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THE PROJECTED IMPACT OF INLAND WATERWAY USER CHARGES ON GRAIN FLOWS AND TRANSPORT COSTS IN 1990

Iowa State University PH.D. 1984

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The projected impact of inland waterway user charges

on grain flows and transport costs

in 1990

by

Jeffrey R. Beaulieu

A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major: Economics

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

For the Major Department

Signature was redacted for privacy.

For the Graduate College

Iowa State University
Ames, Iowa

1984

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CHAPTER I. INTRODUCTION

Brief History of Waterway Development

Toll-free waterways have traditionally served a variety of basic public purposes. These purposes, as outlined by Hull and Hull [23], include the unification of the country, westward expansion and the defeat of sectionalism. However, it was the special benefit of low-cost transportation provided by the inland waterways that encouraged federal support of free access to inland waterways.

As early as 1763, toll-free waterways were recognized as essential to developing the new world. The Treaty of Paris [1763] through which France ceded to Great Britain the territory east of the Mississippi River provided for "mutual liberty of navigation from the source to the sea and stipulated that there be freedom from tolls" [23, p.3]. The Treaty of Paris [1783] between the U.S. and Great Britain reaffirmed this principle. It is however, Article 4 of the Northwest Ordinance[1] of 1787 which had the most direct effect on future legislation. This article stated in part:

> "the navigable waters leading into the Mississippi and St. Lawrence shall be common highways and forever free"

In 1789, an Act of Congress declared the Northwest Ordinance to be officially inoperative "except with regard to Article 4"[23,p.6].

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[1] The Northwest ordinance of 1787 provided for the governance of the area north of the Ohio River, including the present states of Ohio, Illinois, Indiana, Michigan, Wisconsin and parts of Minnesota.

The inland waterways and public roads were accorded the same priority in the early development of the U.S. Both means of transportation were essential to communication between the eastern seaboard and the frontier west. Secondly, both means of transportation were vital to facilitating the movement of people westward, and the agricultural surplus of the Ohio valley to the eastern seaboard. Congress in 1818 recognized the important role the federal government must play in maintaining open trade routes. In that year, the following resolution was passed by Congress:

> Congress has the power to appropriate monies for the construction of roads, canals, and for the improvement of waterways [23,p.12].

Six years later, the Rivers and Harbors Act of 1824 was passed by Congress. This Act entitled the U.S. Army Corps of Engineers to the funding and authority to improve the inland waterways. During the term of John Quincy Adams, an average of $702,000 per year were appropriated for waterway improvements. Andrew Jackson increased the government support of waterway improvements to an annual average of $1,323,000.

In addition to federal support, individual states were encouraged to fund projects during this period. The Erie Canal project, funded by New York, is the most notable example. However, this encouragement of state activity resulted in three separate, but very damaging consequences for waterway improvement [23].

1) Individual Congressional support for 'local' programs pointed out the weaknesses of the national directive.

2) Inadequate collection of tolls or taxes by states, and the undeveloped U.S. financial market required heavy reliance on foreign capital. The London banks, however "were not very concerned with our public purposes" and as the rate of default on state bonds increased, London withdrew her support.

3) Administered in the main by private corporations, waterways were improved only in areas of profitable traffic. Other vital waterway links were not being developed.

As a result, improvements on waterways virtually came to a halt.

The reemergence of federal support after a period of non-activity, resulted in response to the abusive tactics of the railroads. The reaction to rail company practices of establishing monopoly in water competitive regions, by charging initially low rates and then "raising rates to exhorbitant levels" once market power was established, [23, p.23] was decisive. In 1882, Congress appropriated $10,000,000 to improve waterways.

During the twentieth century, the national benefits of waterway improvements were prominent arguments in maintaining free use of the inland waterways. In addition to the low-cost transportation benefit to agriculture, low cost waterway transportation was viewed as essential to industrial growth, employment, a growing economy and defense. In particular, low-cost waterway transportation facilitated the movement of traffic not requiring rapid movement--petroleum, grain, coal, sand and gravel--but essential to the functioning of the U.S. economy.

In 1978, however, waterway user charges were imposed. The Inland Waterway Revenue Act of 1978 [24] was passed by both houses of Congress and subsequently signed into legislation by the Carter Administration. It was not a change in sentiment, but rather a compromise which initiated passage of a user fee schedule. The construction of a new lock and dam at Alton, Illinois would not have proceeded without the support of states independent of waterway usage. A user charge clause was inserted in the legislation to rally the support of these states:

> "There is hereby imposed a tax on any liquid used--as a fuel in a vessel in commercial waterway transportation" [24].

Initiated at four cents per gallon on October 1, 1980, the fuel tax is scheduled to increase to ten cents per gallon by the 1985 navigation season. Revenues generated from the user tax have been earmarked to finance the maintenance and operations of existing navigation structures and practices and to defray the cost of current and planned construction.

Revenues generated from the legislated level of taxation were small in comparison to expenditures. In the first quarter of 1981, about $5 million was raised [73]. By October, 1981, approximately $21 million had been raised. By October, 1982, under the legislated tax levels, about $86 million in tax revenue was generated [47]. In comparison, federal government expenditures on commercial navigation in 1982 totalled $430 million [17].[2] The shortfall in revenues was evident to the Reagan

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[2] In 1982, shallow draft maintenance and operations expenditures totalled over $274 million. The annualized cost--at 3% interest for 50 years--of current and proposed construction approved by Congress totalled $159 million.

Administration. A user fee schedule was proposed that would generate an additional $244 million in fiscal 1983 [47].

The user fee schedule as proposed by the Reagan Administration would have increased the 6 cents per gallon fuel tax, as scheduled by the 1978 legislation for 1983, to 30 cents per gallon. Subsequent increases in the fuel tax to 34 cents per gallon by 1986 were scheduled [48]. The fuel tax, if approved, would have generated revenues equal to 100 percent of navigation related annual expenditures on operations and maintenance and 70 percent of new construction costs. The administration's proposal did not receive congressional approval. Subsequently, on May 19, 1983 the Administration submitted for Congressional approval a proposed user fee schedule designed to recover 70 percent of operations and maintenance expenditures. The proposal included a system-wide ton-mile fee set at 1.1 mills per ton-mile in addition to the 1978 legislated fuel tax. New construction costs would be recovered from segment specific fees on the segments upon which the construction was initiated [72]. At the time of the writing of this dissertation, no congressional action had as yet been taken on this proposal.

The Inland Waterway Revenue Act of 1978, in summary, created a new policy for the recovery of operations, maintenance, repair and construction expenditures which aid inland waterway navigation. In 1985, this policy will be up for review. As current developments suggest, there is little justification for the belief that user charges will be rescinded. It appears more likely that commodity traffic, including grain traffic, will bear a greater percentage of navigation related expenditures. This dissertation considers the implications of alternative user charge mechanisms designed to recover 100 percent of commercial navigation related expenditures.

The Growth of Agricultural Barge Traffic

Of significant importance to agricultural sector analysts is the rapid increase in barge shipments of grain. In 1980, grain shipments accounted for 10.9 percent of all commodity shipments transported by barge. In 1970, grain shipments represented less than 5 percent of commodity traffic on the nation's waterways [49]. Between 1970 and 1980, total commodity shipments on the inland waterways increased by 18 percent. Grain barge shipments, on the other hand, increased by over 90 percent. Of similar importance, is the growth of barge transportation in the movement of grain to exporting ports. As a percentage of total U.S. grain exports, the barge share of grain export shipments has grown from 28 percent in 1970 to 46 percent in 1982 [51]. This dissertation will consider the implications of alternative user charges on the cost of transportation and the competitive share of grain transportation held by the barge, rail and truck modes. Special emphasis will be placed on export shipments.

Objectives of This Study

A full-cost recovery mechanism, its impact on projected 1990 corn, soybean and wheat flows and the resulting increase in cost to agricultural product shippers is the subject of this dissertation. A linear programming model is utilized to estimate traffic flows both in the absence of and after the imposition of user charges. The impact of user charges is estimated by comparison of the base model--no user charge--solution and five separate user charge scenarios. The five user charge scenarios analyzed are:

1. a systemwide fuel tax equal to 38.1 cents per gallon of fuel consumed in the transportation of barged commodities
2. a river-segment specific ton-mile tax
3. a combination systemwide fuel tax and segment specific ton-mile tax
4. a river-segment specific ton-mile tax in combination with an assumed increase in export bound rail rates equal to 50 percent of the user charge in water competitive areas
5. same as scenario 4, with the exception that rail rates are increased the full amount of the tax in water competitive areas.

The impact of full-cost recovery taxation on projected 1990 corn, soybean and wheat flows and transport costs is estimated by quantifying changes from base solution results in the following:

1. The quantity of corn, soybean and wheat barge shipments in total, by river segment, and by originating state;
2, the quantity of corn, soybean, and wheat shipped to export ports by mode;
3. total transport costs and revenues received by mode; and
4. total user charge revenue generated from agricultural shipments and the incidence of the tax at the state level.

CHAPTER II. LITERATURE REVIEW

A number of efforts have been made at modeling the impact of inland waterway user charges on the transportation of agricultural commodities. These studies may be divided into those which focus primarily on national impacts and those which consider the implications of user fees upon a regional scale.

The impact of inland waterway user charges has been estimated at the national level in a study completed by Binkley et al. [7]. Casavant and Thayer [12], Casavant and Mehringer [11], Bunker [10], Minnesota Department of Transportation [32], Welding [76], and Conley and Hill [14] considered the regional impacts of waterway user charges.[1]

The similarities between studies are threefold. First, all studies seek to replicate current, or in the least, reasonably approximate current grain transportation flows. Interviews of grain market participants and previously published data are relied upon to judge the appropriateness of estimated transport flows. Secondly, the full cost of the user fee is then added to the shipping cost of transporting by barge. The incidence of waterway user charges is therefore absorbed by grain shippers and not barge owners and operators. Finally, conclusions are

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[1] This list of regional studies is a sample of available literature on the impacts of inland waterway user charges. In addition, studies have been completed by the Consad Research Corporation [15], the Port of Metropolitan St. Louis Advisory Council [36], Mickle et al. [31], and Warner [74]. The studies selected for review in this chapter highlight the impacts of user charges on grain shipments.

then drawn concerning diversions from river traffic and increased shipping costs.

The major differences between the studies are the size of the geographic areas analyzed, the time frame within which the study is completed, the level and types of user taxes added to barge rates and the sophistication of technique utilized. The methodology and the impacts of inland waterway user charges implied by the national study will be considered first. Regional impact studies will be considered second.

Examination of National Impacts

The Binkley et al. study employs a linear programming model to estimate the impact of user charges on a national scale.[2] The base solutions from separate corn, soybean, and wheat models, replicate 1970-71 grain flows on the Mississippi, Illinois, Arkansas, Missouri, Ohio and Tennessee Rivers. Transportation costs are based upon 1975 rail, barge and ocean rates as collected from industry sources and estimated truck and handling charges. In subsequent solutions, a systemwide fuel tax equal to 0.084 cents per ton-mile and segment specific ton-mile taxes,[3] are added to barge rates. The taxes are

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[2] The Binkley study is the only analysis, independent of the one examined in this dissertation, to employ a national model. In companion studies to this analysis, Hauser [21] and Data Resources Incorporated [17] investigate the impacts of user charges at the national level.

[3] In cents per ton-mile, segment-specific taxes were equivalent to 0.10 for the Upper Mississippi (thru Cairo, IL); 0.04 for the Lower Mississippi River; 0.07, 0.05, 0.82 and 3.55 for the Illinois, Ohio, Missouri and Arkansas Rivers, respectively.

designed to recover 100 percent of 1975 inland waterway operations and maintenance expenditures from all commercial river traffic, including grain shipments. Specific locations on each river segment are allowed to both ship and receive grain. Export grain is transshipped through Gulf, Great Lakes and West Coast Ports. One time period is specified. Therefore, shipments on the Upper Mississippi River and through the Great Lakes Ports may be overstated.

The structure of the Binkley analysis can be represented by a system of six equations [7, p.14].

$$\sum_{i=1}^{n} \sum_{j=1}^{m} t_{ij}X_{ij} + \sum_{j=1}^{m} \sum_{k=1}^{p} t_{jk}X_{jk} \qquad (1)$$

subject to:

$$\sum_{j=1}^{m} X_{ij} = S_i \qquad (2)$$

$$\sum_{j=1}^{m} X_{jk} = D_k \qquad (3)$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} X_{ij} = \sum_{j=1}^{m} \sum_{k=1}^{p} X_{jk} \qquad (4)$$

$$\sum_{i=1}^{n} S_i = \sum_{j=1}^{m} D_j \qquad (5)$$

$$X_{ij}, X_{jk} \geq 0 \qquad (6)$$

where:

tqn = transport cost from point q to point n,

Xqr = quantity shipped from point q to point r,

S_i = production at origin i,

D_j = consumption at destination j.

The objective function (1) specifies that the sum of the transport and handling costs from origin i to intermediate point j and from the intermediate point to final destination k is to be minimized. Origins are production-surplus regions. Destination points are domestic or foreign demand-deficit regions. Constraint (2) requires that grain shipped from an origin region equals the production in that region.[4] Constraint (3) requires that the grain received at a destination equals the demand at that region. Constraint (4) requires that the grain received and shipped at an intermediate point be equal. Constraint (5) requires that supply equal demand, thus precluding storage.

The most interesting feature of this structural formulation is that it is essentially long-run in nature. Key factors which may influence grain shipments in the short-run, i.e., total barge and rail car availability, regional rail multiple-car availability, and intermediate point handling capacity constraints are not included. Indeed, the authors suggest:

> the elimination of capacity constraints from the analysis thus ensured that user charges rather than capacity limits could serve as binding constraints. This procedure obviously forces a long-run viewpoint onto the results obtained [7, p.17].

There are definite reasons why Binkley et al. chose to estimate the impacts of waterway user charges in a long-run framework. First, since the study is composed of three separate models, one for each crop, inland and port capacity designed for all crops would not have become effective. However, the separate model approach does not recognize that corn,

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[4] Regional demands are satisfied at zero transportation costs. If regional demands exceed production the region is in deficit and becomes a destination for grain shipments.

soybeans and wheat do compete for equipment and terminal space. The second reason for not including capacity constraints is that the authors believe that capacity constraints would:

> in one sense, presolve the problem. For example, there may now exist grain movements which, due to capacity limitations, make less use of the barge mode than would be true without such limitations. User charges may not affect such a movement, not because user charges are of no consequence, but due rather to the capacity problem . . . . This is particularly important on a relatively newly opened waterway such as the Arkansas River [7, p.17].

The issue of inland waterway user charges as approached by policy makers, however, is a short-run problem. The most important reason is suggested by the mechanism by which the level of user charges is determined. The extent of annual expenditures to be recovered and consequently the point specific user taxes are fixed given a particular level of annual operations, maintenance and planned construction. Vary these intentions and the level of user charges will vary also. Additionally, a short-run model formulation would be justified because user charges are imposed upon a transportation network confronted with existing constraints. A specific level of produced grain must be allocated to satisfy demands occurring within a rather limited time period. Export shipments through a specific exporting port are limited given port handling capacity. And most important, the utilization of barges and therefore inland waterway traffic, is limited given the size of the barge fleet. It is the level of barge traffic which determines the allocation of total expenditures among barge shipments and thus the per ton cost of the waterway user charge.

The absence of capacity constraints may also effect the results obtained. Binkley et al. admit that barge shipments may be overstated:

> Capacity limits in equipment, elevator and loading and unloading facilities may constrain the amount of grain that will move over a waterway . . . . Thus, where capacity constraints exist, model movements will be greater than actual movements [7, p.28].

Table 1 presents the total bushels of grain--corn, wheat, soybeans--shipped as estimated by Binkley et al. and percent diverted by type of tax and by river segment. In total, the segment tax results in greater diversion of barge traffic than the fuel tax. Diversions on the Illinois, Arkansas, and Missouri Rivers are greater under a segment tax. Diversions on the Upper Mississippi, Lower Mississippi, and Ohio Rivers are greater under a fuel tax. In each case, there is a positive relationship between the percentage diversion and tax levy by river segment, that is, on the Illinois, Arkansas, and Missouri Rivers the segment tax imposed upon barge movements is greater than the fuel tax. The opposite is true for the Upper and Lower Mississippi and Ohio Rivers.

Examination of Regional Impacts

The Minnesota Department of Transportation (MDOT) study is significant because of its identification of the association between the impact of waterway user charges and location of grain-shipping regions. According to this study, 60 percent of the grain destined for export from Minnesota travels by river to the Gulf ports. Additionally, the growth in tonnage originating on the Upper Mississippi has been substantial. Between 1977 and 1980, grain tonnage increased by 80 percent, from 5.2

Table 1. Millions of bushels of grain shipped by river segment in the base solution and percent diverted by river segment in the Binkley analysis[a]

River segment	1970 base solution	Percent diverted	
		Fuel tax	Segment tax
Upper Mississippi	585.2	7.6	6.0
Lower Mississippi	57.9	4.6	0.0
Illinois	222.0	1.9	16.8
Ohio	60.7	14.6	3.2
Missouri	57.7	27.5	85.0
Arkansas	12.7	64.8	100.0
Total	996.3	8.5	13.3

[a] Source [7].

million to over 9.2 million tons. However, Minnesota is at a particular disadvantage because of the cumulative impact of user charges on long-haul commodity movements and the relatively higher operations and maintenance costs associated with the Upper Mississippi River. Full-cost recovery user charges, therefore, could increase barge rates by nearly 50 percent.

The MDOT study points to another important consideration. Of utmost importance in estimating the appropriate fuel tax is the technique utilized to measure fuel consumption by a barge shipment from origin to destination. MDOT based the level of fuel tax from Minnesota grain origins on fuel escalation clauses in towing industry contracts.[5] According to this study, a 40 cent increase in fuel cost would increase barge rates by $4.00 per ton--11.6 cents per bushel--for shipments originating in Minnesota [32, p.12]. A full-cost recovery fuel tax would increase barge rates by 20.3 cents per bushel. Included in this fuel consumption factor is what MDOT admits to be the administrative expense of gauging fuel usage and the reporting of the tax. These administrative expenses are amply estimated to equal about 5 cents per 10 cent increase in barge rates, or 100 percent of the barge rate increase associated with the fuel cost alone. It is questionable whether these administrative expenses could be added to the cost of shipping grain by barge. In 1980, the rate differential between a truck-barge combination rate--assuming

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[5] Eight to twelve cents per ton increase in barge rates per one cent increase in fuel cost. MDOT uses 10 cents per ton.

