through 30 percent, and reduced excess rail capacity by 908 million bushels or 17,295 covered-hopper cars. However, a 10-percent change in rates by all modes reduced seasonal variation by 949 million bushels or 18,076 railcars. Thus, the scenario of an equal percentage rate change by all modes seem most likely.

Regional Impact As hypothesized, the combined peak and off-peak rail rate policy reduced rail service seasonality for all regions, regardless of rate response scenario, although not necessarily with each percentage change in rates (*12*). With an equal percentage rate response from truck and barge, most regions required a larger change in rates to maximize the reduc-

[8] A measure of railcar utilization required the following information: rail demand by time period and total crop year, seasonal index values by time period, and excess car capacity for the total crop year. Estimates of rail service demand were obtained from the model's base solution. Excess car capacity was computed as follows:

(1) Sufficient car capacity was assumed to be available to transport the peak month's quantity demanded. This capacity was assumed to be available throughout each of the remaining 11 months of the crop year.

(2) The peak rail demand period was used to compute the average monthly peak. Rail service demand for the peak period was divided by the number of months in the period.

(3) The average monthly peak was multiplied by 12 to compute the total yearly carrying capacity.

(4) Rail shipments for the crop year were deducted from the total carrying capacity. The remainder represented an excess capacity.

Excess rail capacity was a total crop-year measure of seasonality. A reduction of excess capacity suggested an improvement in railcar utilization. Therefore, if excess capacity declined, fewer railcars would be needed to transport feed grains. These excess cars could be used to haul other commodities or to reduce the need for building additional cars in the future.

[9] Bushels of excess capacity were converted to numbers of railcars using 3,500-bushel cars and assuming 15 trips per year.

Table 5—Estimated seasonal variation of rail service demanded for feed grains on the combined peak and off-peak rail rate policy, total United States, crop year 1974-75[1]

Truck and barge rate response with alternative rate solutions	Time periods								Total quantity	Excess carrying capacity
	T_1 (Oct.-Dec.)		T_2 (Jan.-Mar.)		T_3 (Apr.-May)		T_4 (June-Sept.)			
	Quantity	Seasonal index	Quantity	Seasonal index	Quantity	Seasonal index	Quantity	Seasonal index		
	Million bushels	*Index*	*Million bushels*	*Index*	*Million bushels*	*Index*	*Million bushels*	*Index*	*--Million bushels--*	
Scenario 1:[2]										
Base	841	1.77	613	1.29	186	0.58	263	0.41	1,903	1,645
5 percent	596	1.20	273	.55	460	1.39	662	1.00	1,991	736
10 percent	470	.96	292	.59	489	1.49	713	1.09	1,964	970
15 percent	428	.90	274	.58	506	1.60	687	1.09	1,895	1,741
20 percent	394	.82	263	.55	511	1.59	754	1.18	1,922	1,143
25 percent	352	.75	208	.44	502	1.60	820	1.31	1,882	1,131
30 percent	320	.67	203	.43	503	1.59	867	1.38	1,893	1,123
Scenario 2:[3]										
Base	841	1.77	613	1.29	186	.56	263	.41	1,903	1,645
5 percent	786	1.57	436	.87	379	1.13	403	.60	2,004	1,155
10 percent	681	1.34	273	.54	451	1.33	622	.92	2,027	696
15 percent	613	1.23	286	.57	448	1.35	643	.97	1,990	700
20 percent	603	1.23	293	.60	445	1.36	617	.94	1,958	712
25 percent	524	1.07	306	.63	447	1.37	679	1.04	1,956	728
30 percent	535	1.07	302	.60	469	1.41	696	1.04	2,002	811

[1]See table 2 for combined increase and decrease in rail rates by time period and transportation region.
[2]Combined peak and off-peak rail rates without a rate response from truck and barge modes.
[3]Combined peak and off-peak rail rates with an equal percentage rate response from truck and barge modes.

tion in seasonal variation than without the rate response because less rail traffic was diverted to the competing modes of transportation. Thus, when rates were changed for all modes, a larger increase was required to create an incentive to substitute country storage for rail transport during the peak periods than when rates were changed only for rail.

With many of the alternative percentage changes in rates, rail capacity of most regions would be fully utilized within the newly established peak rail demand periods, regardless of rate-response scenario. If additional capacities had been available, total system costs could have been reduced slightly for many of the different changes in rates. For example, with a 30-percent change in rail rates, an additional bushel of rail capacity would provide savings that ranged from a low of $0.002 per bushel for the Northwest region to a high of $0.22 per bushel for the Southwest region. If this capacity were added, the seasonal variation of rail service demanded would also increase, although total system costs would decline (fixed costs of additional rail cars were not included). However, a rate response by truck and barge reduced the potential cost savings for many regions, when compared to a change in rail rates only. Potential cost savings declined because the substitute modes of transport reduced their rates, which diverted rail traffic to the competing modes of transportation.

Location of Storage Stocks Within the Marketing Chain

A third major goal of demand-sensitive rates was to provide an incentive for rescheduling rail shipments to nonpeak periods. Shippers would likely reduce the quantity of feed grains transported by rail during the peak demand periods and place these quantities into storage. During a later slack demand period these quantities would be scheduled to move by rail to their destination. Thus, the peak rail demand would be alleviated and the overall seasonal demand for rail transportation would decline.

Two conditions seemed necessary to achieve the goal. First, storage capacity must be sufficient to hold the increased quantities stored. These facilities could be furnished through existing underutilized capacity or through the construction of new facilities. The authors estimated total storage capacity for the U.S. feed grain marketing system to be 7.3 billion bushels (table 6). Most of this capacity was located at country points (89 percent). The terminal, domestic demand, and export demand points accounted for the remaining 4, 5, and 2 percent, respectively. In the base solution, excess storage capacity was available at each aggregate storage facility during the peak demand period (T_1). However, storage capacity could be fully utilized within a specific production and consumption region.

The second condition required the substitution of storage for rail transportation services to be greater than the substitution of truck and barge for rail transportation services. Otherwise, rail shipments would be diverted mostly to competing modes of transportation, which could reduce total rail revenue and could increase the seasonal demand for other modes.