100 miles of trucking--from Minneapolis to the Gulf ports and a 75-car rate to the Gulf ports was 1.5 cents per bushel.[6] Competition for traffic between the competing modes would likely hold the increase in barge rates to at most the increase in fuel cost, in this case the fuel tax.

Welding [76] suggests that the impact of inland waterway user charges on agricultural traffic on the Missouri River will depend upon the decrease in the savings associated with shipping by barge rather than rail. In 1979, the average transportation savings of shipping grain via the Missouri River are estimated by Welding at $2.40 per ton for corn, $2.65 per ton for wheat and $2.20 per ton for soybeans.[7] Additionally, Welding suggests that between 1979 and 1981, the introduction of unit trains in the Missouri River basin would decrease the cost savings by an additional 25 percent. Welding concludes that the extra expense associated with user charges recovering only operations and maintenance expenditures "would be sufficient to eventually eliminate agricultural barge traffic on the Missouri River" [76]. In 1977, agricultural commodity traffic equaled about 1.2 million tons or 30 percent of the commercial traffic on the Missouri River [76]. According to Welding, the elimination of this grain traffic would have significantly greater implications when the following is considered:

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[6] Based upon rates as collected from industry sources.

[7] These figures as reported by Welding are based upon average rates as estimated by the U.S. Army Corps of Engineers.

> If agricultural barge traffic were eliminated, the remaining traffic would have to pay higher user charges. Products currently being shipped with marginal total transportation savings would be the first to be diverted, and a snowball effect would be in motion as the remaining traffic pays prohibitively higher user charges. Ultimately the Missouri River would close to all commercial traffic [76].

Illinois is in a unique position with regard to the potential usage of the inland waterways. Conley and Hill [14] report that in 1977, Illinois exported to foreign countries about 53 percent of the corn and 49 percent of the soybeans produced in the state. Furthermore, of all grains shipped to export from Illinois, about 67 percent moved by water [14]. In comparison, Iowa exported 25 and 32 percent of its 1977 corn and soybean production, respectively, and in total 36 percent of grain originating in Iowa for export was shipped by barge [22,26,14]. User charges, therefore, would certainly impact the marketing of Illinois grain. A second indication of the importance of river shipment to Illinois producers is that the average price received by farmers for agricultural produce is higher in Illinois than in surrounding states.[8] While Illinois is closer to Gulf export markets than other Cornbelt states, low-cost water transportation also contributes to the higher prices paid to Illinois grain shippers and producers.

Bunker [10] estimated the impact of waterway user charges on 1973 grain shipments from 24 grain elevators located in Logan County,

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[8] In 1979, the average price received for corn was $2.56 in Illinois. During the same year the average price received was $2.53, $2.42 and $2.26 in Indiana, Iowa, and Minnesota respectively [14].

Illinois.[9] Although no foreign sector is included in the model, about 64 percent of the 617.7 million tons of grain shipped in the base solution moved to the Gulf by truck-barge combination. This amount was required to move to the Gulf in the four subsequent user charge solutions. User charges were applied in 0.05 cents per ton-mile increments which converts to 1.61 cents per bushel of corn. The additional cost to ship by barge amounted to about 16 percent of the base rate—$3.67 per ton--when the smallest user charge is applied. The highest level of user charges analyzed by Bunker was 63 percent of the base rate. The Bunker analysis shows significant diversions from barge traffic. A 15 cent per ton-mile tax is estimated to divert about 67 percent of the barge traffic originating in Logan County. Logan County shippers have the option of shipping on unit train rates in the Bunker analysis. These rates become very competitive with barge rates as user charges are applied.

The approach utilized by Conley and Hill consisted of projecting barge shipments on the Illinois River to 1985 and computing the total cost to Illinois shippers. The total increase in cost is estimated to equal approximately $37,602,000, given a 40 cent fuel tax.[10] There is sufficient reason to believe that this cost is overstated. One possible explanation is the assumed constant market share between rail and barge traffic of Illinois grain as utilized by Conley and Hill.

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[9] The center of Logan County is approximately 45 miles from the Illinois River.

[10] This estimate includes the tax generated by 2.8 million tons of fertilizer and assumed railroad rate increases equal to the tax on 5.0 million tons of grain.

There are two reasons for the constant market share hypothesis. First, grain producers behave as arbitragers in the short-run. Secondly, elevator managers attempt to maintain a stable commodity flow through their facilities. Consequently, if the price received by producers at river elevators should increase, producers will divert grain from rail to barge traffic. However, in response to the higher river bid, the inland terminal, to maintain volume, will willingly accept a smaller margin to keep the inland terminal bid competitive with the river terminal bid. Similarly, if barge rates were to increase relative to rail rates, river elevator managers would accept a lower margin to maintain volume. In the short-run, therefore, an increase in barge rates due to user fees will be absorbed by river elevators as a decrease in margins. It is admitted that this hypothesis is 'difficult to prove' [14,p.2]. Furthermore, it is suggested that:

> the competitive nature of the farm production sector and the supply response evident in any historical study of grain production makes it quite likely that in the long-run much of the impact will be at the farm level [14, p.25].

Conley and Hill do not specifically state if they are considering the short or long-term. However, it seems evident, that since a significant portion of grain (5.0 million tons) remains on rail and is transported at rates including an increase charge, equivalent to the fuel tax at nearby elevators, they are considering a long-term situation.

The only criticism offered on this approach, is that a constant market share implies little, if any, diversion from river traffic. Both inland processors and Great Lakes ports will become viable alternatives to Gulf export when user charges are imposed. Barge shipments to Gulf export ports may decline. The same happens to a greater degree as rail rates are increased to equal 100 percent of the user tax. Both rail and barge shipments to Gulf export may decline. The assumption that Illinois will continue to ship the same quantity of grain to Gulf export and that rail and barge will maintain a constant share of traffic is inconsistent with this possibility. Hence, the total cost to Illinois shippers may be lower than Conley and Hill suggest.

Casavant and Thayer [12] estimated the impact of waterway user charges on Pacific Northwest wheat movements from 66 regions in the four state area of Washington, Idaho, Montana and Oregon. Rates for each mode were collected from industry sources and the lowest rate by mode from each district to Columbia River and Puget Sound export facilities were specified. No foreign sector was specified. Therefore, the combined demand at the two alternative port locations was constrained to equal the total supply transported from the regions. The major thrust of this study was the examination of wheat movements before and after the completion of the Lower Granite Dam which extended Columbia-Snake river traffic to Lewiston, Idaho. Model results indicated that 104 thousand tons shifted from rail to truck-barge due to the opening of this river segment. User charges of 7 cents per gallon, and segment ton-mile taxes designed to recover 10, 30 and 50 percent of Columbia-Snake River operations and maintenance were applied in subsequent analyses.

The Casavant and Thayer study is especially important in demonstrating the impact of the time in which the analysis was concluded. The 1975

Casavant study does not incorporate the recently published low-cost unit train rates from Northwest origins to West Coast ports. To illustrate the impact of these rates, 40 percent of the 1975 export shipments from the Great Falls, Montana area were truck-barge combination shipments; the remaining 60 percent were by single rail-car shipments. An informal survey by Casavant in 1982 indicates that a dramatic change had occurred. Truck-barge shipments had declined to about 5 percent of total shipments and direct multi-car shipments accounted for the remaining 95 percent [4]. Similar trends are applicable for Washington and Idaho shipments.

Additional evidence of the impact of multiple-car rates on the modal distribution of grain shipments in the Pacific Northwest is provided by Casavant and Mehringer [11]. Utilizing the same market regions as the Casavant and Thayer study, 100 percent expenditure recovery fuel and segment tax mechanisms were applied to an updated transport rate base. Six percent of barge traffic on the Columbia/Snake River was diverted. In the earlier Casavant and Thayer study, a segment tax designed to recover 50 percent of Columbia/Snake operations and maintenance expenditures resulted in total barge diversions of 63 percent. The difference in the results is indicative of the dramatic influence of multiple car rates on Pacific Northwest wheat movements. In effect, multiple-car rates have diverted much of the Columbia/Snake River barge traffic. The imposition of user charges, consequently, has a minor impact in this region.

In summary, all of the regional analyses, except Conley and Hill, indicate that user charges will effect the modal distribution of grain shipments. All studies suggest that the cost of transporting grain will increase. It has been demonstrated that the time in which the study is completed and suggested that the method by which the fuel tax is estimated will effect the results obtained. Finally, it is important to consider that the regional analyses do not fully account for the substitution of grain shipments from non-study regions for grain shipments to particular destinations originating in the designated region of study.

CHAPTER III. METHOD OF ANALYSIS

The impact of alternative types and levels of inland waterway user charges on 1990 corn, soybean and wheat flows and transport costs are estimated through linear programming techniques. Linear programming (LP) is essentially a decision-making device. Given available resources, the technical information of how to transform these resources into desired output, and the directive to minimize cost, the LP algorithm selects the optimal pattern of resource use. In a transportation framework, the available resources are the quantities of a commodity available in surplus regions. The desired output is the satisfaction of demand at deficit regions. The technical information required is the alternative means and cost of transportation services. And the optimal pattern of resource use is the least cost combination of shipments which simultaneously satisfies all the demands.

The impact of inland waterway user charges has been modelled within this framework. Baumel, Hauser and Beaulieu [5] present the basic structure of the model in a study completed for the U.S. Department of Transportation. Hauser [21] expands upon this basic structure and applies the model to 1985 corn, soybean, and wheat flows.

Mathematical Model and Verbal Description

The objective of this model is to minimize the total transportation and handling cost of transporting corn, soybeans and wheat from domestic surplus regions to domestic and foreign demand regions. The objective function is:

$$\text{Minimize } Z = \sum_{c}\sum_{o}\sum_{d}\sum_{m}\sum_{t} X_{codmt} C^{x}_{codmt} + \sum_{c}\sum_{e}\sum_{f}\sum_{t} Y_{ceft} C^{y}_{ceft} \quad (7)$$

where

Z = Total annual grain transportation and handling costs

X_{codmt} = Quantity of crop c that is transported from origin o to destination d by mode m in time period t

C^{x}_{codmt} = Per unit transport and handling costs of moving crop crop c from origin o to domestic destination d by mode m in time t

Y_{ceft} = Quantity of crop c that is transported from export port e to foreign demand area f in time t

C^{y}_{ceft} = Per unit ocean freight rate for transporting crop c from export port e to foreign demand area f in time t

The following constraints are imposed on the model to insure that both foreign and endogenous domestic grain demands are satisfied:

$$D_{cdt} \leq \sum_{o}\sum_{m} X_{codmt} \quad (8)$$

$$D_{cft} \leq \sum_{e} Y_{ceft} \quad (9)$$

where

D_{cdt} = Quantity of crop c that must be transported to domestic destination d in time t

D_{cft} = Quantity of crop c that must transported to foreign destination f in time t

The seasonality incorporated in this model is introduced through these demand constraints. The fixed demands are divided into two period demands by assuming a uniform requirement throughout the year at each demand region.

The basic supply region is the crop reporting district (CRD). However, subregions of the CRD are defined to account for differences in trucking and rail rates to barge loading points from different areas within a CRD. Subregions also allow for a better specification of the location of multi-car and unit-train facilities within a CRD. The following constraints are imposed to insure that the quantity of grain transported from supply region o, or the quantity within subregions of o when aggregated, cannot exceed the estimated annual surplus available in supply region o:

$$S_{co..} \geq \sum_{d}\sum_{m}\sum_{i}\sum_{j}\sum_{t} X_{coijdmt} \quad (10)$$

$$S_{coi.} \geq \sum_{d}\sum_{m}\sum_{j}\sum_{t} X_{coijdmt} \quad (11)$$

$$S_{coij} \geq \sum_{d}\sum_{m}\sum_{t} X_{coijdmt} \quad (12)$$

where

$S_{co..}$ = The annual surplus of crop c which is available for transport from origin o

$S_{coi.}$ = The annual surplus of crop c which is available for transport from origin i; origin i is a subregion within region o ($\sum_{i} S_{coi.} = S_{co..}$)

S_{coij} = The annual surplus of crop c which is available for transport from region j ($\sum_{j} S_{coij} = S_{coi.}$ and $\sum_{i}\sum_{j} S_{coij} = S_{co..}$)

Constraints are imposed which limit the annual usage of transport equipment for export shipments. The constraints are expressed in terms of equipment days per time period. The following constraint limits the number of rail car days available for export shipment.

$$ECD_{mt} \geq \sum\sum\sum_{coe} X_{coemt} \cdot RTAT_{oem} \cdot S \qquad (13)$$

where

ECD_{mt} = Number of rail car days available for export rail grain shipments in all sizes of rail shipments. The number of rail car days is equal to the estimated export hopper car supply times the number of days per period.

$RTAT_{oem}$ = Estimated turn-around-time from origin o to export port e by a shipment of size m. Where size m refers to single or multiple car shipments.

S = Number of hopper cars required to haul one unit of X_{coemt}. X_{coemt} is defined in 100,000 ton units. Given an average of 190,000 bushels per hopper car, S would equal approximately 1,050 hopper car loads.

The quantity of barge days used to transport grain can not exceed the available supply of barge days. This constraint limits the quantity of barge days available per time period under contract rates and under spot market rates. Eighty percent of total grain barge days are assumed to be under contract and twenty percent are sold on the spot market.

$$CBD_{t} \geq \sum\sum\sum\sum_{coem} X_{coemt} \cdot BTAT_{oem} \cdot S \qquad (14)$$

$$SBD_{t} \geq \sum\sum\sum\sum_{coem} X_{coemt} \cdot BTAT_{oem} \cdot S \qquad (15)$$

where

CBD_t = Total barge days available for corn, wheat and soybean transport times 0.8 in time t

SBD_t = Total barge days available for corn, wheat and soybean transport times 0.2 in time t

$BTAT_{oem}$ = Estimated turn-around time from river origin o to export port e by barge.

S = Number of barges required to haul one unit of X_{coemt}. X_{coemt} is defined in 100,000 ton units. Given an average of 1,500 tons per barge, S would equal approximately 67 barges.

The specification of both single and multi-car rail rates for many regions required that multiple car loading capacity constraints be included in these regions. The alternative to this constraint would have been to allow all grain to be transported on the least expensive multi-car rate in each region. Clearly this would have understated transportation costs and the quantity shipped by barge. Over 180 multi-car constraints are imposed. The structure of this constraint is similar to the export rail-car day constraint defined above. The interested reader is referred to Hauser [21] for a more complete discussion.

$$RCD_{omt} \geq \sum_c \sum_d X_{codmt} \cdot RTAT_{odm} \cdot S \qquad (16)$$

where

RCD_{omt} = The number of covered hopper cars in a rail shipment of size m times the number of grain elevators capable of loading a rail shipment of size m in origin o times the number of days in time period t. $RTAT_{odm}$ and S are defined as above with the exception that m is now equal only to multiple car shipments and destination d includes both domestic and export facilities.

The quantity of grain received at export port e via mode m in time period t cannot exceed the port unloading capacity for that mode.

$$R_{et} \geq \sum_{c}\sum_{o}\sum_{m} X_{coemt} \tag{17}$$

$$B_{et} \geq \sum_{c}\sum_{o}\sum_{m} X_{coemt} \tag{18}$$

$$T_{et} \geq \sum_{c}\sum_{o}\sum_{m} X_{coemt} \tag{19}$$

where

R = rail

B = barge

T = truck

There are essentially two ways to handle export bound shipments. The first way would be to define an activity from each inland elevator to each foreign destination. However, the modeling cost for this form of activity definition is prohibitive. The second way is to separate the total export movement into two distinct segments. The first segment is the grain flow from the inland elevator to the export facility. At the export facility all grain received from inland elevators is pooled. The second segment is the grain movement by ocean vessel from the pooled export grain to foreign destination. This constraint is imposed as an equality constraint, the total flows from inland elevators received at export facilities are required to equal the total demand at foreign destinations by crop and time period.

$$\sum_o \sum_m X_{coemt} - \sum_f Y_{ceft} = 0 \qquad (20)$$

As stated above, in general there are two time periods employed in the model. The exception to this was incorporated to recognize the shortage of storage capacity in the southeastern U.S. The poultry industry in the Southeast requires an annual supply of livestock feed (principally corn). The quantity exported from the southeast during the harvest period is a function of the storage capacity. The surplus of corn and soybeans in excess of normal storage capacity is required to be transported out of the area. The deficit in the required annual livestock feed is then satisfied by domestic shipments in each of four quarters. The equation specifying the amount of grain that must be transported from the southeast during harvest period is the following:

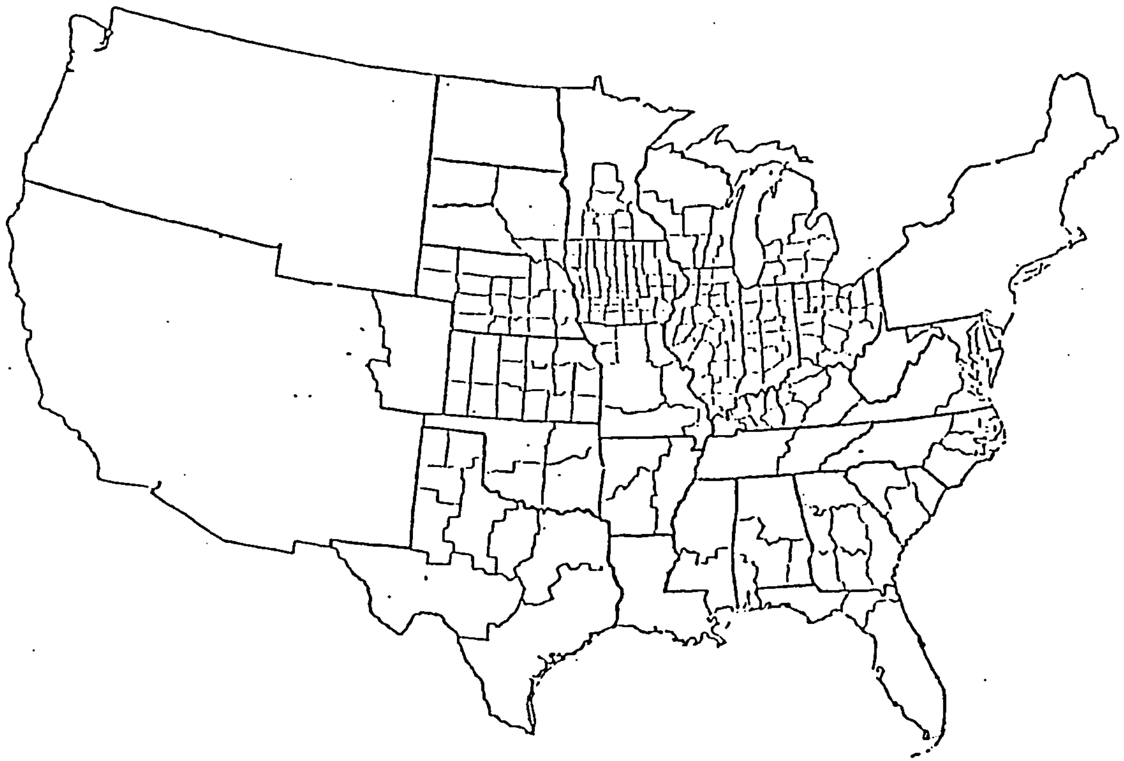
$$I_{ot} \leq \sum_{cdm}\sum\sum X_{codmt} \qquad (21)$$

I_{ot} = Quantity of grain that must be transported out of region o at harvest time.

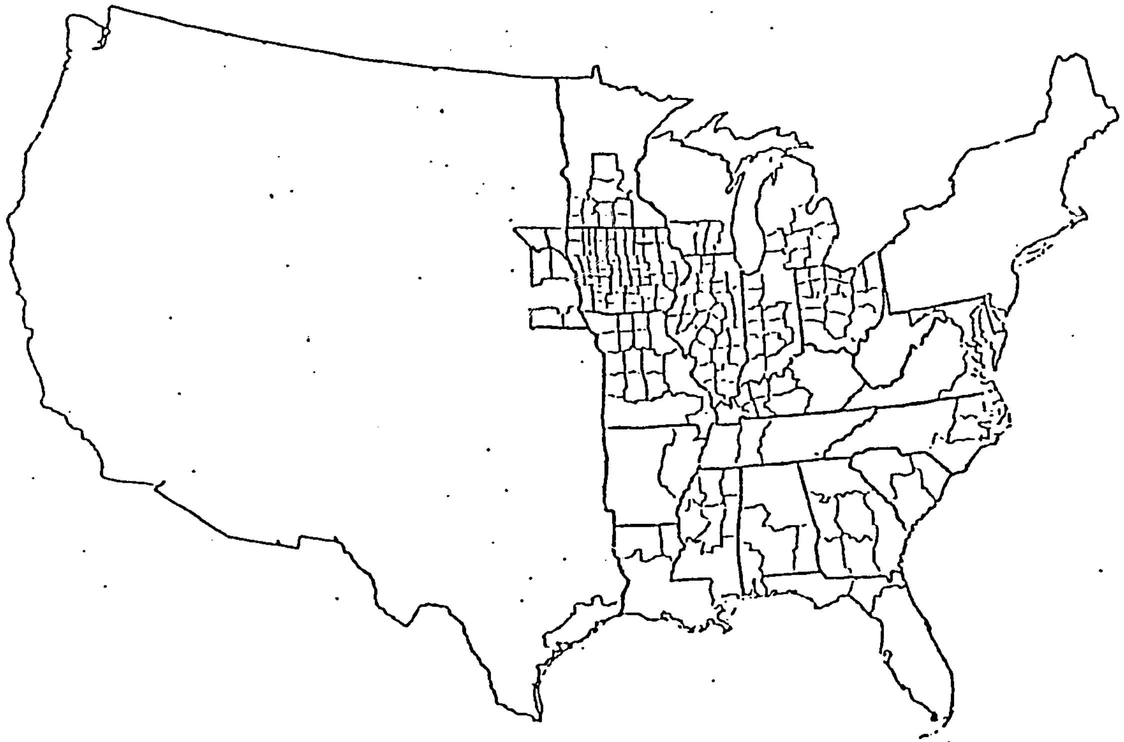
The impact of inland waterway user charges are estimated in the following manner. A computer solution based upon projected 1989 production levels, projected 1989-1990 domestic and foreign demands and 1980 transportation alternatives and costs is obtained. The criteria used to evaluate this solution consisted of comparing flows by crop on particular river segments, flows by crop through individual export facilities, and flows by crop to domestic and foreign demand regions to current shipping patterns. After a reasonable base solution was determined, the impact of inland waterway user charges were estimated by increasing origin specific barge rates by the amount of the user tax from that origin. An additional computer solution is obtained and the results of the tax solution are compared to the base and alternative tax solutions. This process was completed for all five tax scenarios.

For each solution, the linear programming algorithm minimizes the annual transport and handling costs of shipping grain from surplus to deficit regions. There are 218 corn, 200 soybean and 156 wheat-originating regions specified in the model. Sixty-seven regions serve as domestic demand destinations; grain is transported to these destinations to satisfy local livestock feed or processing deficits. Six foreign import demand regions are specified. Grain transported within origin regions for local feed consumption and processing are accounted for by deducting these demands from local supplies. In this way, all demands are satisfied either explicitly as in the case of foreign or endogenous domestic demands, or implicitly as a reduction in the grain surplus in grain originating regions. The surplus and domestic demand regions are shown in Maps 1, 2, and 3 for corn, soybeans and wheat, respectively. Note that region size diminishes depending upon the importance of the area as a grain supply region and the proximity to the inland waterways.

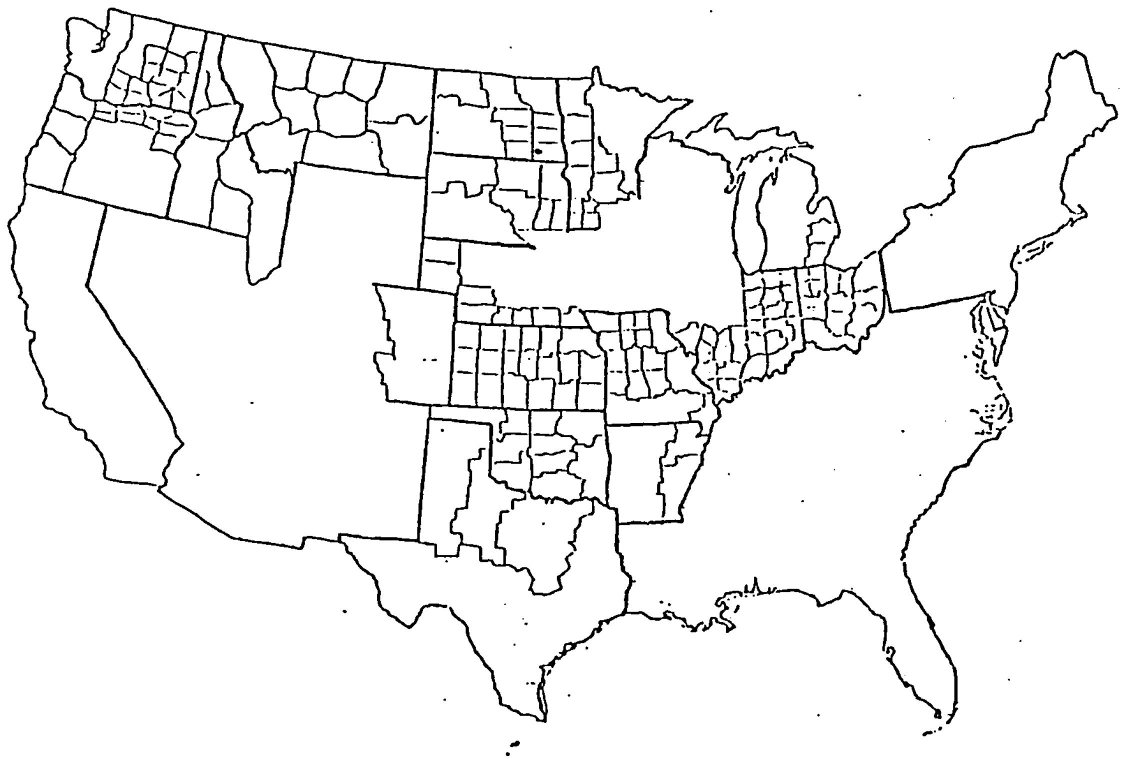
Transport activities are defined as single, three to five, 25, 30, 50 to 54, 60 to 65, 75 to 100, and 125 car rail shipments; single, three,



Map 1. Corn supply and demand regions



Map 2. Soybean supply and demand regions

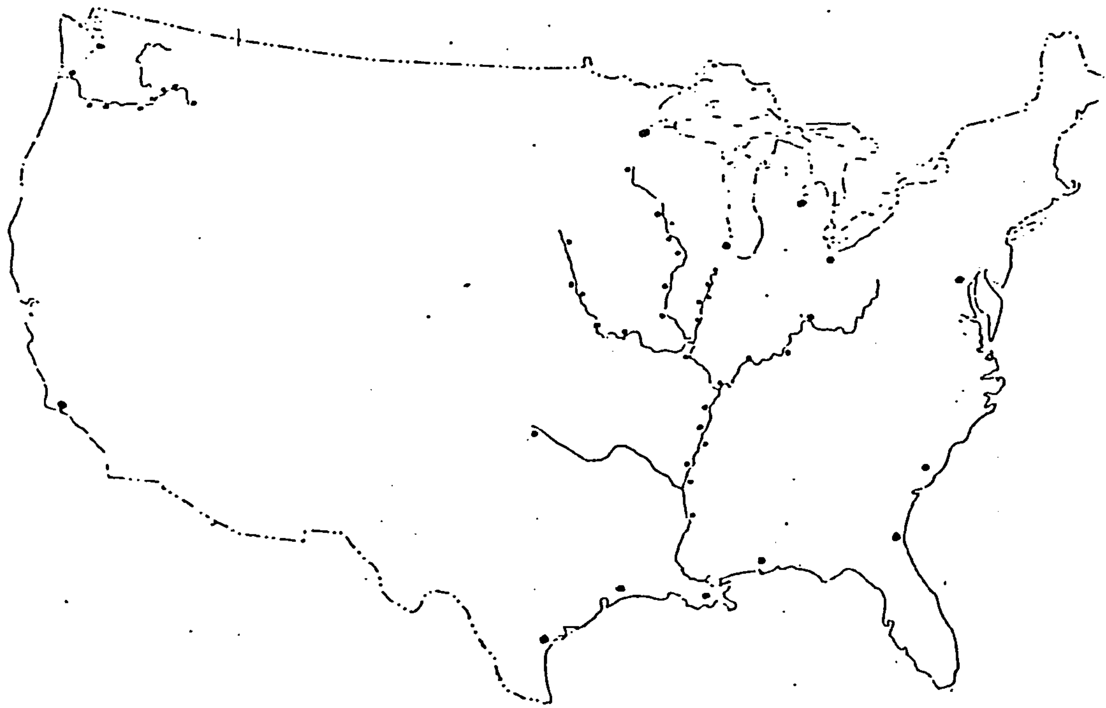


Map 3. Wheat supply and demand regions

five, 25, and 50 car rail-barge combination shipments; truck; truck-barge; and ocean-going vessels. The cost coefficients for the transport activities are based upon the transport rates faced by shippers in 1980. The cost coefficient is equal to the representative rate plus, in the case of rail-barge and truck-barge, an estimated handling charge. Grain can be shipped by rail to export or barge loading points in multi-car rail shipments, if in 1980, one or more elevators in the supply region could load these sizes of shipment.

Activities which utilize barges are given a barge contract and a spot rate. Contract agreements are established in terms of a rate and minimum quantity of barge service for a specified period of time. One level of contract rates was assumed for the entire period under study. Spot rates are differentiated by time period. Since two time periods corresponding to the navigation and winter season on the Upper Mississippi River are included, there are two distinct spot rates for all river origins. In the case of Upper Mississippi River origins, the barge alternative is not available during the winter period.

Thirty-five river origins on eight river segments are specified. The river segments are the Upper, Middle and Lower Mississippi, Illinois, Ohio, Missouri, Arkansas and Columbia-Snake Rivers. Map 4 shows the origin locations on these segments. River origins were selected based upon grain shipping capacity, capacity to receive truck and rail shipments, and the barge rate from the origin to export facility. For example, the Mississippi River and tributaries are divided into thirty-two single rate districts based upon Barge Bulk Grain Tariff #7 [73]. On



Map 4. Representative inland waterway and coastal points

the Columbia-Snake River there are seven rate districts. The river origins selected for this analysis account for twenty-three of the thirty-two districts on the Mississippi River system and all seven districts on the Columbia-Snake River system. Barge rates are discussed in greater detail in the DATA section of this analysis.

The Incidence Assumption

This model was designed and implemented to examine the impact of user charges upon transport costs and grain commodity flows. The major assumption employed in this analysis, that the user charge imposed at a specific origin is equivalent to an increase in the barge rate at that origin, fits well within this design. Treated in this manner, user charges become an increase in transport cost to be absorbed by commodity shippers. Commodity shippers then determine if the imposition of user charges have changed conditions sufficiently to warrant either a modal or destination change. This assumption however, has secondary implications as follows:

1. Barge owners absorb none of the tax.
2. The increase in transportation charges will not be absorbed by foreign purchasers.
3. The increase in transportation charges if passed back from barge companies to producers will not affect the quantity of commodity production.

In effect, this assumption allows the quantity supplied and demanded to remain fixed and exogeneous to the model. Consequently, a linear programming model was considered to be adequate.[1] Each of these three implications will be discussed separately.

Theoretically, the ability of barge owners to avoid the incidence of the user tax is reasonable under two alternative market situations. Either the demand for barge services is perfectly inelastic or the supply of barge services is perfectly elastic. A brief discussion of the first alternative--inelastic demand--will indicate its inapplicability to this analysis. The second alternative--elastic supply--is more appropriate.

Graphically, if the demand for barge services is perfectly inelastic, the market demand curve (D_0), as shown in Figure 1, would be vertical. A tax imposed upon the seller of barge services is equivalent to an increase in the per unit cost of providing barge services. The supply curve would shift from S_0 to S_t.

For simplicity, assume that a total of 60 barge units are required to transport commodities on the inland waterways. Secondly, that total expenditures on inland waterway OMRC are $300.00 for the current year. Hence, a tax of $5.00 per barge unit would recover the expenditures. In Figure 1, the price of barge transportation would increase from P_0 to P_{o+t}. There is no decrease in the barge share of transportation

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[1] A linear model would be inappropriate if the model was designed to consider the impact of user charges on production or foreign imports. McCarl and Spreen [30] note that linear programming models, since they include the "restrictive assumption of fixed market prices or quantities," ignore the relationship between prices and quantities. Quadratic programming would have been appropriate if it was assumed that user charges would be passed on to foreign buyers which in turn would reduce the quantity purchased.

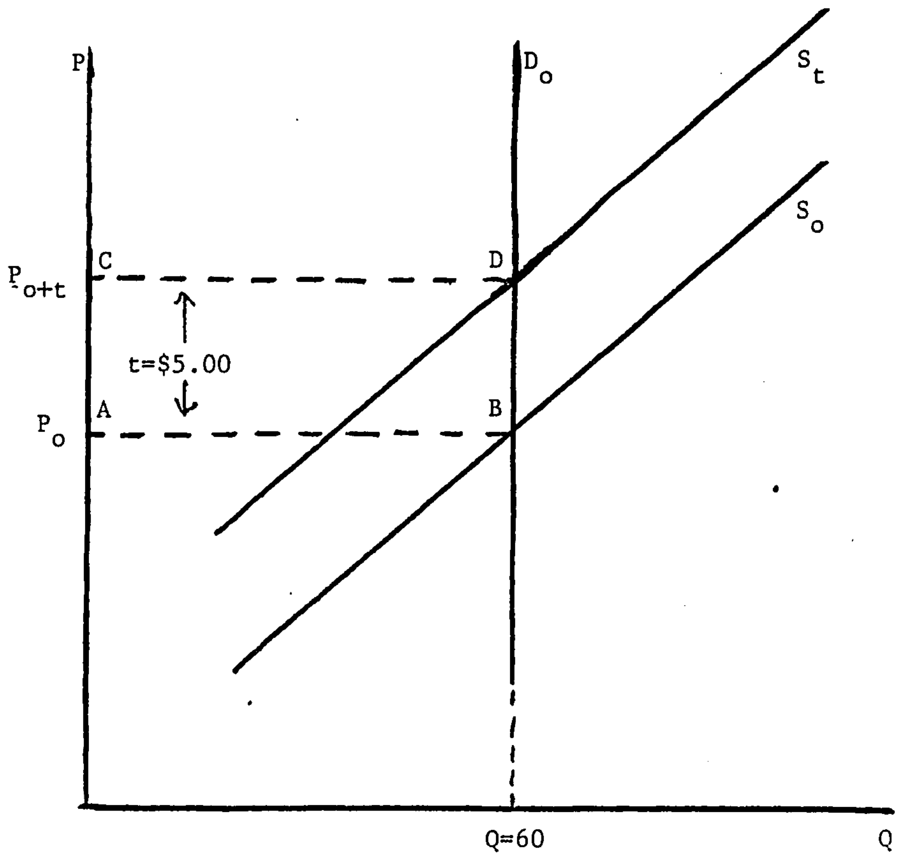


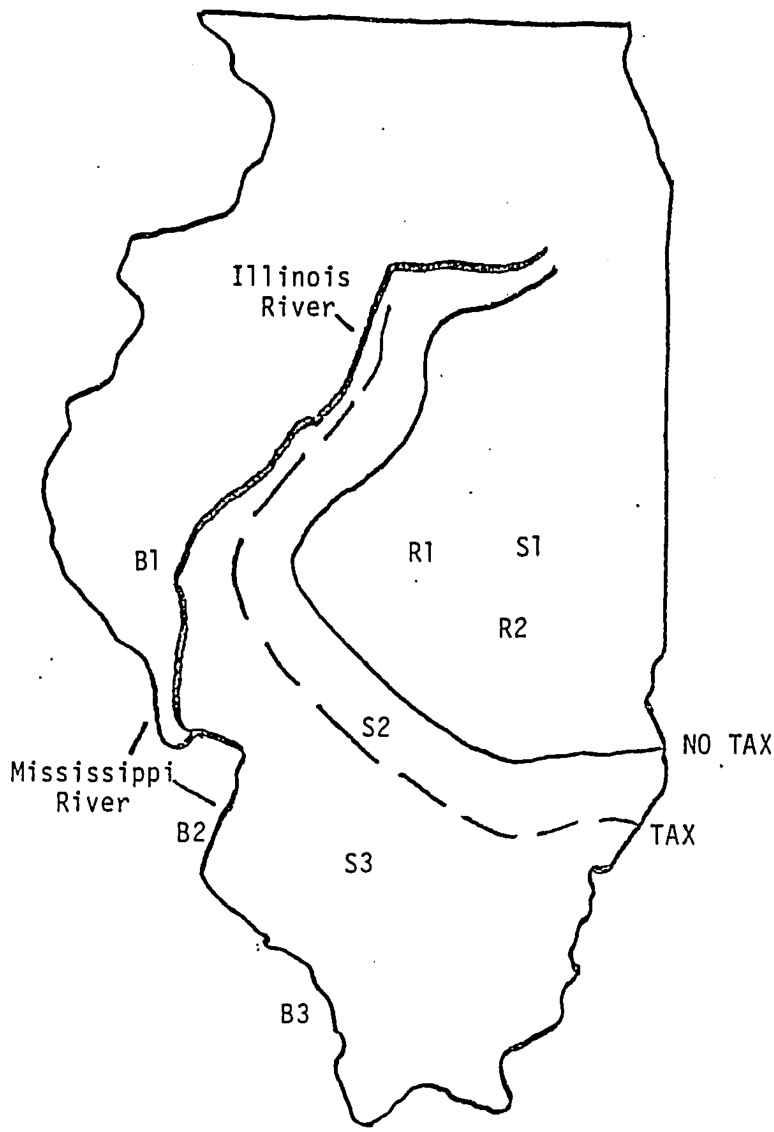
Figure 1. Incidence of user tax: Inelastic market demand for barge transportation services

services. Tax revenue is equal to the area defined by ABCD. The entire tax is absorbed by grain shippers who utilize barges.