The general hypothesis for this section was that storage quantities would increase during the peak demand periods at the country or terminal point with an offsetting decrease at domestic or export demand points. The substitution of storage for rail transportation was expected to be greater than the substitution of competing transport for rail transport service. In the long run, new facilities would be located at the surplus production points or deficit domestic demand areas or a combination of both (incentives permitting).

Shifts in stocks within the marketing chain were expected to differ by surplus and deficit feed grain region. During the peak demand periods, increases in country stocks were hypothesized to occur mostly within the surplus rather than deficit regions. During the off-peak demand periods, increases in domestic demand stocks were hypothesized to occur mostly within the deficit rather than surplus regions.

Changes in Country Storage Stocks Three of the four surplus feed grain regions supported the hypothesized relationship (table 7 and 12). Country storage stocks for the Midwest, Middle Central, and North Central regions increased during their peak rail demand periods regardless of rate response by truck and barge. In contrast to the hypothesis, stocks declined for the South Central region. In general, a rate response by all modes reduced the amount of rail traffic diverted to truck and barge because storage became a more feasible alternative. Country storage stocks for the South Central region declined rather than increased during T_1 and T_2, regardless of rate response by truck and barge. Although rail shipments did not change, inventories at the country storage facilities declined because of increased truck shipments to the west gulf export points and Southwest domestic markets. Thus, regardless of the rate response by truck and barge, the South Central region increased its total shipments during the peak demand periods and replaced some rail shipments from the more distant surplus regions.

Country storage stocks for the deficit feed grain regions were hypothesized to decrease during their respective peak rail demand periods. In contrast to the hypothesis, storage stocks generally rose during the peak demand period, regardless of rate response from truck and barge. Both the Northeast and Southeast deficit regions had surpluses in feed grains during T_1;

Table 6—Estimated total U.S. feed grain storage capacity with base solution quantities stored and percentage of capacity utilization, by facility and time period, crop year 1974-75

Storage facility	Storage capacity	Base solution: T_1 (Oct.-Dec.) Quantities stored	T_1 Capacity utilization	T_2 (Jan.-Mar.) Quantities stored	T_2 Capacity utilization	T_3 (Apr.-May) Quantities stored	T_3 Capacity utilization	T_4 (June-Sept.) Quantities stored	T_4 Capacity utilization
	---Million bushels---		*Percer*	*Million bushels*	*Percent*	*Million bushels*	*Percent*	*Million bushels*	*Percent*
Country	6,528	3,812	58	2,140	32	1,294	20	1,357	21
Terminal	303	172	57	172	57	172	57	173	57
Domestic demand	371	343	92	293	79	259	69	233	63
Export demand	147	92	63	92	63	89	61	59	40

Table 7—Changes in stock levels by storage facility, transportation region, and time period due to changes in rail rates without a rate response from truck and barge, crop year 1974-75

Storage facilities and transportation regions	Alternative rail rate changes in various times periods[1,2]											
	10 percent				20 percent				30 percent			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
	Million bushels											
Country facilities:												
Northeast	17	-23	6	0	15	-22	6	4	11	-16	6	5
Southeast	-5	-4	9	1	19	-17	-2	0	23	-30	7	1
Midwest	39	106	-99	-77	58	149	-97	-140	71	246	-95	-253
North Central	75	-34	-55	-1	79	-36	-61	36	95	-82	-64	31
Middle Central	47	109	-31	-158	44	87	-52	-159	49	49	-34	-161
South Central	-109	-42	74	47	-101	-52	68	41	-96	-57	68	37
Northwest	-9	4	4	9	-13	9	4	9	-13	10	3	14
Southwest	-4	1	3	36	-4	1	3	51	-4	1	3	51
Total[3]	51	117	-89	-143	99	136	-131	-158	136	121	-106	-277
Terminal facilities:												
Northeast	0	0	[4]	[4]	0	0	0	1	-53	42	20	6
Midwest	-5	0	0	0	-5	0	0	0	0	0	0	1
North Central	0	0	0	0	0	0	0	0	-5	0	0	0
Middle Central	0	0	0	0	-7	-1	5	0	-39	39	0	0
South Central	0	0	0	13	0	1	6	12	-9	[4]	6	0
Northwest	0	0	0	2	0	0	0	1	0	3	14	3
Total[3]	-5	0	[4]	15	-12	[4]	11	14	0	0	0	2
Domestic demand facilities:												
Northeast	-9	-13	10	28	-9	-12	10	27	-10	-25	43	50
Southeast	0	-50	19	57	-15	-51	38	55	-11	-58	15	89
Midwest	0	-5	6	7	0	-29	1	23	0	-29	2	23
North Central	0	0	0	0	-4	4	0	0	-11	10	-4	4
Middle Central	0	-18	-21	38	-21	3	-1	19	-38	20	-8	25
South Central	0	-33	20	15	0	-33	20	9	0	-33	12	18
Northwest	-4	-3	6	0	-3	-2	6	0	-4	-2	6	0
Southwest	-21	17	24	-20	-22	17	27	-22	-22	17	34	-30
Total[3]	-34	-103	64	125	-74	-103	101	111	-94	100	100	179
Export demand facilities:												
Northeast	0	-11	11	2	0	-11	13	8	0	-11	2	19
Southeast	0	-14	14	0	0	-14	14	14	0	-14	0	29
Midwest	0	0	0	0	0	-1	-8	6	0	-26	-12	39
North Central	-16	16	-1	0	-16	16	-4	4	16	16	-4	4
South Central	4	-4	0	1	4	-4	0	0	-27	-27	0	0
Northwest	0	0	0	0	0	0	0	0	0	0	0	0
Southwest	[4]	-1	[4]	0	1	-1	[4]	1	[4]	-1	[4]	1
Total[3]	-12	-14	25	2	-11	-15	18	33	11	-63	-14	92

[1]See table 2 for the combined increase and decrease in rail rates by time period and transportation region.
[2]T_1 = (Oct.-Dec.); T_2 = (Jan.-Mar.); T_3 = (Apr.-May); T_4 = (June-Sept.).
[3]May not add to total due to rounding.
[4]Less than 1 million bushels.

however, they also received rail shipments of feed grains from surplus regions during this period. Because of an increase in rail rates, country storage stocks within the deficit regions were expected to be used to supply the domestic demands of their region. Instead, country stocks increased and rail shipments declined within the deficit regions, and rail shipments continued from the surplus regions. However, during T_2, rail shipments from the deficit regions increased but declined from the surplus regions because T_2 was an average rail demand period (no change in rail rates) for the deficit regions but a peak demand period (increased rail rates) for the surplus regions. Thus, from a total system viewpoint, it appeared less costly to receive feed grains from the surplus areas during T_1 than to rely more heavily upon the deficit regions' country storage stocks during T_2.