The inapplicability of perfect demand inelasticity may be demonstrated by reference to Map 5. The options available to grain shippers located in southern Illinois, as represented by S1, S2 and S3; are to ship to export through 125-car rail terminals (R1, R2) located in central Illinois, or by barge on the Illinois or Mississippi Rivers (B1, B2, B3). In either case, a trucking charge to the rail or barge terminal is added to the rail or barge rate to determine the total transportation cost to grain shipper. At a particular mileage, the total cost of shipping by barge is equivalent to the total cost of shipping by rail. This mileage is shown in Map 5 as the solid line labeled "no tax". Given no tax, S1 would ship by rail, S2 and S3 would ship by barge.

After the tax is imposed, the cost of barging grain increases relative to the cost of rail transportation. The break-even mileage for equivalent truck-barge and truck-rail rates would shift to the line labeled "tax". Shipper S2 would find it relatively cheaper to shift to rail service. The quantity demanded of barge services would decrease. A downward sloping, not vertical, demand curve is implied.

A downward sloping demand curve and perfectly elastic supply curve are presented in Figure 2. The market supply curve (S_o) is horizontal. An increase in per unit costs resulting from the imposition of taxes would shift the supply curve from S_o to S_t. Given the 60 barge units, a tax of $5.00 would be required to recover the $300.00 in expenditures. However, given a downward sloping demand curve, the quantity



Map 5. Transport alternatives of Illinois grain producers

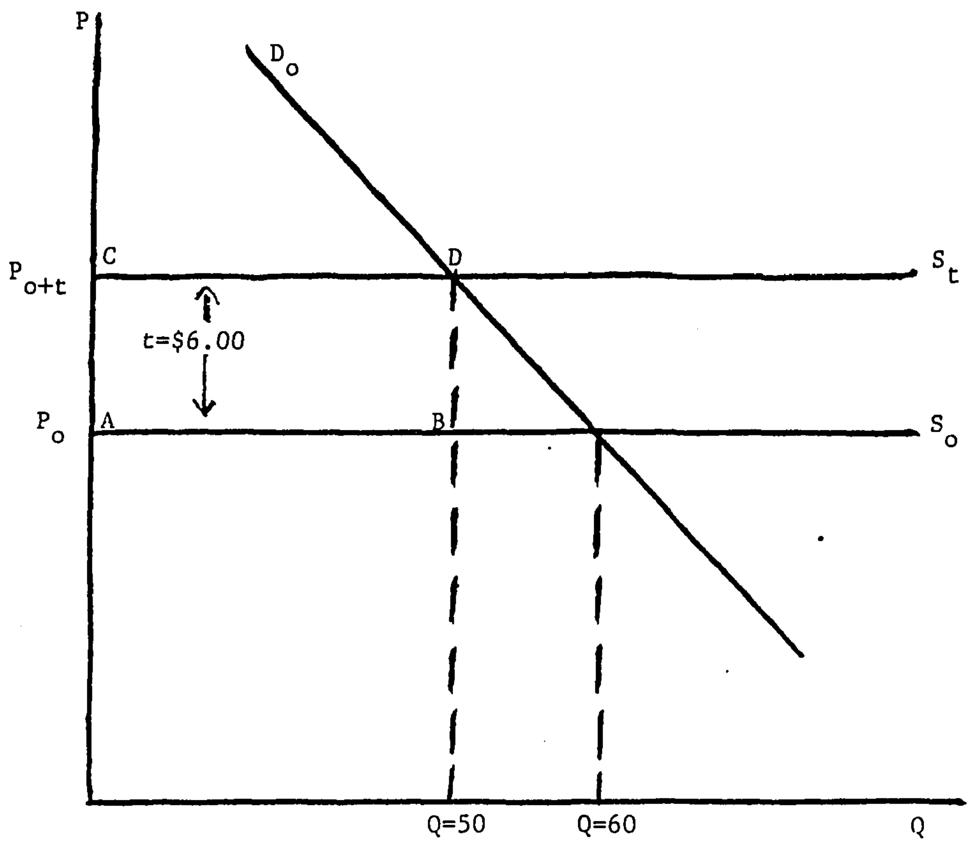


Figure 2. Incidence of user tax: Elastic market supply of barge transportation services

demanded of barge services declines as the price of barge service increases. If, for example, the quantity of barge services demanded declines to 52, tax revenue would equal $260.00 and therefore be inadequate by $40.00. An increase in the tax rate is required. In Figure 2, equilibrium is established at a quantity of 50 barges demanded and a tax per unit equal to $6.00. Tax revenue is equal to the area defined by ABCD. The entire tax is absorbed by shippers. However, in this case, the barge share of transportation services has declined and a larger per unit tax was required to recover the fixed level of expenditures.[2]

Perfect elasticity of supply, in a short-run context, would imply an almost instantaneous adjustment of resources in the barge industry. Barge owners collectively decrease the size of the existing barge fleet. Consequently, barge rates are increased to cover user charges. However, given that the replacement cost of barges is considerable[3] and that the expected life of barges is twenty years, as long as barge rates exceed variable cost, including increased operational costs due to user charges, it is doubtful that barge owners would collectively idle barges in the short run as long as barge rates exceed variable costs. Barge owners, therefore, may be forced to absorb user taxes. Baumel [3] and Binkley and Sharples [8] suggest that additional factors may determine which

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[2] As discussed in the final section of this chapter, this is precisely the methodology used to determine the per gallon and ton-mile taxes used in this analysis.

[3] Consultation with industry sources suggested that covered hopper barges cost about $270,000 in 1980.

industry group--barge companies, grain shippers, producers or foreign importers--will absorb user charges.

The incidence of user taxes, as implied by these authors, may be governed by the same forces which ultimately determine the demand for barge services. The demand for barge services is essentially a derived demand. Total barge usage will depend upon conditions in the primary market as well as the market for barge equipment. In this case, the primary market is the market in which agricultural commodities are traded. Therefore, whether barge rates may be increased to cover user charges, is a question which cannot be answered without consideration of the factors determining the demand for agricultural commodities.

Baumel suggests that in addition to conditions in the intermediate market for barge services--the level of barge rates and availability of transport equipment--the strength of foreign demand for agricultural commodities will determine who ultimately absorbs user charges. Baumel outlines three market environments under which the incidence of user charges will be shared, or possibly absorbed in entirety, by grain producers, barge companies, or foreign grain producers. Table 2 duplicates a table as presented by Baumel outlining his hypothesis.

An important implication of the Baumel article is that, in general:

> the supply and demand for export grain and for grain transportation determine who will be forced to absorb inland waterway user charges. These economic forces will not permit one group to deliberately force another group to absorb inland waterway user charges [3].

Baumel is very careful, however, to discuss this general statement in terms of actual market occurences. Foreign purchasers, according to

Table 2. General short run market conditions which will tend to force farmers, barge companies, elevators and foreign buyers to absorb a significant share of inland waterway user charges

Groups forced to absorb a significant share of user charges	Demand for grain	Barge rates	Barge and Rail car supply
Foreign buyers and export elevators	Strong demand. Gulf corn basis greater than 25¢ per bushel[a]	Well over full barge costs	Shortage of barges and rail cars
Farmers and river elevators	Moderate demand. Gulf basis less than 25¢ per bushel	Near or slightly over full barge costs	Little or no surplus of barges and rail cars
Barge companies	Low demand. Gulf corn basis well below 25¢ per bushel	Between variable and full barge costs	Large surplus of barges and rail cars

[a] Baumel, as a result of consultation with colleagues in the grain business and academia, asserts that a Gulf basis of 25 to 35 cents over the nearby Chicago Board of Trade futures price, combined with a shortage of grain transportation, is indicative of very strong foreign demand for U.S. agricultural products.

Baumel, would be likely to absorb some of the user charges given a Gulf basis in excess of 25 cents per bushel and a critical shortage of grain transportation equipment. Although these conditions existed during the decade of the 1970s, the Gulf basis has exceeded 25 cents per bushel in only four months since the Russian grain embargo was imposed in January, 1980. Additionally, since mid-1980 there has been a surplus of grain transportation equipment [3,p.9]. The implication is that foreign purchasers would not have absorbed user charges since 1980. This study assumes there will be no change in these conditions through 1990.

Binkley and Sharples would disagree and are very definite in suggesting who will absorb user charges. Based upon results obtained from an existing world wheat trade model, to which a five cent per bushel user fee was added to transport cost, the following is suggested:

> less than one-half of a waterway user fee would actually be paid by grain producers. A substantial portion would in fact be incurred by importers [8].

This conclusion is based, in part, upon consideration of the foreign demand elasticity for U.S. agricultural goods as estimated by Bredahl, Meyers and Collins [9]. Bredahl et al. suggest that protectionist policies as employed by agricultural commodity importers will cause a decrease in the elasticity of demand for U.S. agricultural export.[4] In the case of the European Economic Community, an increase in import grain prices will result in a decrease in the variable levy. Import demand

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[4] As an example, Bredahl et al. suggest that the elasticities of demand for U.S. corn would equal -3.13 if free trade prevailed, but would be reduced to -1.31 given existing trade restrictions.

will remain constant. Similarly, effective import quotas would result in constant import demand.

Viewing the imposition of user charges as an increase in the cost of production of U.S. export grain, Binkley and Sharples suggest the following:

> to the extent that U.S. grain farmers can shift to alternative crops, to alternative markets, and/or alternative transportation (all factors which increase the elasticity of supply of barged grain), they will be able to shift part of the burden of the charge, unless demand is perfectly elastic. The more inelastic the demand, the greater the proportion of the charge that can be shifted to foreign consumers [8, p.121].

Utilizing an elasticity of foreign demand for U.S. wheat equal to -1.0, Binkley and Sharples estimate that approximately sixty-five percent of the 5 cent per bushel user charge would be absorbed by foreign importers. The remaining thirty-five percent would be absorbed by the U.S. market.

Again it is important to consider actual occurences in the market place. Schuh [39] notes that between 1981 and 1982 the value of the dollar increased by 25 percent. In effect, an increase in the value of the dollar will result in an increased price of U.S. agricultural exports to foreign countries. This increase in price

> reduced the value of our agricultural exports $3 billion dollars and 16 million tons, 10 million of which was corn. These numbers indicate the extent to which the foreign demand for our agricultural output is responsive to price . . . . In addition, the rise in prices is a strong stimulus to increase output in other countries [39,p.67].

The implication is that the foreign demand for U.S. exports may be more elastic than Bredahl et al. suggest. Additionally, since output in foreign countries is increasing, the substitutes for U.S. grain exports are increasing. Consequently, the elasticity of demand for U.S. agricultural exports may be increasing over time. Given an elastic demand, foreign purchasers would absorb little or no user charges.

If, as suggested, neither barge owners or foreign importers absorb user charges, there is still one final issue that needs to be addressed, that is, will the imposition of user charges, if passed back to producers, cause a change in the quantity of commodity production. Certainly, if user charges are passed back to producers in the form of lower grain bids, the price received by producers will decrease. It is assumed, however, that producers will not respond by reducing the quantity of export commodities produced. As an approximation this assumption may be reasonable for two reasons.[5] First, given a $3.00 per bushel Gulf export price, the grain bid to a farmer located 100 miles west of Clinton, Iowa would equal about $2.42.[6] A user charge of 5¢ per bushel, which exceeds the charges employed in this study, would represent only about 2 percent of the grain bid. Secondly, at least in the short run, grain supply is not very responsive to price. Tomek and Robinson [46] report short-run elasticities of supply equal to 0.5, 0.4, and 0.3 for soybeans, corn and wheat, respectively.

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[5] The assumption that producers will not respond to a decrease in the price received for grain is required in linear programming analysis. Grain supplies must remain fixed. A more detailed treatment of producer response is considered in Chapter VI of this dissertation.

[6] Based upon an analysis completed for the U.S. DOT by the author, transportation charges equal 18.9 cents for trucking 100 miles, 34.7¢ barge contract rate from Clinton to Gulf ports in 1980 and 4¢ handling charge at river elevator.

In summary, the major assumption employed in this analysis is that user charges will be absorbed by grain shippers. Barge owners will absorb none of the tax. In the long-run, this assumption implies that barge owners will be able to raise barge rates to cover the additional cost of barge service due to user charges. In the short-run, it may be likely that the incidence of user charges will be shared.

Additional Assumptions

Two types of additional assumptions are employed by this analysis. First, there are assumptions peculiar to this analysis, which although secondary in importance to the incidence assumption, will effect the results obtained from this model. Secondly, there are the assumptions associated with linear analysis. These assumptions will be cast within a transportation framework.

The assumptions pertaining exclusively to this analysis are the following:

1. Supplies and demands are predetermined. There is sufficient supply to satisfy all the demands.
2. There is no difference in the quality of a commodity in different uses. For example, corn transported to domestic processing locations or used as livestock feed is of the same quality as corn shipped to export ports.
3. The only factor that affects the selection between alternative transportation modes is the cost of transportation. Contractual

agreements or corporate affiliation as it may reflect upon modal choice are not considered.

4. All grain originates at the inland elevator. Consequently, farm to elevator costs as they may reflect upon modal choice are not a factor in modal choice in this model.

The assumptions required by linear programming, in addition to the specification of a finite number of activity, supplies and demands, are:

1. Linearity of the objective function implies that the cost per unit transported will not vary with the quantity shipped. For example, the per unit cost of shipping by barge from St. Louis to New Orleans will remain the same whether one, two or a dozen bargeloads are transported. Similarly, given this example, linearity of the constraints implies that the turnaround-time from St. Louis to New Orleans, and hence the decrease in barge equipment availability, will not vary given the quantity shipped.

2. Divisibility implies that an entire unit or fractional part of the unit may be utilized. In this study, units are defined in terms of 100,000 tons. An activity, if selected, may utilize one unit (100,000 tons) or .001 units (100 tons) or any other fractional designation, as well as multiple units.

3. Activities are Independent. For example, each unit received at the Gulf ports will require a specified unloading time. This unloading time will be unaffected whether the units are shipped by multiple car train or single car, that is, a larger quantity

will not cause an increase in unloading time due to congestion at the port facility.

4. Proportionality implies that to double the amount of grain received by multiple-car trains at Gulf ports, the number of days required in transport for one multiple car shipment, the port unloading capacity required for one shipment, and any other constraints must be doubled.

Differential Impacts by Type of Tax

In this study, the impact on agricultural shipments of a systemwide fuel tax and a segment specific ton-mile tax are examined. Both taxes are designed to recover 100 percent of estimated 1990 shallow-draft operations, maintenance, repair, and new construction (OMRC) expenditures that have, as of 1980, been approved by the U.S. Congress.

The level of waterway user taxes used in this analysis were taken from a study conducted by Data Resources Incorporated (DRI) [17].[7] DRI calculated the fuel and segment taxes by first projecting total barge traffic in five year increments to the year 2000. Given these levels of traffic, the total projected annual inland waterway navigation costs of operations, maintenance, repair and construction (OMRC) were converted to

[7] Studies to estimate the impact of user charges were mandated by section 205 of the Inland Waterway Revenue Act of 1978. Data Resources Incorporated received funding to complete a study. Iowa State University subsequently contracted with the U.S. Department of Transportation to further investigate grain impacts.

per gallon and segment specific ton-mile taxes to recover 100 percent of the annualized costs. Adding these taxes to barge rates causes some barge traffic to be diverted to other modes. The reduced level of traffic no longer yields the desired level of cost recovery, so it is necessary to raise the user tax. The higher user tax is then applied to rates on the remaining traffic. This iterative process was repeated four times. By the fourth iteration, traffic tended to stabilize.

Based on Corps of Engineers allocations of $208.8 million of public funds spent in 1977 on inland waterway OMRC for commercial navigation and on construction already authorized by Congress, public costs for 1990 commercial navigation are estimated to be $330 million in 1979 dollars [17]. Based on total projected 1990 barge traffic, a fuel tax of 38.1 cents per gallon and segment-specific taxes as presented in Table 3 would be required to recover these expenditures. Since the estimated costs are in 1979 dollars, the appropriate inflation rate would need to be applied to convert these estimates to nominal 1990 prices. The procedure utilized to estimate origin-specific per bushel tax levies is outlined in the DATA chapter.

The tax revenue generated from a systemwide fuel tax is based upon round-trip fuel consumption from the waterway origin to Baton Rouge, Louisiana on the Mississippi River and from waterway origin to the Bonneville Locks and Dam on the Columbia-Snake system.[8] The tax is

[8] Under current law, Baton Rouge, Louisiana and the Bonneville Locks and Dam are designated as the end of the shallow-draft navigation system on the Mississippi and Columbia-Snake River systems, respectively.

Table 3. Estimated 1990 segment specific tax in cents per ton-mile

River segment	Fuel-segment[a] combination	Segment tax: No rail response	Segment tax: 50% Rail response	Segment tax: 100% Rail response
Upper Mississippi	0.14	0.23	0.22	0.21
Middle Mississippi	0.14	0.23	0.21	0.20
Lower Mississippi	0.03	0.05	0.05	0.05
Illinois	0.11	0.17	0.16	0.14
Ohio	0.02	0.03	0.03	0.03
Missouri	0.19	0.31	0.27	0.24
Arkansas	0.38	0.62	0.55	0.51
Columbia-Snake	0.24	0.38	0.36	0.35

[a] System-wide fuel tax equals 9.9 cents per gallon.

systemwide because the tax level is constant over all river segments. Each gallon of fuel usage is charged the same--38.1 cents per gallon in 1990--regardless of commodity shipped or river segment travelled. The fuel consumed in both the revenue generating portion of the trip--grain movement to exporting port--and non-revenue generating portion--empty backhaul--is charged.[9] Only fuel used in propulsion of the towboat is taxable. Fuel used in generating electricity and other such amenities is not subject to taxation. The fuel tax is designed to recover the total expenditures on OMRC for all river segments combined.