Stock levels for the Northwest and Southwest increased during their peak periods because rail rates in these regions were increased during these periods; rates were generally decreased for the surplus regions supplying these deficit regions.

Changes in Domestic Demand Storage Stocks The combined peak and off-peak rail rate policy created an incentive for additional storage stocks to be located at the domestic demand points during the off-peak rail demand periods of T_3 and T_4.

One exception to this general finding was the deficit Southwest region. Instead of increasing, storage stocks declined during the off-peak rail demand periods, T_1 and T_4. Stock levels declined during these periods because the Southwest experienced a deficit in feed grains during each time period, and its supply regions experienced increased rail rates during this time period. Thus, the only movement of feed grains was for immediate consumption.

With the equal percentage rate response from trucks and barges, inventory levels at the deficit demand points tended to increase slightly beyond those levels without a rate response from truck and barge (*12*). However, most of the increase in domestic demand stocks occurred within the surplus regions. Thus, an overall freight rate increase created a slight incentive to expand inventory levels within the deficit domestic demand regions and a greater incentive within the surplus regions.

Construction of Additional Storage Capacity In addition to shifting the location of storage stocks within the existing marketing chain, a question arose on whether new storage facilities would be constructed within the marketing chain as a result of railroad rate incentives. Assuming these incentives existed, the authors hypothesized that new facilities would be constructed at the surplus production or deficit demand points, or a combination of both.

As expected, additional storage capacity was constructed at several deficit demand points but required at least 25-percent change in rail rates. The 25-percent change in rail rates created an incentive for approximately 7 million bushels of new storage capacity to be built at the domestic demand point in northern Georgia, a deficit feed grain region. Both existing and new storage facilities were full during T_3 and T_4, with a 25-percent change in rail rates.

Assuming an equal percentage rate response from truck and barge, the above incentives for additional storage at the deficit demand points should increase. Results from the 15-, 20-, 25-, and 30-percent rate change solutions supported this hypothesis. For example, a 15-percent change in rates created an incentive for 8.6 million bushels of storage capacity to be built in the Northeast.

Feed Grain Prices at Country Points

Another goal of demand-sensitive rail rates was to improve the financial stability of markets served by railroads. The market selected for analysis was the country point, a major market for feed grain producers. The authors assumed the feed grain producers would face an elastic demand curve and a relatively inelastic supply curve during the four time periods. Since the producer is generally considered a price taker, higher peak-period rail rates would tend to reduce the price received by producers. However, the impact of an off-peak (lower) rail rate would tend to increase the price received. Because of the combined peak and off-peak rail rate policy, the average quarterly price received in the country was not expected to change significantly.

In contrast to the hypothesized relationship, the average quarterly price increased slightly for east central Illinois (#19), a landlocked surplus feed grain region.[10] The average quarterly price rose from $0.004 to $0.022 per bushel for a 10- and 30-percent change in rail rates, respectively. Average quarterly prices rose because the price gains of T_3 and T_4 exceeded price declines of T_1 and T_2. During T_1 and T_2, the peak rail rate periods, east central Illinois (#19) discontinued its rail shipments to the Gulf of Mexico ports. Although prices declined during T_1 and T_2, the decline was not equal to the increase in rail rates. Barge, rail, or truck shipments from other regions were increased to replace those rail shipments. During T_3 and T_4, the off-peak rail periods, rail rates were reduced and rail shipments from east central Illinois (#19) were resumed. As a result, the price increase during these periods was nearly equal to the decline in rail rates.

Assuming an equal percentage rate response from truck and barge, the average quarterly price change for east central Illinois was −$0.001, +$0.004, and +$0.005 per bushel with a 10-, 20-, and 30-percent change in rail rates respectively (table 8). These price changes were somewhat less than the corresponding

[10]Numbers in parentheses identify the domestic producing and consuming regions delineated in appendix A.

Table 8—Changes in country feed grain prices relative to the New Orleans price due to changes in rail rates by selected production region and time period, crop year 1974-75

Production region and time period	Price change between base and alternative rail rate solutions					
	Without a rate response from truck and barge[1]			With an equal percentage rate response from truck and barge[1]		
	10 percent	20 percent	30 percent	10 percent	20 percent	30 percent
	Dollars per bushel					
New England and New York (#1):						
T_1 (Oct.-Dec.)	0.022	0.040	0.047	0.004	0.004	0.004
T_2 (Jan.-Mar.)	.011	.029	.035	.001	−.006	−.007
T_3 (Apr.-May)	.044	.080	.098	.045	.042	.160
T_4 (June-Sept.)	−.013	−.026	−.005	−.013	−.018	−.117
Average	.016	.031	.044	.037	.006	.036
North Alabama (#8):						
T_1	.005	−.005	.012	.001	−.003	−.009
T_2	−.005	0	.015	−.001	−.009	−.001
T_3	.028	.050	.077	.043	.075	.119
T_4	.008	.002	.001	.004	.011	.015
Average	.009	.012	.026	.012	.019	.031
East Central Illinois (#19):						
T_1	−.005	−.005	−.005	−.021	−.032	−.051
T_2	−.016	−.016	−.016	−.025	−.043	−.062
T_3	.017	.035	.047	.020	.041	.060
T_4	.021	.049	.062	.023	.049	.074
Average	.004	.016	.022	−.001	.004	.005
West Central Illinois (#20):						
T_1	−.003	−.003	−.003	−.015	−.027	−.039
T_2	−.013	−.013	−.014	−.019	−.041	−.050
T_3	.019	.037	.048	.025	.046	.071
T_4	.008	.033	.046	.012	.036	.068
Average	.003	.013	.019	.001	.004	.013
Nebraska (#31):						
T_1	−.015	−.039	−.047	−.019	−.033	−.055
T_2	−.026	−.050	−.058	−.023	−.044	−.065
T_3	.008	.002	.005	.022	.040	.056
T_4	−.004	−.003	.001	.008	.029	.052
Average	−.009	−.023	−.025	−.003	.002	−.003

[1]See table 2 for combined increase and decrease in rail rates by time period and transportation region.

changes without a rate response from truck and barge. The average quarterly prices were lower because barge shipments were reduced from other regions and some rail shipments resumed during T_1 and T_2 for east central Illinois. Thus the price decline during T_1 and T_2 tended to offset the gains during T_3 and T_4. Therefore, an equal percentage rate response by truck and barge tended to support the hypothesized relationship of an insignificant change in average prices received.

Average quarterly prices increased slightly beyond the base solution for west central Illinois (#20), a surplus feed grain region with access to both barge and rail transportation. Increases in average quarterly prices ranged from $0.013 to $0.019 per bushel for the 10- through 30-percent change in rail rates, respectively (table 8). Assuming an equal percentage rate response from truck and barge, the average quarterly price increased again from $0.001 to $0.013 per bushel for the 10- through 30-percent change in rates, respectively. Thus, average prices tended to increase slightly rather than remain constant, as hypothesized, regardless of rate response by truck and barge. Average prices increased because barge shipments expanded during the peak rail demand periods and thus the price decline was minimal. Secondly, during the slack rail demand period, rail shipments to the East Coast expanded due to a reduction in rail rates. Thus, the price increase of T_3 and T_4 was greater than the decline of T_1 and T_2.

In contrast to the results for central Illinois (#19 and #20), average quarterly prices declined in Nebraska (#31), a surplus feed grain region. Prices in New Orleans declined from $0.009 to $0.025 per bushel with a 10- through 30-percent change in rail rates, respectively. Prices for Nebraska declined because there was a lack of lower priced alternative transportation. Since the Missouri River was frozen during T_2, barge transportation was not an alternative mode of transportation during this period. Thus, long-haul shipments from Nebraska during T_2 had to move by rail, which was assessed a higher rate. As a result of an equal percentage rate response by truck and barge, the quarterly prices also declined, but less than the prior scenario without a rate response by truck and barge. Prices declined by about $0.003 per bushel with a 10-, 20-, or 30-percent change in rates. The reduction in barge rates during T_3 and T_4 apparently caused a greater price rise during these periods, which more nearly offset the declines during T_1 and T_2.

The feed grain deficit regions, the Northeast (#1) and North Alabama (#8), each had positive price gains relative to the New Orleans price. The increase in average quarterly price for the Northeast (#1) ranged from $0.016 per bushel for the 10-percent change in rail rates to $0.044 per bushel for the 30-percent change in rail rates. With an equal percentage rate response by truck and barge, prices rose more than without the rate response by truck and barge.

North Alabama (#8) had an average quarterly price rise which ranged from $0.005 per bushel for the 10-percent change in rail rates to $0.026 per bushel for the 30-percent change. The average quarterly price improved slightly with the equal percentage rate response by truck and barge. Thus, results from both deficit regions did not support the hypothesized relationship. Instead, country prices in the deficit regions increased relative to the New Orleans price. Prices in the deficit feed grain regions rose more than the prices in some surplus regions. Although the results suggest an increased advantage for producers in the deficit regions, this analysis was static and did not capture the regional dynamics of feed grain supply and demand. Thus, while deficit areas may gain in comparative advantage relative to the surplus areas, this analysis did not measure the exact gains.

Total Costs

Total costs for the base solution were $1.36 billion for the crop year 1974/75 (T_1-T_4). Transportation, handling, and storage accounted for 64, 16, and 20 percent of all costs, respectively. Total costs for transportation, handling, and storage were expected to increase as a result of the combined peak and off-peak rail rate policy.

National Impact Both rate response scenarios increased total costs although not for each alternative rate change solution. A 10-percent change in rail rates caused total costs to rise from $1.36 to $1.38 billion, an increase of 1 percent (table 9). Transportation costs accounted for the greatest portion of the increase, followed by storage costs. Handling costs declined slightly. In contrast, a 20- and 30-percent change in rail rates caused total costs to decline by $853,000 and $6.7 million, respectively.

Table 9—Alternative total costs by transportation region and cost component due to a change in rail rates, crop year 1974-75