The tax revenue generated from a river segment specific ton-mile tax is based upon shipment tonnage and miles travelled on specific river segments. The total tax resulting from a commodity shipment under a segment specific tax is the summation of the charges assessed for each segment. The ton-mile charge varies by river segment. Only the revenue generating ton-mile are taxed, that is, no tax is generated by an empty barge movement. The segment specific ton-mile tax is designed to recover the total expenditures on OMRC that are specific to the river segment upon which the barge shipment is travelling. The summation over all river segments and commodities will equal the expenditures on OMRC of all segments combined.

Given the basic differences between the fuel and segment ton-mile tax, a significant issue to be discussed in this dissertation is whether the impact on agricultural shippers will vary by type of tax.

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[9] For the purposes of this study, an empty backhaul was assumed. According to barge industry executives, a 25 percent backhaul would be average. In effect, any backhaul would lessen the burden of the tax upon grain shipments.

CHAPTER IV. DATA

Data requirements for this analysis will be discussed in three subsections of this chapter. The first section describes the data required and technique utilized to project the quantity of 1990 corn, soybeans and wheat available to satisfy the fixed demands at domestic and foreign markets and the estimation of these demands. The second section considers the transport rate structure and the constraints imposed upon rail, truck and barge mode utilization. The final section describes the method by which the aggregate user charges, as specified in the METHOD OF ANALYSIS Chapter, are converted to origin specific tax levies.

Quantity of Grain Requiring Transportation

Between 1969 and 1979, corn production increased by 65.6 percent, soybean production by 99.7 percent, and wheat production by 47.7 percent [62]. This rapid rate of production growth is not expected to continue through the 1980s. United States Department of Agriculture (USDA) projections for 1990 [58] place the increase in corn production at 17.7 percent, soybean production at 15.4 percent, and wheat production at 27.6 percent over 1979 production levels. Actual 1981 production [62] and the USDA 1985 and 1990 production projections of corn for grain, soybeans and wheat are presented in Table 4.

The USDA projections are adapted for use by this analysis in two ways. First, the 1985 and 1990 USDA projections are adjusted to reflect the quantity of grain requiring transportation in the 1984-1985 and

Table 4. Actual 1981 and USDA projected 1985 and 1990 U.S. production of corn, and wheat in millions of bushels

Crop	1981[a]	Projections 1985	1990
Corn	8,207	8,436	9,128
Soybeans	2,033	2,377	2,629
Wheat	2,793	2,498	2,728

[a] Source: [62].

1989-1990 crop years.[1] A uniform annual increase in production between 1979 and 1985 and between 1985 and 1990 is assumed to adjust the USDA projections to 1984 and 1989 levels. Secondly, the 1989-1990 production levels[2] are allocated among states, crop reporting districts within states, and to the regions as shown in Maps 1 to 3. This allocation procedure as detailed in the next few pages may be summarized as follows:

1. Separate projections of planted acreage by state for the 1989-1990 crop year are made for corn, soybeans and wheat. Planted acreage is assumed dependent upon the level of current exports, substitution of cropland among the three crops, and/or time. A separate routine is then utilized to ensure that projected planted acreage when aggregated across the crops does not overstate the historical proportion of planted acreage in the major crops to total acreage planted in all crops.
2. Production is equal to harvested acreage times yield. Harvested acreage by state for each crop is projected as a function of planted acreage. Yield is projected as a function of time.
3. Individual state production projections are proportionally increased or decreased so that, in total, projected 1989-1990

[1] The 1985 production projections were utilized by Hauser [21].

[2] All analysis from this point on will be cast in terms of the 1989-1990 crop year. The same procedures were utilized in the 1984-1985 production projections.

production in corn, soybeans and wheat equal USDA projections for these crops.

4. The proportion of state production by crop reporting district within a state is projected as a function of time.

State planted acreage

The response of planted acreage in corn, soybeans and wheat at the state level to market conditions and cropland availability is estimated by equations (22) to (25).

$$AP_{ijt} = f\ (AP_{kjt},\ X_{it} \text{ or } T) \quad (22)$$

$$PLAC_{jt} = b_o + b_i \ln(TT) \quad (23)$$

$$PPLAC_{jt} = bo + bi \ln(TT) \quad (24)$$

$$ADP_{ijt} = (PPLAC_{jt} \cdot PLAC_{jt}) \cdot \frac{AP_{ijt}}{AP_{ijt}} \quad (25)$$

where

AP_{ijt} = Acres planted of crop i (i = corn, soybeans or wheat) in state j, at time t (t = 1970 to 1979)

AP_{kjt} = Substitutes available to the ith crop (k = soybeans or wheat if i = corn), in state j, at time t

X_{it} = U.S. exports of crop i at time t

T = Time trend for the period 1970 to 1979. (T = 70-79)

$PLAC_{jt}$ = Planted acreage of all crops in state j at time t

$PPLAC_{jt}$ = The percentage in corn, soybean and wheat acres of planted acres in all crops in state j, at time t

ADP_{ijt} = Adjusted planted acres of crop i, in state j, at time t

TT = Time trend for the period 1965 to 1979 (TT = 65-79)

Equation (22) expresses the assumed functional relation between the planted acreage of the dependent variable, i.e. corn acreage, the acreage planted in alternative crops, wheat or soybeans, current exports, and/or a time trend. The time trend was inserted if exports did not significantly contribute to the level of planted acreage. The choice of a logarithmic scale for the time trend reflects the fact that over the period 1970 to 1979 planted acreage increased at a decreasing rate. Equation (23) projects the total planted acreage of all crops by state. Equation (24) projects the percentage of total crop acreage in combined corn, soybeans and wheat acreage. In both equations, the dependent variable is projected for 1989 as a function of time over the period 1965 to 1979. In equation (25), the term in parentheses projects the 1989 level of combined planted acres in corn, soybeans, and wheat. The second term is the ratio of projected planted acreage of crop i, as projected by equation (22), to the combined projected planted acreage of corn, soybeans and wheat, as determined by aggregating the crop planted acreages as projected by (22).

Tables 5 to 7 present the estimated regression equations represented by equation (22), standard errors of the regression coefficients, the coefficient of determination (R^2), and the actual 1979 and projected 1984 and 1989 state planted acreage by crop. Projections were made for 42 states. Tables 8 to 10 present the distribution of F-statistics, by level of significance, for these equations.

Soybean exports are influential in farm planting decisions in 20 of the 30 states for which soybean acreage is projected. Of these states,

Table 5. Actual 1979 and projected 1984 and 1989 corn planted acreage in thousands of acres, regression coefficients, and standard errors of coefficients, by state

State	Constant	AP_{kt}	X_t	T	R^2	Planted acreage 1979	1984	1989
AL	-21,850.3 (8,738)	-0.398 (0.15)		5,351.2 (2,069)	0.51	570	683	759
AZ	-1,259.8 (593)			301.6 (138)	0.38	60	771	94
AR	-31.1 (320)			17.9 (74)	0.01	50	49	50
CA	-3,424.1 (1,071)			888.1 (249)	0.61	430	511	562
CO	-9,663.4 (1,245)			2,433.9 (289)	0.90	960	1,121	1,262
DE	-1,916.8 (895)	-0.604 (0.22)		518.8 (217)	0.53	180	194	194
FL	-19,971.6 (4,641)	-1.794 (0.50)		4,859.6 (1,109)	0.75	426	572	692
GA	-48,776.9 (14,157)	-0.886 (0.26)		11,982.7 (3,346)	0.65	1,670	2,021	2,254
ID	142.8 (17)	-0.03 (0.02)	0.012 (0.008)		0.32	122	119	117
IL	-86,914.5 (25,769)	-0.06 (0.25)		23,818.7 (6,357)	0.69	10,850	11,737	12,913
IN.	-55,794.6 (6,765)	-0.672 (0.17)		14,880.8 (1,663)	0.93	6,160	6,939	7,592
IA	10,539.9 (634)		1.47 (0.4)		0.63	13,500	14,470	14,970
KS	2,107.4 (353)	-0.65 (0.3)	0.37 (0.14)		0.51	1,750	1,837	1,772
KY	-43,764 (12,274)	-0.847 (0.35)		10,687 (2,935)	0.81	1,440	1,812	2,033

Table 5. (Continued)

State	Constant	AP_{kt}	X_t	T	R^2	Planted acreage 1979	1984	1989
LA	2,318.0 (750)			-516.9 (174)	0.52	57	28	0
MD	-7,688.2 (1,861)			1,983.4 (452)	0.81	690	785	850
MI	1,616.9 (112.2)		0.55 (0.07)		0.89	2,900	3,084	3,271
MN	-63,995 (20,370)	-0.334 (0.27)		16,558 (4,882)	0.67	6,900	8,001	8,766
MS	2,467.8 (1,121)			-519.5 (260)	0.33	190	166	136
MO	-15,374 (11,752)	-0.57 (0.15)		4,845.2 (2,866)	0.80	2,400	2,306	2,022
MT	-649.4 (344)			169.9 (80)	0.36	85	104	114
NB	-59,816 (8,132)			15,396 (1,887)	0.89	7,350	8,401	9,292
NV						0	0	0
NJ	-2,178.9 (860)	-0.19 (0.13)		540.4 (203)	0.62	124	154	172
NM	-2,867.3 (631)			685.0 (146)	0.73	106	168	207
NY	-15,431 (2,204)			3,843.6 (511)	0.88	1,300	1,560	1,822
ND	-2,378.2 (1,385)			678.5 (321)	0.36	590	628	667
NC	-29,077 (3,746)	-0.74 (0.13)		7,394.6 (905)	0.91	1,850	2,086	2,249

Table 5. (Continued)

State	Constant	AP_{kt}	X_t	T	R^2	Planted acreage 1979	1984	1989
OH	-37,871 (3,894)	-0.59 (0.09)		10,088 (955)	0.95	3,850	4,161	4,470
OK	-186.6 (489)			72.8 (114)	0.05	125	136	140
OR	35.5 (1.5)		0.005 (0.001)		0.77	46	49	51
PA	-9,551.4 (1,723)			2,568.9 (400)	0.84	1,640	1,831	1,980
SC	-20,240 (5,856)			5,071.9 (1,437)	0.66	570	783	924
SD	17,860 (10,084)			-3,339.6 (2,340)	0.20	3,440	3,062	2,870
TN	-3,311.2 (2,420)			948.8 (561)	0.26	750	893	948
TX	-30,681.8 (21,272)			7,406.7 (4,904)	0.36	1,400	2,136	2,564
UT	-801.2 (331)			206.1 (77)	0.47	96	112	124
VA	-4,413.7 (928)			1,203.3 (215)	0.80	810	918	987
WV	-58.8 (215)			36.6 (49.9)	0.06	98	103	105
WA	72.5 (13.8)		0.23 (0.01)		0.52	155	141	149
WI	-35,009 (3,952)			8,921.2 (917)	0.92	3,950	4,520	5,035
WY	-457.2 (287)			124.5 (66.6)	0.31	87	95	102

Table 6. Actual 1979 and projected 1984 and 1989 soybean planted acreage in thousands of acres, regression coefficients, and standard errors of coefficients, by state

State	Constant	AP_{kt}	X_t	T	R^2	Planted acreage 1979	1984	1989
AL	-836.3 (173)		3.68 (0.3)		0.95	2,300	2,950	3,538
AZ						0	0	0
AR	3,623.8 (212)		1.67 (0.4)		0.73	5,150	5,343	5,609
CA						0	0	0
CO						0	0	0
DE	-3,585.3 (716)			879.3 (166)	0.78	270	311	361
FL	-27.1 (42)		0.56 (0.1)		0.88	460	551	641
GA	-755.5 (273)		3.25 (0.5)		0.86	2,150	2,592	3,112
ID						0	0	0
IL	5,241.9 (893)		5.32 (1.5)		0.61	9,800	10,719	11,570
IN	2,618.2 (447)		2.06 (0.8)		0.48	4,500	4,760	5,070
IA	-73,914.7 (21,612)			18,730.6 (5,014)	0.64	8,200	9,028	10,105
KS	205.9 (241)		1.72 (0.4)		0.65	1,580	1,897	2,203
KY	-33,792.8 (3,450)			8,099.9 (800)	0.93	1,720	2,096	2,565

Table 6. (Continued)

State	Constant	AP_{kt}	X_t	T	R^2	Planted acreage 1979	1984	1989
LA	(15.6) (242)		3.76 (0.4)		0.91	3,250	3,883	4,484
MD	-5,169.7 (1,386)			1,270.5 (322)	0.66	390	460	534
MI	146.2 (76.7)		0.90 (0.1)		0.86	980	1,076	1,221
MN	1,611.4 (681)		3.71 (1.2)		0.56	5,300	5,431	6,025
MS	901.8 (201)		3.96 (0.3)		0.94	4,200	4,986	5,620
MO	1,837.8 (432)		4.76 (0.73)		0.84	6,000	6,612	7,596
MT						0	0	0
NB	-25,149 (6,297)			6,087.3 (1,461)	0.68	1,630	1,823	2,175
NV						0	0	0
NJ	-120.4 (19.4)		0.42 (0.03)		0.95	227	313	380
NM						0	0	0
NY	-9.95 (3.5)		0.04 (0.006)		0.86	24	33	39
ND	814.7 (792)			-145.4 (184)	0.07	210	170	162
NC	-25,313.6 (6,305)			6,202.9 (1,462)	0.69	2,000	2,071	2,529

Table 6. (Continued)

State	Constant	AP_{kt}	X_t	T	R^2	Planted acreage 1979	1984	1989
OH	1,543.0 (430)		2.93 (0.7)		0.68	4,050	4,556	5,024
OK	10.71 (39.1)		0.43 (0.07)		0.84	350	452	520
OR						0	0	0
PA	-1,433.3 (376)			345.1 (87)	0.66	85	96	116
SC	606.3 (119)		1.21 (0.2)		0.82	1,700	1,856	2,049
SD	1.26 (109)		0.61 (0.18)		0.58	650	632	730
TN	-52,159 (3,974)			12,533 (922)	0.96	2,700	3,372	4,097
TX	-579.3 (98.9)		1.79 (0.17)		0.93	860	1,268	1,555
UT						0	0	0
VA	301.7 (35.1)		0.22 (0.06)		0.80	500	530	565
WV						0	0	0
WA						0	0	0
WI	-3,384.1 (1,437)			831.6 (333)	0.44	300	301	349
WY						0	0	0

Table 7. Actual 1979 and projected 1984 and 1989 wheat planted acreage in thousands of acres, regression coefficients, and standard errors of coefficients, by state

State	Constant	AP_{kt}	X_t	T	R^2	Planted acreage 1979	1984	1989
AL	-29.02 (998)			41.46 (232)	0.01	95	155	157
AZ	150.6 (133)	-2.2 (1.7)	0.15 (0.1)		0.25	135	205	199
AR	-12,240 (5,958)			2,953.0 (1,382)	0.36	530	844	1,015
CA	-9,499.3 (7,802)			2,389.5 (1,810)	0.18	867	1,088	1,226
CO	-24,939.5 (5,131)			6,438.6 (1,190)	0.79	3,245	3,589	3,961
DE	19.9 (7.8)		0.15 (0.01)		0.31	32	41	44
FL						0	0	0
GA	881.3 (1,425)			-164.5 (331)	0.03	190	152	143
ID	460.9 (166)		0.88 (0.2)		0.78	1,470	1,736	1,925
IL	1,773.8 (801)	-0.214 (0.1)	1.46 (0.6)		0.48	1,360	1,608	1,742
IN	2,168.0 (724)	-0.674 (0.3)	1.51 (0.5)		0.62	1,000	1,163	1,281
IA	-2,283.1 (910)			546.1 (211)	0.46	85	137	168
KS	-155,318 (30,381)	-3.42 (1.2)		39,583 (7,250)	0.82	10,800	13,575	14,821
KY	-5,129.6 (2,790)			1,268.2 (647)	0.33	380	490	563

Table 7. (Continued)

State	Constant	AP_{kt}	X_t	T	R^2	Planted acreage 1979	1984	1989
LA	87.7 (12.4)		-0.013 (0.005)		0.42	48	36	28
MD	-234.1 (937)			84.6 (217)	0.02	122	141	145
MI	-26,789 (10,298)	-1.42 (0.6)		6,600.5 (2,476)	0.51	800	933	1,110
MN	-110,543 (31,658)	-0.73 (0.3)		26,838 (7,497)	0.65	2,440	4,410	5,529
MS	206.6 (1,519)			-10.5 (352)	0.01	160	160	160
MO	-75,514 (13,328)	-0.71 (0.18)		18,586.7 (3,262)	0.85	1,780	2,140	2,516
MT	-67,032 (12,252)			16,680.1 (2,843)	0.81	5,985	6,875	7,839
NB	-16,630 (9,887)			4,535.7 (2,294)	0.33	3,000	3,467	3,729
NV	-557.6 (159)			134.7 (37)	0.63	30	39	47
NJ	-1,986.6 (418)	-0.23 (0.06)		458.4 (99)	0.77	51	63	74
NM	-8,733 (823)			2,130 (191)	0.94	560	705	828
NY	-386.6 (1,467)			126.9 (341)	0.02	170	176	183
ND	-91,176.4 (42,612)			23,369.1 (9,886)	0.41	9,900	12,368	13,719
NC	1,033.2 (1,291)			-179.5 (299)	0.04	235	238	227

Table 7. (Continued)

State	Constant	AP_{kt}	X_t	T	R^2	Planted acreage 1979	1984	1989
OH	-47,621 (11,215)	-0.74 (0.23)		11,909 (2,737)	0.73	1,350	1,755	2,095
OK	-77,239 (27,108)			19,424 (6,290)	0.54	7,000	8,823	9,946
OR	-23,637 (5,020)			5,750.6 (1,165)	0.75	1,450	1,841	2,176
PA	606.8 (1,650)			-73.0 (382)	0.01	270	283	279
SC	232.9 (1,092)			-23.8 (253)	0.01	120	127	126
SD	-86,734 (14,537)	-2.40 (1.16)		21,012 (3,438)	0.87	3,455	4,846	5,826
TN	-5,256.2 (1,935)			1,294.8 (449)	0.51	400	481	556
TX	-37,398 (41,359)			9,988.8 (9,550)	0.18	5,800	6,860	7,438
UT	146.2 (28.4)		0.12 (0.03)		0.70	278	326	352
VA	-353.9 (1,722)			138.8 (399)	0.02	215	262	269
WV	125.9 (113)			-25.9 (26.3)	0.11	12	11	10
WA	1,493.3 (271)		1.59 (0.27)		0.81	3,650	3,804	4,147
WI	-1,165 (1,142)			284.0 (264)	0.13	57	93	109
WY	-2,871.8 (636)			738.5 (148)	0.76	34	400	443

Table 8. Distribution of F-statistics by level of significance for planted corn acreage equations[a]

Critical values of F-statistic (F_c)[b]		Number of States	States with $F>F_c$
$F_{1,8,}$	$F_{2,7,}$		
9.55	11.3[c]	20	CA, CO, FL*, IN*, IA, KS*, KY*, MD, MI, MO*, NB, NJ*, NY, NM, NC*, OH*, OR, PA, VA, WI
4.74	5.32[d]	9	AZ, GA*, IL*, LA, MN*, MT, SC, UT, WA
3.26	3.46[e]	5	AL*, DE*, MS, ND, WY
NS[f]		7	AR, ID*, OK, SD, TN, TX, WV

[a] Tables 8 to 10 indicate the level of confidence to be placed in individual state regression equations. The null hypothesis ($B_i=0$) is tested against the alternative hypothesis ($B_i \neq 0$). At the indicated level of significance--($1-\alpha$)--and degrees of freedom equal to 1,8 or 2,7 the null hypothesis is rejected for the regression equations for the states listed.