Rail rate solutions and transportation region[1]	Cost components[2]										New capacity[3]	Total costs	Percentage change from base solution
	Transportation				Handling	Storage							
	Truck	Rail	Barge	Total		Country	Terminal	Domestic demand	Export demand	Total			
	Million dollars												Percent
Base solution:													
Northeast	14.4	10.7	0	25.2	8.3	4.1	0.1	2.1	0.5	6.8	0	40.3	
Southeast	35.5	17.3	0	52.9	19.9	10.1	0	4.4	.7	15.3	0	88.1	
Midwest	16.7	188.4	40.2	245.3	95.4	61.2	.5	2.7	3.5	67.8	0	408.5	
North Central	29.8	71.0	21.6	122.4	25.2	42.8	1.9	1.1	1.1	47.1	0	194.6	
Middle Central	58.1	122.2	30.7	210.9	46.7	83.7	8.8	4.3	0	96.8	0	354.5	
South Central	97.2	17.4	1.4	115.9	19.7	24.5	.3	2.5	0	27.3	0	162.9	
Northwest	3.3	13.2	5.0	21.4	.9	2.7	.04	.5	0	3.2	0	25.5	
Southwest	68.6	5.7	0	74.4	10.5	1.4	0	2.2	.01	3.6	0	88.5	
Total	323.6	446.0	98.8	868.4	226.5	230.5	11.8	19.9	5.9	268.0	0	1,363.0	
10-percent rail rate solution:													
Northeast	13.9	12.2	0	26.2	8.3	4.5	.2	1.9	.3	6.9	0	41.4	
Southeast	35.2	16.7	.04	52.0	19.9	9.8	0	3.8	.4	13.9	0	85.7	
Midwest	24.1	185.5	40.3	245.0	103.9	67.1	.08	2.8	3.5	73.6	0	427.4	
North Central	29.8	76.6	21.6	128.0	23.5	45.1	1.9	1.2	.9	49.1	0	200.6	
Middle Central	60.4	143.9	25.5	229.8	37.1	89.4	8.8	3.2	0	101.7	0	368.6	
South Central	107.5	19.5	1.7	128.7	20.8	17.5	.7	1.8	.2	20.1	0	169.6	
Northwest	4.8	9.9	4.4	19.2	1.2	2.6	.09	.3	0	3.0	0	23.4	
Southwest	45.5	6.2	0	51.7	9.4	2.4	0	1.9	.07	4.4	0	65.4	
Total	321.2	470.6	93.6	885.5	224.0	238.3	11.8	17.1	5.4	272.7	0	1,382.2	1.4
20-percent rail rate solution:													
Northeast	17.8	7.6	0	25.4	8.0	4.4	.2	1.8	.6	7.0	0	40.6	
Southeast	35.0	17.7	0	52.7	19.8	10.9	0	3.3	.8	15.0	0	87.6	
Midwest	25.6	178.3	40.3	244.2	99.9	71.4	.08	1.6	3.4	76.5	0	420.6	
North Central	31.0	47.1	21.6	99.8	22.4	46.5	1.9	1.1	.9	50.4	0	172.6	
Middle Central	66.5	148.2	28.6	243.3	38.9	86.6	8.4	3.6	—	98.6	0	380.8	
South Central	106.2	32.8	.6	139.6	22.3	17.1	.9	1.7	.2	19.9	0	181.8	
Northwest	10.3	6.6	3.2	20.1	2.0	2.5	.09	.3	0	2.9	0	25.1	
Southwest	38.5	4.2	0	42.7	5.4	2.9	—	1.9	.07	4.9	0	53.0	
Total	331.1	442.6	94.3	868.0	218.8	242.4	11.7	15.4	5.9	275.4	0	1,362.1	−.06
30-percent rail rate solution:													
Northeast	20.2	8.0	0	28.2	8.1	4.5	.2	2.8	.4	7.9	4.4	48.5	
Southeast	44.9	13.9	0	58.8	19.6	10.8	0	3.3	.6	14.7	2.3	95.3	
Midwest	27.3	159.4	35.1	221.9	92.9	78.2	.08	1.6	2.6	82.5	0	397.3	
North Central	35.6	45.0	26.5	107.2	23.2	44.2	1.5	1.0	.8	47.5	0	178.0	
Middle Central	77.3	130.5	30.7	238.5	32.6	85.1	8.4	3.0	—	96.5	0	367.6	
South Central	106.3	44.1	1.7	152.0	19.4	17.1	1.2	1.5	1.2	21.0	0	192.4	
Northwest	9.1	6.3	3.2	18.5	1.2	2.7	.09	.3	—	3.1	0	22.8	
Southwest	38.5	3.7	0	42.2	7.2	2.9	—	2.0	.07	5.0	0	54.4	
Total	359.2	411.0	97.2	867.5	204.2	245.4	11.4	15.6	5.8	278.2	6.6	1,356.3	−.50

— = less than $50,000.
[1]See table 2 for the combined increase and decrease in rail rates by time period and transportation region. [2]Totals may not add due to rounding.
[3]These costs represent annual replacement costs for new storage capacity.

With a change in rates by all modes, total costs increased steadily (12). A change in all rates by 10, 20, and 30 percent increased costs by $37, $59, and $85 million, respectively. Transportation and storage costs increased with each rate change by all modes. Handling costs declined with 10- and 30-percent changes in rates but increased slightly with a 20-percent change.

Transportation. Transportation costs, the first cost component, are costs to shippers, but they represent gross revenue to the transport carrier. Thus, if the shippers' transport costs rise, gross revenue to the carrier must also rise. When only rail rates were changed by 10 percent, transportation costs increased by $17 million; but when rail rates were increased by 20 to 30 percent, transport costs declined by $446,000 and $997,000, respectively. Transport costs increased due to an increase in rail revenue but declined with the larger rate increases because rail and barge revenue declined.

Assuming an equal percentage rate response by truck and barge, transport costs increased by $42, $41, and $63 million with 10-, 20-, and 30-percent changes in transport rates, respectively. Transport costs generally increased for each mode because of the general increase in rate level.

Handling. Handling costs, the second cost component, generally declined with each rate change solution regardless of rate response scenario. Since these costs differed by transport mode, grain handling facility, and region, a reduction in costs suggested a shift to a less costly mode or handling facility. Since shipper handling costs would decline, grain handling firms could experience a drop in revenue.

Storage. Storage costs, the third cost component, increased with each alternative rate solution, regardless of rate response by truck and barge. In general, most of the rise in storage costs occurred at the country point facilities. Storage costs at terminal, domestic demand, and export demand points generally declined as transport rates were changed. Such a shift in costs indicates that stocks are being stored longer at the country points. Although storage revenue at the country facilities may rise, the effect on the farmer would be increased storage costs.

Regional Impact Total costs generally increased for all transportation regions that were surplus in feed grains with each alternative rate solution, regardless of rate response by truck and barge. In contrast, the deficit feed grain regions generally experienced a decline in total costs. The decline in costs for deficit regions was due mostly to a reduction in the transportation and handling components. Transportation costs declined because most of the feed grains were transported during normal or off-peak periods.

Limitations of the Study

Several limitations existed with this study. Results of this study were normative in nature. Changes in transportation shipments and quantities stored were observed due to changes in transportation rates. Other decision variables such as transport service characteristics were not considered or were held constant. Thus, transport service characteristics such as transit time or loss and damage could alter the results of this study.

This study assumed that rail rates were changed for each region of the country. Thus, findings of this study could differ if these rates were applied to only one region of the country rather than to all regions.

Only feed grains were considered in the analysis. Other commodities such as wheat and soybeans compete for the use of transportation and storage resources. Although an adjustment was made to account for the exclusion of these commodities, results of this study would have been more realistic had they been included.

Costs of storage and handling were used in the model as a proxy for storage and handling rates. Significant differences between costs and rates could alter the quantities stored or transported by region.