[b] In tables 8 to 10 and 12 to 16 critical values are from [78].

[c] $\alpha = .01$.

[d] $\alpha = .05$.

[e] $\alpha = .10$.

[f] Not significant at $\alpha = .10$.

* Indicates two independent variables.

Table 9. Distribution of F-statistics by level of significance for planted soybean acreage equations

Critical values of F-statistic (F_c) $F_{1,8}$,	$F_{2,7}$,	Number of States	States with $F > F_c$
9.55	11.3[a]	25	AL, AR, DE, FL, GA, IL, IA, KY, LA, MD, MI, MS, MO, NB, NJ, NY, NC, OH, OK, PA, SC, SD, TN, TX, VA
4.74	5.32[b]	3	IN, MN, WI
3.26	3.46[c]	1	KS
NS[d]		1	ND

[a] α = .01.

[b] α = .05.

[c] α = .10.

[d] Not significant at α = .10.

Table 10. Distribution of F-statistics by level of significance for planted wheat acreage equations

Critical values of F-statistic (F_c) $F_{1,8}$,	$F_{2,7}$,	Number of States	States with $F>F_c$
9.55	11.3[a]	13	CO, ID, KS*, MO*, MT, NV, NJ*, NM, OR, SD*, WA
4.74	5.32[b]	8	IN*, IA, LA, MN, ND, OH*, OK, TN
3.26	3.46[c]	6	AR, DE, IL*, KY, MI, NB
NS[d]		14	AL, AZ*, CA, GA, MD, MS, NY, NC, PA, SC, TX, VA, WV, WI

[a] $\alpha = .01$.

[b] $\alpha = .05$.

[c] $\alpha = .10$.

[d] Not significant at $\alpha = .10$.

* Indicates two independent variables.

Minnesota, Illinois, Indiana, Ohio, Missouri, Arkansas, Mississippi, Louisiana, Kansas, and South Dakota border the Mississippi River or tributaries. Given that alternative uses of soybeans except processing --over 60 percent soybean utilization in 1979--are essentially non-existent, a strong export demand for soybeans would generate an increase in barge traffic. Additionally, soybean acreage is substituted for corn acreage in 11 of 41 states. These 11 states include Alabama, Georgia and North Carolina, traditionally corn deficit markets; and Illinois, Indiana and Ohio, areas that serve the deficit Southeastern markets. A strong export demand for soybeans could conceivably cause a shift in the relative amount of corn available for export from the Midwestern surplus areas and hence a decrease in the relative share of corn shipments by barge.

Table 11 presents the actual planted acreage in all crops for 1970 and 1979, as well as the actual percentage of total acreage in corn, soybeans and wheat for these years. Also included in Table 11 are the 1989-1990 projections for total crop acreage and percentage in the major crops as projected by equations (23) and (24). Tables 12 to 13 present the distribution of t statistics, by level of significance, for the independent time variable in equations (23) and (24) respectively.

As demonstrated in Table 11, total U.S. planted acreage increased by 47 million acres--16.3 percent--between 1970 and 1979 [62]. Between 1979 and 1989, projected additional 26.5 million acres are planted. This constitutes a decline in the rate of growth to about 8 percent over the

Table 11. Total planted acreage and percent of planted acreage in corn, soybeans and wheat by state; 1970, 1979 and projected 1989

State	Planted acreage 1970[a]	Planted acreage 1979[a] (000 acres)	Planted acreage 1989[a]	Percent of planted acres in corn, soybeans and wheat 1970[b]	Percent of planted acres in corn, soybeans and wheat 1979[b]	Percent of planted acres in corn, soybeans and wheat 1989[b]
AL	2,640	4,161	4,663	.66	.69	.82
AZ	1,130	1,207	1,371	.17	.16	.37
AR	7,353	8,343	9,303	.66	.69	.67
CA	6,742	6,510	6,047	.14	.20	.33
CO	6,215	6,107	6,337	.51	.69	.69
DE	491	530	512	.76	.91	.91
FL	1,140	1,520	1,525	.54	.58	.76
GA	4,283	5,348	5,824	.55	.75	.93
ID	3,963	4,493	4,927	.28	.39	.38
IL	20,299	23,442	25,225	.90	.94	.98
IN	10,612	12,515	14,121	.86	.93	.96
IA	20,790	24,984	28,157	.79	.87	.94
KS	18,968	21,009	23,253	.65	.73	.73
KY	3,707	5,231	6,182	.51	.68	.80
LA	3,634	4,974	5,816	.53	.67	.77
MD	1,445	1,572	1,531	.64	.77	.92
MI	5,653	6,907	6,689	.48	.68	.80
MN	17,453	21,863	24,473	.52	.67	.79
MS	4,921	6,389	7,453	.62	.71	.71
MO	11,390	14,345	15,698	.67	.71	.68
MT	8,206	8,828	9,702	.43	.69	.67

[a] Source: [62].

[b] Computed based upon state totals in [62].

Table 11. (Continued)

State	Planted acreage			Percent of planted acres in corn, soybeans and wheat		
	1970	1979 (000 acres)	1989	1970	1979	1989
NB	16,014	17,858	19,731	.55	.67	.75
NV	486	530	565	.04	.06	.06
NJ	478	556	438	.42	.72	.73
NM	1,131	1,305	1,313	.31	.51	.71
NY	4,305	4,309	3,763	.23	.35	.49
NC	4,069	5,243	5,519	.69	.78	.86
ND	17,327	20,881	22,201	.43	.51	.63
OH	8,793	10,995	12,286	.77	.84	.91
OK	7,950	9,600	10,707	.67	.78	.90
OR	2,625	2,641	2,591	.29	.57	.68
PA	4,364	4,454	4,338	.36	.45	.51
SC	2,340	2,871	3,210	.71	.83	.96
SD	14,430	15,491	15,274	.38	.48	.56
TN	4,043	5,276	5,941	.53	.73	.84
TX	18,986	22,421	24,006	.23	.36	.45
UT	1,060	1,100	1,108	.27	.34	.41
VA	2,651	2,827	2,954	.47	.54	.61
WA	4,403	4,561	5,075	.54	.83	.83
WV	722	714	725	.14	.15	.17
WI	9,075	9,376	9,211	.32	.46	.56
WY	1,831	1,844	1,824	.17	.23	.26
U.S.	288,118	335,131	361,589	.55	.66	.75

Table 12. Distribution of t-statistics by level of significance for planted acreage equations[a]

Critical value of t-statistic (t_{13})	Number of states	States with $\|t\| > t_3$
3.01[b]	23	AL, AZ, AR, GA, ID, IL, IN, IA, KS, KY, LA, MN, MS, MO, MT, NB, NC, ND, OH, SC, TN, VA, WA
2.16[c]	4	CO, NV, OK, TX
1.35[d]	4	FL, MI, NM, NY
NS[e]	11	CA, DE, MD, NJ, OR, PA, SD, UT, WV, WI, WY

[a] Tables 11 to 15 indicate the level of confidence to be placed in individual state regression equations. The null hypothesis ($B_1=0$) is tested against the alternative hypothesis ($B_1 \neq 0$). At the indicated level of significance--(1-α)--and degrees of freedom equal to 13, the null hypothesis is rejected for the regression equations for the states listed.

[b] $\alpha = .01$.

[c] $\alpha = .05$.

[d] $\alpha = .10$.

[e] Not significant at $\alpha = .10$.

Table 13. Distribution of t-statistics by level of significance for the percentage planted acreage in corn, soybean and wheat equations

Critical value of t-statistic (t_{13})	Number of states	States with $\|t\| > t_3$
3.01[a]	32	AL, AZ, CA, DE, FL, GA, IL, IN, IA, KY, LA, MD, MI, MN, NB, NJ, NM, NY, NC, ND, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, WA, WI
2.16[b]	3	MT, WV, WY
1.35[c]	2	ID, MS
NS[d]	5	AR, CO, KS, MO, NV

[a] $\alpha = .01$.

[b] $\alpha = .05$.

[c] $\alpha = .10$.

[d] Not significant at $\alpha = .10$.

previous 10 year period. During the 1970 to 1979 period, the percentage of planted acres dedicated to corn, soybeans and wheat grew steadily. In 1970, 55 percent of all planted acres were in corn, soybeans and wheat. By 1979, 66 percent of planted acres were in these three crops [62]. By 1989, it is projected that about 75 percent of all planted acreage will be in corn, soybeans and wheat.

The corn belt states of Illinois, Iowa, Indiana, Ohio, Missouri and Nebraska account for 20.6 million acres and about 44 percent of the growth in acreage between 1970 and 1979. Between 1979 and 1989, these states account for 42 percent of the projected growth in planted acres. The percentage of planted acres planted in corn, soybeans and wheat in the corn belt states is 83 percent in 1979. By 1989, it is projected that 88 percent of the acreage will be planted in these crops. The northern plains states of Minnesota, North Dakota and South Dakota account for 18 percent and the Southeastern states of Alabama, Mississippi, Georgia, South Carolina, North Carolina and Tennessee about 14 percent of the growth in total planted acres between 1970 and 1979. Between 1979 and 1989, this percentage is projected to decline to 13 and 12 percent for the northern plains and southeast, respectively. However, the percentage of these acres planted in corn, soybeans and wheat are projected to increase sharply in both areas. In 1979, about 75 percent of all planted acres in the southeast were planted in corn, soybeans and wheat; by 1989, this percentage is projected to grow to over 85 percent. In the northern plains, the percentage of planted acres dedicated to corn, soybeans and wheat is projected to increase from 56 percent in 1979 to about 68 percent in 1989. Since corn, soybeans and wheat comprise over 90 percent of all grains shipped by the different transport modes, this increased specialization implies a certain increase in demand for transportation services.

State harvested acres

The following two equations were used to project the 1989 harvested acres of corn, soybeans and wheat:

$$AH_{ijt} = b_o + b_1 (AP_{ijt}) \tag{26}$$

$$ADH_{ijt} = \frac{AH_{ijt}}{AP_{ijt}} \cdot ADP_{ijt} \tag{27}$$

where

AH_{ijt} = Acres harvested of crop i, in state j, at time t.

ADH_{ijt} = Adjusted harvested acreage of crop i, in state j, at time t.

Equation (26) projects harvested acres as a linear function of planted acres to 1989 based upon the 1970 to 1979 period. The first term in equation (27) projects the 1989 percentage harvested acres of corn, soybeans and wheat. The second term is adjusted planted acres as estimated by equation (25). A distribution of t-statistics table is not presented for these equations. The relationship between harvested acres and planted acres as can be expected is very strong. All t-statistics were significant to at least the 95 percent level of confidence.

State average yields

State average yields of corn for grain, soybeans and wheat are projected to 1989 by the following equation:

$$Y_{ijt} = b_o+b_1 \ln(T) \quad (28)$$

where

Y_{ijt} = Yield in bushels per acre of crop i, in state j, at time t.

T = time trend for the period 1970 to 1979 (T = 70-79)

In 1970, southern corn leaf blight dramatically reduced corn yields. Therefore, in the Southeast and parts of the Midwest, 1969 was substituted for 1970. Secondly, in a few states particularly good years in the beginning of the series imparted a noticeable downward bias to projected yields. In these cases, projected yields were constrained from falling below a five-year average (1975-1979) of state yields for that crop. The distribution of t-statistics, by level of significance is presented in Tables 14 to 16.

<u>State production levels</u>

State production of corn for grain, soybeans, and wheat are projected and adjusted to be consistent with USDA projections through equations (29) and (30).

$$PP_{ijt} = ADH_{ijt} \cdot Y_{ijt} \quad (29)$$

$$P_{ijt} = \frac{PP_{ijt}}{\sum_{j}^{42} PP_{ijt}} \cdot USDAP \quad (30)$$

where

PP_{ijt} = Preliminary production of crop i, in state j, at time t.

Table 14. Distribution of t-statistics by level of significance for average corn yield equations[a]

Critical value of t-statistic (t_8)	Number of states	States with $|t| > t_8$
3.36[b]	7	AZ, AR, CA, CO, NM, OR, TX
2.30[c]	7	KY, MS, NJ, OH, PA, TN, WA
1.86[d]	1	MD
1.40[e]	8	AL, DE, FL, ID, KS, ND, NB, WV
NS[f]	17	GA, IL, IN, IA, MI, MN, MO, MT, NB, NY, NC, OK, SC, SD, UT, VA, WI

[a] States with 1969 substituted for 1970 are AL, GA, IN, KS, KY, MS, MO, NB, NC, OH, TN.

[b] $\alpha = .01$.

[c] $\alpha = .05$.

[d] $\alpha = .10$.

[e] $\alpha = .20$.

[f] Not significant at $\alpha = .20$.

Table 15. Distribution of t-statistics by level of significance for average soybean yield equations[a]

Critical value of t-statistic (t_8)	Number of states	States with $\lvert t \rvert > t_8$
3.36[b]	0	
2.30[c]	6	MN, ND, OH, SD, VA, WI
1.86[d]	3	IA, MN, NY
1.40[e]	3	IN, KY, PA
NS[f]	15	AL, AR, DE, IL, KS, MD, MO, MI, NB, NJ, OK, SC, TN, TX, WI

[a] States constrainted at 5-year average are FL, GA, and NC.

[b] $\alpha = .01$.

[c] $\alpha = .05$.

[d] $\alpha = .10$.

[e] $\alpha = .20$.

[f] Not significant at $\alpha = .20$.

Table 16. Distribution of t-statistics by level of significance for average wheat yield equations[a]

Critical value of t-statistic (t_8)	Number of states	States with $\|t\| > t_8$
3.36[b]	1	CA
2.30[c]	1	AZ
1.86[d]	2	MI, OK
1.40[e]	2	AR, MS
NS[f]	16	ID, IL, IN, IA, KS, KY, MD, MN, MO, MT, NV, OH, OR, TN, TX, WI

[a] States constrainted at 5-year average are AL, CO, DE, GA, NB, NJ, NM, NY, NC, ND, PA, SC, SD, UT, VA, WA, WY.

[b] $\alpha = .01$.

[c] $\alpha = .05$.

[d] $\alpha = .10$.

[e] $\alpha = .20$.

[f] Not significant at $\alpha = .20$.

P_{ijt} = Adjusted production of crop i, in state j, at time t.

$USDAP_{it}$ = USDA production projections of crop i at time t.

Equation (30) preserves the distribution of projected crop production among states while correcting for deviation from the USDA projected production level at the national level.[3]

Tables 17 to 19 present adjusted planted acreage, harvested acreage, projected yields and state production levels as estimated by this procedure. Also presented in these tables are the final state production levels after 1989 projected U.S. production was made consistent with the USDA projections (titled USDA-1989).

In comparison with aggregate USDA projections, this procedure underestimated corn production by about 140 million bushels, overestimated soybean production by 233 million bushels, and overestimated wheat production by 23 million bushels. For all three crops, aggregated projected harvested acres were greater and yields lower than the USDA projections. Soybean production accounts for the largest percentage difference--9 percent--between projections in this analysis and USDA projections. It must be remembered that soybean acreage was highly influenced by soybean exports. Secondly, soybean acreage substituted for corn acreage in many of the major corn producing states. A lower 1989-1990 projected soybean

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[3] As explained earlier, this analysis and the Data Resources, Inc. analysis were completed during the same time period. In addition to the level of user charges, USDA total production projections were used by both analyses for consistency. Regional projections are not available in sufficient detail from the USDA. Therefore, an allocation procedure was required in both studies.

Table 17. Projected corn planted acres, harvested acres, yield and production and USDA production estimates, 1989

State	Acres Planted	Acres Harvested	Yield	Production 1989 Unadjusted	Production 1989 Adjusted to USDA total
	(000 acres)		(bushels/acre)	(000 bushels)	
AL	654	565	67.2	37,942	38,534
AZ	94	74	107.9	7,944	8,068
AR	46	35	85.9	2,985	3,032
CA	562	328	147.8	48,416	49,173
CO	1,059	806	144.5	116,481	118,300
DE	151	140	112.7	15,769	16,015
FL	598	402	67.2	26,982	27,403
GA	2,225	1,728	62.8	108,529	110,223
ID	108	30	91.3	2,726	2,769
IL	12,213	11,937	128.2	1,530,364	1,554,262
IN	7,412	7,184	114.9	825,409	838,299
IA	14,970	13,865	121.1	1,679,070	1,705,291
KA	1,592	1,274	121.8	155,200	157,623
KY	1,958	1,783	112.6	200,740	203,875
LA					0
MD	785	677	109.8	74,364	75,525
MI	3,124	2,625	94.7	248,543	252,424
MN	8,311	6,908	102.2	706,000	717,025
MS	122	67	64.4	4,339	4,406
MO	1,782	1,689	90.4	152,684	155,068
MT	93	10	73.0	759	770

Table 17. (Continued)

State	Acres: Planted (000 acres)	Acres: Harvested (000 acres)	Yield (bushels/acre)	Production: 1989 Unadjusted (000 bushels)	Production: 1989 Adjusted to USDA total (000 bushels)
NB	9,057	8,354	118.2	987,423	1,002,842
NV					0
NJ	88	49	102.9	5,007	5,085
NM	187	158	123.0	19,478	19,782
NY	1,629	831	81.2	67,440	68,493
NC	2,142	1,938	75.1	145,555	147,828
ND	646	288	88.2	25,436	25,833
OH	4,295	4,017	130.6	524,566	532,758
OK	128	83	99.6	8,260	8,389
OR	40	9	115.8	1,018	1,033
PA	1,860	1,370	111.3	152,502	154,883
SC	919	793	72.8	57,698	58,599
SD	2,585	1,751	78.6	137,653	139,803
TN	848	688	94.2	64,800	65,812
TX	2,422	2,257	119.9	270,561	274,786
UT	117	18	101.5	1,794	1,822
VA	981	729	82.4	60,094	61,033
WA	147	89	128.5	11,459	11,638
WV	105	63	90.7	5,727	5,817
WI	4,694	3,424	104.2	356,734	362,305
WY	90	31	98.9	3,048	3,095
U.S.	90,839	79,064	112.0	8,851,496	---
U.S.[a]		78,042	115.2	---	8,989,722

[a] Source: [56].