Some of the transportation capacity estimates used in the model were hypothetical. These estimates are crucial because they make available or restrict transport capacity, which could affect quantities stored or transported.

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Appendix A—Identification number and name of domestic producing and consuming regions and export ports

Identification number	Name of domestic producing and consuming region
1	New England and New York
2	Pennsylvania, New Jersey, Delaware, and Maryland
3	Virginia and West Virginia
4	North and South Carolina
5	North Georgia
6	South Georgia
7	Florida
8	North Alabama
9	South Alabama
10	North and West Mississippi
11	Southeast Mississippi
12	Tennessee
13	Kentucky
14	Ohio
15	Michigan
16	Indiana
17	Wisconsin
18	North Illinois
19	East Central Illinois
20	West Central Illinois
21	South Illinois
22	Minnesota
23	West Iowa
24	Central Iowa
25	East Iowa
26	Missouri
27	Arkansas
28	Louisiana
29	North Dakota
30	South Dakota
31	Nebraska
32	Kansas
33	Oklahoma
34	Northeast Texas
35	Southeast Texas
36	West Texas and New Mexico
37	Colorado
38	Montana and Wyoming
39	Washington and Oregon
40	Idaho, Nevada, and Utah
41	California and Arizona

Identification number	Name of export ports
42	California:
	San Francisco[1]
	Stockton
	Sacramento
	Long Beach
43	Oregon and Washington:
	Portland[1]
	Kalama
	Astoria
	Longview
	Vancouver
	Seattle
44	Duluth-Superior[1]
45	Chicago[1] and Milwaukee
46	East Great Lakes:
	Saginaw, Michigan
	Carrollton, Michigan
	Zilwaukee, Michigan
	Toledo, Ohio[1]
	Huron, Ohio
	Erie, Pennsylvania
	Buffalo, New York
47	North Atlantic:
	Philadelphia, Pennsylvania[1]
	Albany, New York
48	South Atlantic:
	Baltimore, Maryland
	Norfolk, Virginia[1]
	Charleston, South Carolina
49	East Gulf:
	Mobile, Alabama[1]
	Pascagoula, Mississippi
50	Mississippi River:
	New Orleans, Louisiana[1]
	Destrehan, Louisiana
	Port Allen, Louisiana
	Myrtle Grove, Louisiana
	Ames, Louisiana
	Reserve, Louisiana
51	Texas Gulf:
	Houston[1]
	Port Arthur
	Galveston
	Beaumont
	Corpus Christi
	Brownsville

[1]Indicates port selected as a base point for the geographic area.

Appendix B—Base point location for domestic regions and ports of export by activity center

Identification number	Activity centers				
	Country and domestic demand point	Country point	Domestic demand point	Terminal point	Export point
			City and State		
Domestic regions:					
1	NA	Geneva, NY	Concord, NH	Buffalo, NY	NA
2	NA	Lancaster, PA	Salisbury, MD	NA	NA
3	Harrisonburg, VA	NA	NA	NA	NA
4	Wilson, NC	NA	NA	NA	NA
5	Gainesville, GA	NA	NA	NA	NA
6	Valdosta, GA	NA	NA	NA	NA
7	Tampa, FL	NA	NA	NA	NA
8	Guntersville, AL	NA	NA	NA	NA
9	Montgomery, AL	NA	NA	NA	NA
10	Indianola, MS	NA	NA	NA	NA
11	Jackson, MS	NA	NA	NA	NA
12	Nashville, TN	NA	NA	NA	NA
13	Louisville, KY	NA	NA	NA	NA
14	Columbus, OH	NA	NA	Toledo, OH	NA
15	Jackson, MI	NA	NA	NA	NA
16	Indianapolis, IN	NA	NA	NA	NA
17	Milwaukee, WI	NA	NA	NA	NA
18	Freeport, IL	NA	NA	Chicago, IL	NA
19	Tuscola, IL	NA	NA	NA	NA
20	Decatur, IL	NA	NA	NA	NA
21	Cairo, IL	NA	NA	NA	NA
22	Minneapolis, N	NA	NA	Minneapolis MN	na
23	Onawa, IA	NA	NA	NA	NA
24	Des Moines, IA	NA	NA	NA	NA
25	Davenport, IA	NA	NA	NA	NA
26	St. Louis, MO	NA	NA	St. Louis, MO	NA
27	Little Rock, AR	NA	NA	NA	NA
28	Alexandria, LA	NA	NA	NA	NA
29	Fargo, ND	NA	NA	NA	NA
30	Sioux Falls, SD	NA	NA	NA	NA
31	Omaha, NE	NA	NA	Omaha, NE	NA
32	Kansas City, MO	NA	NA	Kansas City, MO	NA
33	Enid, OK	NA	NA	Enid, OK	NA
34	Fort Worth, TX	NA	NA	Fort Worth, TX	NA
35	San Antonio, TX	NA	NA	NA	NA
36	Amarillo, TX	NA	NA	Amarillo, TX	NA
37	Denver, CO	NA	NA	NA	NA
38	Billings, MT	NA	NA	NA	NA
39	Spokane, WA	NA	NA	Portland, OR	NA
40	Ogden, UT	NA	NA	NA	NA
41	Fresno, CA	NA	NA	NA	NA
Export ports:					
42	NA	NA	NA	NA	San Francisco, CA
43	NA	NA	NA	NA	Portland, OR
44	NA	NA	NA	NA	Duluth, MN
45	NA	NA	NA	NA	Chicago, IL
46	NA	NA	NA	NA	Toledo, OH
47	NA	NA	NA	NA	Philadelphia, PA
48	NA	NA	NA	NA	Norfolk, VA
49	NA	NA	NA	NA	Mobile, AL
50	NA	NA	NA	NA	New Orleans, LA
51	NA	NA	NA	NA	Houston, TX

NA = not applicable.

Appendix C—Mathematical representation of model

The objective function of this model minimized the cost of storing, handling, and transporting a unit of feed grain as expressed in equation,[1]

$$\begin{aligned}
\text{Min } Z = {} & \sum_t \sum_m \sum_c \sum_l C_{tmcl} L_{tmcl} \quad (1) \\
& + \sum_t \sum_m \sum_c \sum_d C_{tmcd} D_{tmcd} \\
& + \sum_t \sum_m \sum_c \sum_e C_{tmce} E_{tmce} \\
& + \sum_t \sum_m \sum_l \sum_d C_{tmld} D_{tmld} \\
& + \sum_t \sum_m \sum_l \sum_e C_{tmle} E_{tmle} \\
& + \sum_t \sum_c \sum_l \sum_d \sum_e C_{tclde} S_{tclde} \\
& + \sum_c \sum_l \sum_d \sum_e C_{clde} CP_{clde}
\end{aligned}$$

where:

Z = total system costs (transportation, handling, storing, and storage construction)
t = time period (t = 1, 2, 3, 4, 5)
m = mode of transport (truck, rail, or barge)
c = country point (c = 1.....41)
l = terminal point (l = 1.....11)
d = domestic demand point (miller and processer combined) (d = 1.....41)
e = export port (e = 42.....51)
r = transport region (r = 1.....8)
s = river segment (s = 1.....9)

[1]The term "cost" refers to shipper's cost.

C_{tmcl} = Cost of transferring (transportation and handling) a unit of feed grains from country point to terminal point by mode of transport and time period

L_{tmcl} = Quantity of feed grains transferred from country point to terminal point by mode of transport and time period

C_{tmcd} = Cost of transferring (transportation and handling) a unit of feed grains from country point to domestic demand point by mode of transport and time period

D_{tmcd} = Quantity of feed grains transferred from country point to domestic demand point by mode of transport and time period

C_{tmce} = Cost of transferring (transportation and handling) a unit of feed grains from country point to export demand point by mode of transport and time period

E_{tmce} = Quantity of feed grains transferred from country point to export demand point by mode of transport and time period

C_{tmld} = Cost of transferring (transportation and handling) a unit of feed grains from terminal point to domestic demand point by mode of transport and time period

D_{tmld} = Quantity of feed transferred from terminal point to domestic demand point by mode of transport and time period

C_{tmle} = Cost of transferring (transportation and handling) a unit of feed grains from terminal point to export demand point by mode of transport and time period

E_{tmle} = Quantity of feed grains transferred from terminal point to export demand point by mode of transport and time period

C_{tclde} = Cost of storing a unit of feed grains at a country point, terminal point, domestic demand point, and export demand point by time period

S_{tclde} = Quantity of feed grains stored at a country point, terminal point, domestic demand point, and export demand point by time period

C_{clde} = Cost of building an additional unit of storage capacity at a country point, terminal point, domestic demand point, and export demand point

CP_{clde} = Quantity of additional storage capacity built at a country point, terminal point, domestic demand point, and export demand point

The objective function was subject to the following seven constraints, equations (2)-(8).

$$\sum_t \sum_c \sum_l L_{tcl} + \sum_t \sum_c \sum_d D_{tcd} + \sum_t \sum_c \sum_e E_{tce} + \sum_t \sum_c D_{tc} + \sum_t \sum_c S_{tc} = \sum_t \sum_c I_{tc} + \sum_t \sum_c P_{tc} \tag{2}$$

L_{tcl} = Quantity of feed grains transferred from a country point to terminal point by time period

D_{tcd} = Quantity of feed grains transferred from a country point to domestic demand point by time period

E_{tce} = Quantity of feed grains transferred from a country point to an export demand point by time period

D_{tc} = Quantity of feed grains demanded locally by time period

S_{tc} = Quantity of feed grains stored at a country point by time period

I_{tc} = Quantity of feed grain inventory at a country point transferred between time periods

P_{tc} = Regional production of feed grains by country point and time period

$$\sum_t \sum_l \sum_d D_{tld} + \sum_t \sum_l \sum_e E_{tle} + \sum_t \sum_l S_{tl} - \sum_t \sum_c \sum_l L_{tcl} = \sum_t \sum_l I_{tl} \tag{3}$$

where:

D_{tld} = Quantity of feed grains transferred from a terminal point to a domestic demand point by time period

E_{tle} = Quantity of feed grains transferred from a terminal point to an export demand point by time period

S_{tl} = Quantity of feed grains stored at a terminal point by time period

L_{tcl} – Quantity of feed grains transferred from a country point to a terminal point by time period

I_{tl} – Quantity of feed grain inventory at a terminal point transferred between time periods

$$\sum_t \sum_d D_{td} + \sum_t \sum_d S_{td} - \sum_t \sum_c \sum_d D_{tcd} \quad (4)$$

$$- \sum_t \sum_l \sum_d D_{tld} - \sum_t \sum_d I_{td}$$

where:

D_{td} – Quantity of feed grains demanded domestically (millers and processors) by domestic demand point and time period

S_{td} – Quantity of feed grains stored at a domestic demand point by time period

D_{tcd} – Quantity of feed grains transferred from a country point to a domestic demand point by time period

D_{tld} – Quantity of feed grains transferred from a terminal point to a domestic demand point by time period

I_{td} – Quantity of feed grain inventory transferred between time periods by demand point

$$\sum_t \sum_e E_{te} + \sum_t \sum_e S_{te} - \sum_t \sum_c \sum_e E_{tce} \quad (5)$$

$$- \sum_t \sum_l \sum_d E_{tld} - \sum_t \sum_e I_{te}$$

where:

E_{te} = Quantity of feed grains demanded for export by export demand point and time period

S_{te} = Quantity of feed grains stored at an export demand point by time period

E_{tce} = Quantity of feed grains transferred from a country point to an export demand point by time period

E_{tle} = Quantity of feed grains transferred from a terminal point to an export demand point by time period

I_{te} = Quantity of feed grain inventory transferred between time periods by export point

$$\sum_t \sum_c \sum_l \sum_d \sum_e S_{tclde} \leq \sum_c \sum_l \sum_d \sum_e SC_{clde} \quad (6)$$

where:

S_{tclde} = Quantity of feed grains stored at a country point, terminal point, domestic demand point, and export demand point by time period