Table 18. Projected soybean planted acres, harvested acres, yield and production and USDA production estimates, 1989

State	Acres Planted	Acres Harvested	Yield	Production 1989 Unadjusted	Production 1989 Adjusted to USDA total
	(000 acres)		(bushels/acre)	(000 bushels)	
AL	3,051	2,984	23.2	69,226	634,80
AZ					0
AR	5,253	5,213	27.4	142,848	130,993
CA					0
CO					0
DE	282	276	30.1	8,322	7,631
FL	553	542	25.8	13,986	12,826
GA	3,073	2,960	23.2	68,668	62,969
ID					0
IL	10,943	10,793	39.7	428,471	392,910
IN	4,949	4,885	39.0	190,523	174,710
IA	10,160	10,085	41.7	420,525	385,624
KA	1,979	1,953	22.2	43,353	39,755
KY	2,470	2,404	33.4	80,295	73,631
LA	4,446	4,374	29.0	126,850	116,322
MD	493	487	32.2	15,672	14,371
MI	1,166	1,165	30.0	34,947	32,046
MN	5,712	5,649	41.2	232,749	213,432
MS	5,048	4,938	29.2	144,195	132,228
MO	6,694	6,620	32.0	211,836	194,255
MT					0

Table 18. (Continued)

State	Acres		Yield	Production	
	Planted	Harvested		1989 Unadjusted	1989 Adjusted to USDA total
	(000 acres)		(bushels/acre)	(000 bushels)	
NB	2,120	2,088	33.2	69,317	63,564
NE					0
NJ	195	190	34.0	6,475	5,938
NM					0
NY	35	33	28.6	936	858
NC	2,409	2,390	24.0	57,354	52,594
ND	157	149	37.6	5,600	5,135
OH	4,827	4,795	41.0	196,600	180,283
OK	474	446	20.4	9,100	8,345
OR					0
PA	109	105	34.4	3,598	3,299
SC	2,037	1,993	22.4	44,638	40,933
SD	658	645	41.1	26,510	24,309
TN	3,667	3,546	25.7	91,145	83,580
TX	1,469	1,382	26.2	36,201	33,197
UT					0
VA	561	566	34.3	19,421	17,810
WA					0
WV					0
WI	325	317	39.7	12,601	11,556
WY	---	---	---	---	---
U.S.	85,313	83,973	33.5	2,811,960	---
U.S.[a]		78,841	32.7	---	2,578,583

[a] Source: [56].

Table 19. Projected wheat planted acres, harvested acres, yield and production and USDA production estimates, 1989

State	Acres: Planted (000 acres)	Acres: Harvested (000 acres)	Yield (bushels/acre)	Production: 1989 Unadjusted (000 bushels)	Production: 1989 Adjusted to USDA total (000 bushels)
AL	135	89	26.2	2,344	2,324
AZ	199	187	80.4	15,025	14,895
AR	951	802	41.6	33,359	33,070
CA	1,226	1,045	95.7	99,997	99,131
CO	3,324	2,795	23.4	65,399	64,833
DE	34	31	33.6	1,057	1,048
FL			12.9		0
GA	141	110	31.6	3,464	3,434
ID	1,770	1,616	53.9	87,109	86,355
IL	1,648	1,583	40.4	63,963	63,409
IN	1,251	1,186	42.3	50,173	49,739
IA	168	145	34.8	5,057	5,013
KA	13,317	12,158	31.2	379,318	376,033
KY	542	428	35.9	15,354	15,221
LA	27	13	39.6	519	514
MD	134	123	36.4	4,460	4,421
MI	1,061	1,044	44.5	46,465	46,063
MN	5,242	5,062	38.0	192,342	190,676
MS	143	112	34.8	3,907	3,873
MO	2,217	1,966	42.0	82,555	81,840
MT	6,445	5,928	29.5	174,880	173,365

Table 19. (Continued)

State	Acres: Planted (000 acres)	Acres: Harvested (000 acres)	Yield (bushels/acre)	Production: 1989 Unadjusted (000 bushels)	Production: 1989 Adjusted to USDA total (000 bushels)
NB	3,635	3,203	33.0	105,692	104,776
NV	34	31	57.6	1,794	1,779
NJ	38	28	36.2	1,014	1,005
NM	746	535	23.0	12,314	12,207
NY	164	153	38.0	5,814	5,763
NC	216	177	31.8	5,643	5,594
ND	13,277	12,908	26.4	340,784	337,833
OH	2,013	1,941	48.5	94,133	93,318
OK	9,064	7,974	38.9	310,197	307,511
OR	1,721	1,602	44.1	70,631	70,020
PA	262	251	32.0	8,021	7,952
SC	125	112	29.4	3,279	3,251
SD	5,248	4,121	20.0	82,420	81,706
TN	497	386	36.4	14,051	13,929
TX	7,026	5,374	27.0	145,091	143,835
UT	333	299	26.0	7,775	7,708
VA	268	234	32.8	7,667	7,601
WA	4,090	3,563	42.2	150,346	149,044
WV	10	8	32.4	263	261
WI	102	95	40.6	3,871	3,837
WY	392	329	23.6	7,765	7,697
U.S.	89,238	79,746	33.9	2,705,314	---
U.S.[a]		76,165	35.2	---	2,681,885

[a] Source: [56].

export level would have lowered soybean and increased corn production. The difference between these projections and the USDA estimates would then have narrowed.

Crop reporting district production levels

The Crop Reporting District (CRD) percentage of state production by crop for 1989 is projected by equation (31) based on data contained in state crop reporting bulletins over the period 1970 to 1978.

$$CRDP_{ikjt} = b_o \; T^{b_1} \qquad (31)$$

where

$CRDP_{ikjt}$ = Preliminary percentage production of crop i, in CRD k, in state j, at time t.

T = time trend for the period 1970 to 1978 (T = 70-78)

The preliminary projected CRD percentages were adjusted so that, in total, the percentages summed across CRDs in the state equaled 100 percent. The adjusted CRD percentage times state production as projected by equation (15) equals CRD production as used in this analysis. These production levels, as well as CRD seed, livestock consumption and processing, as discussed below are presented in Appendix A.

Table 20 presents the proportion of the CRD surplus allocated to subregions when the district is divided into smaller areas. The proportion of the total CRD surplus assigned to subdivisions is based upon county production data for 1978 as reported in each state's annual crop and livestock reporting bulletin. In some cases, a second division for

Table 20. Estimated 1978 subdivision proportions of CRD crop production by CRD, type of division, and crop

	CRD	First division	Second division	Proportion [a] Soybeans	Corn	Wheat
Illinois	1	NE[b]	---	.18	.20	---
		NE	N[c]	.50	.50	---
		NE	S[d]	.50	.50	---
		NW[e]	---	.04	.14	---
		SE[f]	---	.41	.28	---
		SE	N	.50	.50	---
		SE	S	.50	.50	---
		SW	---	.37	.38	---
		SW	N	.33	.33	---
		SW	S	.67	.67	---
	3	N	---	.33	.39	---
		SE	---	.15	.11	---
		SW[g]	---	.52	.50	---
		SW	N	.50	.50	---
		SW	S	.50	.50	---
	4	E[h]	---	.44	.38	---
		E	N	.50	.50	---
		E	S	.50	.50	---
		W[i]	---	.56	.61	---

[a] Proportion of CRD surplus allocated to regions designated by divisions.

[b] Northeast quadrant.

[c] Northern half, in this case, of the Northeast quadrant.

[d] Southern half.

[e] Northwest quadrant.

[f] Southeast quadrant.

[g] Southwest quadrant.

[h] Eastern half.

[i] Western half.

Table 20. (Continued)

	CRD	First division	Second division	Proportion Soybeans	Corn	Wheat
		W	N	.70	.70	---
		W	S	.30	.30	---
	5	E	---	.49	.54	---
		E	N	.50	.50	---
		E	S	.50	.50	---
		W	---	.51	.46	---
		W	N	.50	.50	---
		W	S	.50	.50	---
	6	NE	---	.28	.30	---
		NW	---	.29	.26	---
		SE	---	.25	.23	---
		SW	---	.18	.20	---
	7	NE	---	.35	.38	.31
		NW	---	.40	.39	.54
		SE	---	.10	.14	.05
		SW	---	.15	.10	.09
	40	NE	---	.30	.33	.06
		SE	---	.35	.26	.60
		W	---	.35	.41	.34
	60	NE	---	.37	.40	.19
		NW	---	.21	.25	.13
		SE	---	.25	.23	.37
		SW	---	.17	.12	.30
Indiana	1	N	---	.27	.34	.50
		S	---	.73	.66	.50
	2	N	---	---	.40	.46
		S	---	---	.60	.54
	3	N	---	---	.52	.48
		S	---	---	.48	.52
	4	N	---	.63	.60	.48
		S	---	.37	.40	.53
	5	N	---	.57	.49	.45
		S	---	.43	.51	.55

Table 20. (Continued)

	CRD	First division	Second division	Proportion Soybeans	Corn	Wheat
	6	N	---	.64	.48	.60
		S	---	.35	.52	.40
	7	N	---	.42	.47	.49
		S	---	.58	.53	.51
	8	N	---	.57	.45	---
		S	---	.42	.55	---
Iowa	1	NE-E[j]	---	.12	.09	---
		NE-W	---	.10	.09	---
		NW	---	.22	.24	---
		SE-E	---	.17	.13	---
		SE-W	---	.15	.13	---
		SW	---	.23	.31	---
		SW	E	.50	.50	---
		SW	W	.50	.50	---
	2	NE-E	---	.10	.10	---
		NE-W	---	.11	.11	---
		NW-E	---	.11	.11	---
		NW-W	---	.09	.08	---
		SE-E	---	.11	.13	---
		SE-W	---	.13	.14	---
		SW-E	---	.17	.16	---
		SW-W	---	.18	.16	---
	3	NE	---	.06	.18	---
		NW	---	.31	.22	---
		SE	---	.19	.34	---
		SW	---	.44	.27	---
	4	NE-NE	---	.15	.19	---
		NE-NW	---	.09	.08	---
		NE-SE	---	.07	.04	---
		NE-SW	---	.05	.04	---
		NW-NE	---	.05	.07	---
		NW-NW	---	.06	.13	---
		NW-SE	---	.07	.05	---
		NW-SW	---	.04	.04	---

[j] The eastern half of the northeast quadrant.

Table 20. (Continued)

CRD	First division	Second division	Proportion Soybeans	Corn	Wheat
	SE-NE	---	.07	.04	---
	SE-NW	---	.05	.04	---
	SE-SE	---	.05	.05	---
	SE-SW	---	.04	.06	---
	SW-NE	---	.04	.05	---
	SW-NW	---	.04	.04	---
	SW-SE	---	.07	.09	---
	SW-SW	---	.09	.09	---
5	NE-NE	---	.08	.08	---
	NE-NW	---	.08	.09	---
	NE-SE	---	.04	.05	---
	NE-SW	---	.03	.04	---
	NW-NE	---	.11	.09	---
	NW-NW	---	.07	.05	---
	NW-SE	---	.05	.04	---
	NW-SW	---	.12	.10	---
	SE-NE	---	.04	.05	---
	SE-NW	---	.03	.04	---
	SE-SE	---	.05	.06	---
	SE-SW	---	.06	.09	---
	SW-NE	---	.05	.04	---
	SW-NW	---	.05	.04	---
	SW-SE	---	.06	.06	---
	SW-SW	---	.07	.07	---
6	E	---	.61	.69	---
	W-NE	---	.08	.05	---
	W-NW	---	.20	.12	---
	W-SE	---	.05	.05	---
	W-SW	---	.06	.09	---
7	NE	---	.24	.30	---
	NE	N	.50	.50	---
	NE	S	.50	.50	---
	NW	---	.29	.31	---
	SE	---	.18	.16	---
	SW	---	.29	.23	---
8	NE-N	---	.19	.21	---
	NE-S	---	.05	.06	---
	NW-N	---	.19	.21	---
	NW-S	---	.06	.07	---

Table 20. (Continued)

	CRD	First division	Second division	Proportion Soybeans	Corn	Wheat
		SE	---	.13	.11	---
		SW	---	.36	.34	---
	9	NE	---	.28	.34	---
		NW	---	.30	.33	---
		SE	---	.19	.17	---
		SW	---	.22	.17	---
Kansas	1	E	---	---	.27	.37
		W	---	---	.73	.63
	2	C[k]	---	---	---	.37
		E	---	---	---	.28
		W	---	---	---	.35
	4	E	---	---	---	.42
		W	---	---	---	.58
	5	C	---	---	---	.34
		E	---	---	---	.30
		W	---	---	---	.36
	6	E	---	---	---	.34
		W	---	---	---	.66
	7	E	---	---	.33	.56
		W	---	---	.67	.44
	8	E	---	---	.22	.66
		W	---	---	.78	.34
	9	E	---	---	---	.41
		W	---	---	---	.59
Kentucky	2	NE	---	.26	.26	---
		NW	---	.29	.44	---
		SE	---	.30	.21	---
		SW	---	.15	.09	---

[k] Central.

Table 20. (Continued)

	CRD	First division	Second division	Proportion Soybeans	Corn	Wheat
Michigan	7	N	---	.02	.44	---
		S	---	.98	.56	---
	8	N	---	.56	.45	---
		S	---	.44	.55	---
	9	N	---	---	.41	.33
		S	---	---	.59	.67
Minnesota	1	N	---	---	---	.61
		S	---	---	---	.39
	4	N	---	---	---	.64
		S	---	---	---	.36
	5	N	---	.03	.24	.10
		S	---	.97	.76	.90
	7	NE	---	.32	.22	.35
		NW	---	.14	.25	.46
		SE	---	.36	.22	.13
		SW	---	.18	.31	.06
	8	NW	---	.28	.21	---
		NE	---	.15	.24	---
		SW	---	.29	.29	---
		SE	---	.28	.25	---
Missouri	1	N	---	.32	.50	.65
		S	---	.68	.50	.35
	2	NE	---	.19	---	.10
		NW	---	.21	---	.17
		SE	---	.22	---	.22
		SW	---	.38	---	.51
	4	N	---	.60	---	.66
		S	---	.40	---	.34
	5	NE	---	.23	---	.30
		NW	---	.73	---	.57
		SE	---	.01	---	.05
		SW	---	.03	---	.08

Table 20. (Continued)

	CRD	First division	Second division	Proportion		
				Soybeans	Corn	Wheat
Nebraska	1	N	---	---	.25	.27
		S	---	---	.75	.73
	2	N	---	---	.84	---
		S	---	---	.16	---
	3	E	---	.36	.49	---
		W	---	.74	.51	---
	5	NE	---	---	.20	---
		NW	---	---	.15	---
		SE	---	---	.36	---
		SW	---	---	.28	---
	6	E	---	.82	.27	---
		W	---	.18	.63	---
	7	N	---	---	.41	.44
		S	---	---	.59	.56
	8	E	---	---	.53	.48
		W	---	---	.47	.52
	9	E	---	.64	.27	.39
		W	---	.36	.73	.61
North Dakota	5	N	---	---	---	.80
		S	---	---	---	.20
	6	N	---	---	---	.71
		S	---	---	---	.29
	9	E	---	---	---	.40
		W	---	---	---	.60
Ohio	1	NE	---	.24	.27	.25
		NW	---	.22	.25	.24
		SE	---	.23	.21	.22
		SW	---	.31	.26	.29
	2	NE	---	.19	.18	.16
		NW	---	.31	.23	.24
		SE	---	.13	.26	.19
		SW	---	.36	.33	.40

Table 20. (Continued)

	CRD	First division	Second division	Proportion Soybeans	Corn	Wheat
	3	E	---	.75	.62	---
		W	---	.25	.38	---
	4	N	---	.48	.42	.53
		S	---	.52	.58	.47
	5	N	---	.58	.49	.48
		S	---	.42	.51	.52
Oklahoma	2	E	---	---	---	.65
		W	---	---	---	.35
	4	N	---	---	---	.44
		S	---	---	---	.56
	5	N	---	---	---	.61
		S	---	---	---	.39
Oregon	2	NE	---	---	---	.44
		NW	---	---	---	.09
		SE	---	---	---	.38
		SW	---	---	---	.09
	3	NE	---	---	---	.38
		NW	---	---	---	.51
		SE	---	---	---	.09
		SW	---	---	---	.27
South Dakota	9	E	---	.93	.70	---
		W	---	.07	.30	---
Texas	1	NE	---	---	.04	---
		NW	---	---	.16	---
		S	---	---	.80	---
Washington	2	NE	---	---	---	.34
		NW	---	---	---	.10
		SE	---	---	---	.23
		SW	---	---	---	.26
	5	C	---	---	---	.30
		N	---	---	---	.34
		NW	---	---	---	.07

Table 20. (Continued)

	CRD	First division	Second division	Proportion Soybeans	Corn	Wheat
		S	---	---	---	.09
		WC[1]	---	---	---	.20
	9	N	---	---	---	.52
		S	---	---	---	.22
		SW	---	---	---	.26
Wisconsin	8	E	---	.50	.46	---
		W	---	.50	.54	---

[1] West-central.

greater precision in allocating grain to possible transport alternatives is taken. These areas are listed under "second division".

Seed usage

Seed usage is projected to 1990 at one bushel per planted acre for all crops. Adjusted planted acres as projected by equation (30) are increased proportionally by state to the levels indicated by 1990 USDA estimates of harvested acres [58]. CRD shares of 1990 state planted acres are estimated based upon the 1970 to 1978 time period as follows:

$$CRDS_{ikjt} = b_o \; T^{b_1} \qquad (32)$$

where

$CRDS_{ikjt}$ = Preliminary percentage planted acreage of crop i, in CRD k, in state j, at time t.