SC_{clde} = Feed grain storage capacity by country point, terminal point, domestic demand point, and export demand point

$$\sum_t \sum_m \sum_r \sum_c \sum_l CL_{tmrcl} \quad (7)$$

$$+ \sum_t \sum_m \sum_r \sum_c \sum_d CD_{tmrcd}$$

$$+ \sum_t \sum_m \sum_r \sum_c \sum_e CE_{tmrce}$$

$$+ \sum_t \sum_m \sum_r \sum_l \sum_d LD_{tmrld}$$

$$+ \sum_t \sum_m \sum_r \sum_l \sum_e LE_{tmrle} \leq \sum_t \sum_m \sum_r TC_{tmr}$$

where:

CL_{tmrcl} = Quantity of feed transferred from a country point to a terminal point by transport region, transport mode, and time period

CD_{tmrcd} = Quantity of feed grains transferred from a country point to a domestic demand point by transport region, transport mode, and time period

CE_{tmrce} = Quantity of feed grains transferred from a country point to an export demand point by transport region, transport mode, and time period

LD_{tmrld} = Quantity of feed grains transferred from a terminal point to a domestic demand point by transport region, transport mode, and time period

LE_{tmrle} = Quantity of feed grains transferred from a terminal point to an export demand point by transport reigon, transport mode, and time period

$TC_{tm\,r\,or\,s}$ = Transport capacity for feed grains by transport region or river segment, transport mode and time period[2]

$$\sum_t \sum_m \sum_r \sum_c \sum_l RCL_{tmrcl} \tag{8}$$

$$+ \sum_t \sum_m \sum_r \sum_c \sum_d RCD_{tmrcd}$$

$$+ \sum_t \sum_m \sum_r \sum_c \sum_e RCE_{tmrce}$$

$$+ \sum_t \sum_m \sum_r \sum_l \sum_d RLD_{tmrld}$$

$$+ \sum_t \sum_m \sum_r \sum_l \sum_e RLE_{tmrle} = \sum_t \sum_m \sum_r TR_{tmr}$$

where:

RCL_{tmrcl} = Gross transport revenue derived from transferring a unit of feed grains from a country point to a terminal point by transport region, transport mode, and time period

RCD_{tmrcd} = Gross transport revenue derived from transferring a unit of feed grains from a country point to a domestic demand point by transport region, transport mode, and time period

RCE_{tmrce} = Gross transport revenue derived from transferring a unit of feed grains from a country point to an export point by transport region, transport mode, and time period

RLD_{tmrld} = Gross transport revenue derived from transferring a unit of feed grains from a terminal point to a domestic demand point by transport region, transport mode, and time period

RLE_{tmrle} = Gross transport revenue derived from transferring a unit of feed grains from a terminal point to an export demand point by transport region, transport mode, and time period

[2]Transport region (I, . . .8) were used with truck and rail modes, but river segments were used with the barge mode.

TR_{tmr} = Total gross transport revenue derived from transporting feed grains by transport region or river segment, transport mode, and time period.

Model Assumptions There are four basic assumptions inherent in linear programming models: (1) deterministic, (2) divisibility, (3) proportionality, and (4) additivity. While all assumptions are not completely valid in the study data, they are sufficiently approximated to justify use of the linear programming model.

Computation of Price Effects In order to explain the price effects, quarterly price differences between selected origins and a basing (destination) point were computed. These differentials denote implied prices and thus are not actual prices. Shadow prices (dual activity values from the model) were used to compute the price differentials. A shadow price represents the marginal cost of each activity center within the model (*19*). For example, country point shadow prices of −$0.10 and +$0.05 per bushel represent a reduction and increase, respectively, in total system costs due to a reduction in 1 bushel of feed grains at each location. Shadow prices also reveal the relative value of feed grains among regions. If the northeast (#1) country point had a shadow price of $0.052 per bushel and east central Illinois had a price of −$0.135 per bushel, the value of feed grains would be $0.187 per bushel more in the Northeast United States (#1) relative to region (#19). (The shadow price of region (#1) relative to region (#19): $0.135 + $0.052 = $0.187.)

The dual solution of a simple least cost transportation problem explains the use of shadow prices in computing price differences. The dual solution becomes a maximization problem as found in equation (1) subject to the constraint of equation (2).

$$\text{Maximize } Z = \Sigma_a D_a Y_a - \Sigma_b O_b Y_b \qquad (1)$$

$$\text{subject to} \qquad D_a - O_b \geq C_{ab} \qquad (2)$$
$$Y_1, Y_2 \geq 0$$

D_a represents the value per unit at the destination, and O_b represents the value per unit at the origin. Equation (1) maximizes the total gain in value of shipments given the values of D_a and O_b subject to the following constraint: the value per unit at the destination (D_a) minus the value per unit at the origin (O_b) is less than equal to the cost (C_{ab}) of transporting one unit between locations. (Note: The D_a's and O_b's are shadow prices derived from the original cost minimization model.) An example of this constraint is as follows: The shadow price (D_a) at New Orleans ($0.115) less the shadow price (O_b) at central Illinois (−$0.179) is less than or equal to the cost of transporting one unit by rail ($0.294). With this example, the difference between shadow prices is exactly equal to the cost of transportation.

Appendix D—Domestic production and consumption regions with access to barge transportation services, by river segment

River segment[1]	Domestic production and consumption regions
Mississippi:	
Minnesota and Wisconsin	Minnesota (#22) and Wisconsin (#17)
Iowa and northern Illinois	Central Iowa (#24), East Iowa (#25), North Illinois (#18), and West Illinois (#20)
St. Louis area	Missouri (#26), West Illinois (#20), and South Illinois (#21)
Memphis area	North and West Mississippi (#10), Tennessee (#12), Arkansas (#27), and Oklahoma (#33)
Missouri:	
Nebraska and Iowa	West Iowa (#23) and Nebraska (#31)
Kansas City area	Missouri (#26) and Kansas (#32)
Illinois	North Illinois (#18), West Illinois (#20), and East Iowa (#25)
Ohio	South Illinois (#21), Indiana (#16), Ohio (#14), Kentucky (#13), Tennessee (#12), and North Alabama (#8)
Snake and Columbia	Montana (#38), Idaho (#40), and Washington and Oregon (#39)

[1]See methodology section for a description of the river segments.

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