T = time trend for the period 1970 to 1978 (T = 70-78)

Similar to the preliminary CRD production percentages, as estimated in equation (31), the percentage planted acres were summed across CRDs in the state and constrained to equal 100 percent. The adjusted CRD planted acre percentages time state planted acres equals CRD planted acres as used in the estimation of seed usage. Seed use by CRD is presented in Appendix A.

Livestock feed consumption

Projected 1990 livestock consumption of corn is based on USDA 1990 livestock grain consumption projections. USDA projected total livestock consumption of corn is 4,680 million bushels in 1990 [58]. Livestock consumption of wheat in 1977 -- 158 million bushels -- is considered to be a reasonable estimate for 1990 and that quantity was used for 1990. Regional livestock consumption in 1990 is based on 1977 feed consumption shares by livestock category as estimated by the USDA for 10 regions of the United States [57]. The livestock categories consist of milk cows, other dairy animals, cattle on feed, hens and pullets, chickens, broilers, turkeys and hogs. Regional feed consumption is disaggregated to the state level in proportion to the reported state inventories or marketings of livestock reported in Cattle [60], Cattle on Feed [61], Milk Production [63], Sheeps and Lambs on Feed [64], Poultry and Egg Situation [65], and Hogs and Pigs [68]. Horses and other livestock feed is distributed among states in proportion to corn consumed by all other categories of livestock. Feed consumed within each CRD of a state is based on the state's annual Crop and Livestock Reporting Bulletin or on data reported, on a county basis, in the 1974 Agriculture Census [70]. Corn consumed as feed by livestock category in each CRD is adjusted from 1977 to 1990 levels by multiplying each regions estimated 1977 corn feed consumption by 1.1788. Wheat consumed as feed by livestock category in each CRD is not adjusted from 1977 consumption levels. Livestock feed consumption by CRD is presented in Appendix A.

Processing demands

Domestic processing of corn, soybeans and wheat[4] is the third major regional component of the demand for grain in the 1989-1990 crop year.

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[4] Robert J. Hauser conducted the statistical work associated with the projection of processing demands. The procedure used is reported in greater detail in Hauser [21].

Corn is used in the processing of dextrose, glucose, starch, high-fructose-corn syrup, ethanol, cereal and meal. The demand for corn in all products, except ethanol, is derived from the projected 1990 per capita consumption the product. Projected per capita consumption[5] multiplied by the conversion rate of bushels of corn to 100 pounds of the product [21] equals the demand for corn. Corn consumption for ethanol is an approximation based on consultation with industry executives. Soybean crushings are projected to 1990 based on the historical relationship between soybean crushings and soybean exports over the period 1960 to 1977. Wheat consumption for flour milling is estimated as a residual quantity equal to total domestic wheat consumption as projected by the USDA [58] minus projected 1990 livestock feed and seed requirements. The equations used in estimating processing demands and the projected 1990 consumption of corn (by type of processing), wheat and soybeans are presented in Table 21.

The location and capacity of individual corn wet milling plants are obtained from the Milling and Baking News [16], and from two unpublished surveys [6, 35]. Total projected corn usage for wet processing is allocated among the plants according to estimated capacity. The proportion of total projected corn used for wet processing that is processed by an individual plant is equal to that plant's proportion of total U.S. wet milling capacity.

The location of corn dry milling plants are obtained from the Milling and Baking News [19]. Data on the capacity of these plants are

[5] Projected 1990 population is equal to 254.7 million persons [67].

Table 21. Total 1990 processing demands in millions of bushels and estimation equation by type of processing[a]

Type of processing	Estimation equation	1990 Processing (million bushels)
Corn: Meal[b]	$M = 6.079 + .103\ T$ $(.136)\ (.013)$	28.1
Dextrose[b]	$D = 3.05 + .575\ T^{1/2}$ $(.106)\ (0.34)$	52.5
Glucose[b]	$\ln(G) = 2.266 + .051\ T$ $(.033)\ (.003)$	394.8
HFCS[b]	$H = -1.301 + .739\ T^{1.25}$ $(.554)\ (.061)$	242.1
Cereal[b]	C = Average over T	195.9
Starch[b]	S = Average over T	13.5
Ethanol	E = industry consultation	325.0
Soybeans: Crushing	$SC = 327.31 + .91\ SE$ $(21.1)\ (.041)$	1,307.1
Wheat: Milling	WM = residual	661.6

[a] See Hauser [21] for more complete discussion.

[b] Estimates per capita consumption. 1990 projected population is T = time 1960-1977, for HFCS T = 1967-1978, SE = Soybean exports for 1960-1977.

not available. Therefore, total dry milling corn utilization is divided evenly across individual plants.

Location and plant capacities of individual soybean processors are based on American Soybean Association [1], Sharp [40], and an unpublished survey [35]. The proportion of total soybean crushings for an individual plant is equal to the plant's proportion of total crushing capacity.

Location and plant capacities of individual wheat milling plants are based upon Milling and Baking Survey [77] results. The assignment of transport rates to southeastern and northeastern U.S. wheat millers is very difficult. The large number of small millers in these areas are responsible for a sizeable demand overall. However, the demand of individual millers is quite small and not concentrated within specific regions of these areas. Therefore, these demands are satisfied exogenously by subtraction of the total demand from wheat surpluses in other regions. The location of wheat processors and proportion of their total demands satisfied in this way are presented in Table 22. The total quantities of exogenous supplied wheat by origin are presented in Table 23. Local processing, by CRD, is presented in Appendix A.

<u>Export demands</u>

The level of exports is an important determinant of the volume of barge grain traffic. 1990 export demands used in this analysis are based on USDA 1990/91 crop year export projections for corn, wheat and soybeans [58]. Actual 1980 [54] and USDA export projections are presented in Table 24.

Table 22. The proportion of city or regional 1990 wheat processing demand satisfied exogenously by location of demand and type of wheat

City or region	Type of wheat Spring	Hard-red winter	Soft-red winter
Buffalo	1	---	---
Chicago	.3	.7	---
New Orleans	.3	.7	---
Northeast	---	---	1
Northwest	1	---	---
Southeast	.3	.7	---
St. Louis	.5	.5	---
Virginia	.5	.5	---

Table 23. Projected wheat available for processing outside supply regions by type of wheat and state in millions of bushels.

Type of wheat	State	Quantity
Spring	Minnesota	130.7
	North Dakota	298.7
	South Dakota	66.6
Hard-red winter	Kansas	302.0
	Missouri	60.0
	Oklahoma	222.0
Soft-red winter	Illinois	35.0
	Indiana	28.6
	Michigan	52.8
	Ohio	22.3

Table 24. Actual 1980 and USDA projected exports of corn, soybeans and wheat from the United States for crop years 1985/86 and 1990/91, in millions of bushels[a]

Crop	1980 Actual	USDA Projections 1985/86	1990/91
Corn	2,481	2,754	3,072
Soybeans	800	1,077	1,217
Wheat	1,313	1,558	1,747

[a] Source: [52], [54].

The 1990/91 USDA projections were adjusted to represent exports in the 1989/90 crop years. A uniform annual change in export levels was assumed for this adjustment. Projected 1985 exports of corn, soybeans and wheat are 11.7 percent over 1980 levels. The percentage increase in 1990 exports over 1980 is projected to be 21.7 percent.

Export demands by foreign demand region[6] are projected to 1985 by linear regression of historical shares over the period 1967-1978 [66]. The projected 1990 shares are set at the projected 1985 levels. Projected percentage shares by region are presented in Table 25.

Southeast inventory constraints

In the southeastern United States, the relatively limited amount of grain storage requires that some grain produced in this region be

[6] A complete description of the export demand projection techniques can be found in Hauser [21].

Table 25. Projected percentage share by foreign demand region of total U.S. exports by crop in 1985 and 1990

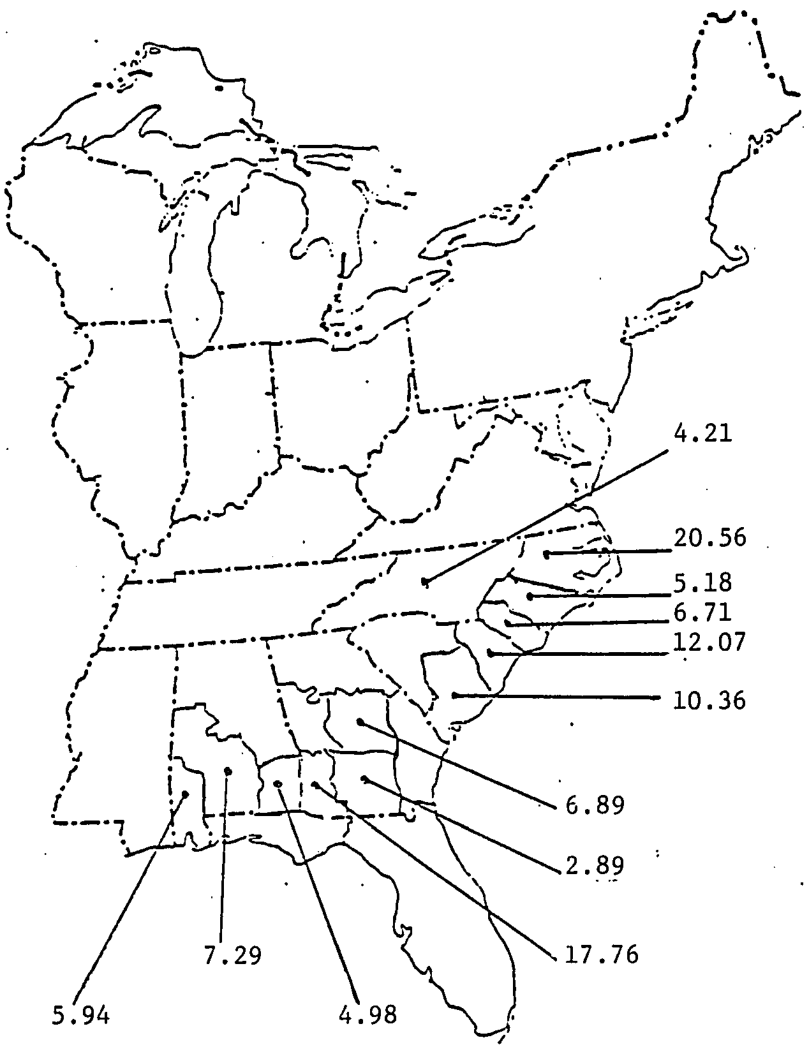
Demand Region	Percentage shares by crop corn	soybeans	wheat
Western Europe	27.2	57.7	7.8
Far East	31.8	25.4	34.5
Eastern Europe and the USSR	35.6	6.6	19.4
Middle East and Africa	1.4	7.4	18.7
Mexico, Central and South America	4.0	2.9	19.6

exported during harvest time. It was suggested by grain industry representatives that a more realistic approach to southeastern grain movements in this analysis is to include storage capacities by region allowing the excess grain to flow to export. The unsatisfied demand could then be filled by surplus grain from other regions of the United States. To approximate this condition, the available storage by state was determined by aggregating county bushel storage capacity for shelled-ear corn and off-farm commercial storage [55] and subtracting the average carryover for all crops in 1976 and 1977 [67]. The ratio of average 1976 and 1977 production of crops requiring storage, to available storage determined the amount of excess or insufficient storage capacity. By multiplying this ratio times the 1990 corn and soybean projections the maximum amount of corn and soybeans in 1990 that could be stored is estimated. The residual production, if positive, is forced out of the area at harvest time. Map 6 indicates the estimated quantity of grain in millions of bushels of corn forced out of southeastern regions. In total, 104.8 million bushels are transported out of these regions due to insufficient storage.

Transportation Costs and Use Restrictions

Rail rates

Rail rates are obtained from published railroad freight tariffs available to grain shippers in 1980. A listing of tariff publications from which the rail rates are taken is presented in Table 26. All rates



Map 6. Excess Southeastern United States grain production by region in millions of bushels

Table 26. Rail freight tariffs and rate books used to obtain rail rates

Organization which compiled rates	Title of tariff, tariff supplement, or grain book
Agri Industries	Grain Rate Book
Atchison, Topeka and Santa Fe Railway Co.	Freight Tariff 14715-J
Burlington Northern, Inc.	Freight Tariff 55-A Freight Tariff BN 4015-A Freight Tariff BN 4010; Sup.150 Freight Tariff 41; Sup.126
Cargill	Grain Rate Book
Chicago Board of Trade	Grain Rate Book
Chicago, Milwaukee, St. Paul and Pacific Railroad Co.	Freight Tariff 11244-M Freight Tariff 17000-L Freight Tariff 18710-E Freight Tariff 18100-N Freight Tariff 4001-A
Chicago and Northwestern Transportation Co.	Freight Tariff 17194-C Freight Tariff 17150-H Freight Tariff 17042-G Freight Tariff 17194-C; Sup.25
Consolidated Rail Corp.	Freight Tariff CR 4171
Far-Mar-Co	Grain Rate Book Single Car Export Wheat Rate Grain Book
Farmland Industries, Inc.	Grain Rate Book
Grow-Mark, Inc.	Grain Rate Book
Illinois Central Gulf Railroad Co.	Freight Tariff 609 Freight Tariff ICG 4012; Sup.75 Freight Tariff 602; Sup.72 Freight Tariff 601-B; Sup.62 Freight Tariff ICG 4011; Sup.99

Table 26. (Continued)

Organization which compiled rates	Title of tariff, tariff supplement, or grain book
Indiana Grain	Grain Rate Book
Interstate Commerce Commission	Tariff ICC PSFB 4013-A; Sup.14
Kansas City Board of Trade	Grain Rate Book
Landmark, Inc.	Grain Rate Book
Louis Dreyfus Corp.	Grain Rate Book Inter-Office Correspondence
Minneapolis Grain Exchange	Grain Rate Book
Missouri Farmer's Association, Inc.	Grain Rate Book
Missouri Pacific Railroad	Freight Tariff 42-B; Sup.91 Freight Tariff 57-G Freight Tariff 65-J
North Pacific Coast Freight Bureau, Agent	Freight Tariff 10-Q; Sup.61 Freight Tariff ICC NPCF 4011-A; Sup.17
St. Louis-San Francisco Railroad Co.	Freight Tariff 5721-T
Southern Freight Tariff	Freight Tariff SFA 1011-B Freight Tariff 972-F
Southwestern Freight Bureau, Agent	Southwestern Lines Freight Tariff 182-K Southwestern Lines Freight Tariff 182-K; Sup.68 Southwestern Lines Freight Tariff 180-L; Sup.266 Southwestern Lines Freight Tariff 225-N; Sup.100

Table 26. (Continued)

Organization which compiled rates	Title of tariff, tariff supplement, or grain book
Trans-Continental Freight Bureau	Freight Tariff TCFB 4045-0; Sup.88
	Freight Tariff TCFB 4045-0; Sup.15
	Freight Tariff TCFB 4045-0; Sup.10
	Freight Tariff TCFB 3029-P; Sup.216
	Freight Tariff TCFB 3029-P; Sup.113
	Freight Tariff TCFB 3029-P; Sup.103
	Freight Tariff 29-P; Sup.45
	Freight Tariff 4045-N; Sup.366
	Freight Tariff 45-N
	Freight Tariff TCFB 6005-C; Directory
Union Pacific Railroad Co.	Freight Tariff UP 4035-A
	Freight Tariff UP 4020-A
	Freight Tariff UP 4035-A; Sup.10
	Freight Tariff 6080-J
	Freight Tariff 4010-A

are adjusted to Ex Parte level 375-C, which was effective during the summer of 1980.

Rate selection for individual origin-destination pairs is based primarily on consultation with shippers regarding the frequency of use. Other criteria as outlined in Hauser [21] include:

1. covered hopper-car rates
2. direct rates
3. multiple-car unit train rates with commonly used consecutive trip requirements, and
4. rates from a centrally located town on a main railroad line servicing an origin district when more than one railroad services the district.

A sample of direct rail and rail-barge combination rates from major grain producing areas to points of export are presented in Tables 27 to 29.

Barge rates

Barge transportation of bulk commodities is not regulated by the Interstate Commerce Commission (ICC). This exemption means that barge rates for corn, soybeans and wheat traffic and changes in barge rates for these commodities are not required to be filed with the ICC. Hence, barge rate availability is a problem. The data on 1980 barge rates were collected from three sources. Executives of barge companies which operate on the Mississippi River system supplied contract rates for the 1980 navigation season. Spot rates were compiled from daily publications

Table 27. Selected 1980 rail and rail-barge rates for corn to port areas by originating region and shipment size in cents per bushel

Originating region	Number of rail cars in shipment	Rail rates to port areas: Louisiana Gulf	Pacific Northwest	Lakes	Atlantic	Rail-barge to Gulf ports: Rate[a]	River entry point
Central Nebraska	1	76.9	103.8	75.2	---	99.9	Omaha
	25	70.0	70.8	---	---	---	---
	50	66.1	68.9	---	---	---	---
	75	63.3	66.1	---	---	---	---
Western Iowa	1	70.8	---	45.7	---	73.4	Clinton
	25	65.1	70.8	42.8	---	62.0	Clinton
	50	60.9	68.9	34.8	---	---	---
	75	57.2	66.1	31.1	---	---	---
Eastern Iowa	1	72.1	---	42.6	---	65.1	Clinton
	25	66.3	---	35.6	---	54.4	Clinton
	50	60.9	---	32.8	---	52.7	Clinton

[a] Rail-barge rate is equal to rail rate to river entry point plus contract-barge rate plus 4.9 cents per bushel handling charge.

Table 27. (Continued)

Originating region	Number of rail cars in shipment	Rail rates to port areas: Louisiana Gulf	Pacific Northwest	Lakes	Atlantic	Rail-barge to Gulf ports: Rate[a]	River entry point
Southern Minnesota	1	78.2	103.8	72.1	---	74.4	Minnea-polis
	25	71.7	71.4	51.0	---	---	---
	50	66.6	---	46.8	---	---	---
	75	62.7	---	43.7	---	---	---
Central Illinois	1	82.7	---	35.6	--	---	---
	65	42.6	---	---	44.7	---	---
	125	41.9	---	---	44.7	---	---
Central Ohio	1	71.2	---	25.0	67.2	---	---
	100	---	---	---	35.7	---	---
Eastern Colorado	1	92.3	103.8	131.9	---	---	---
Southwest Kansas	1	70.3	---	116.5	---	---	---

Table 28. Selected 1980 rail and rail-barge rates for soybeans to port areas by originating region and shipment size in cents per bushel

Originating region	Number of rail cars in shipment	Rail rates to port areas				Rail-barge to Gulf ports	
		Louisiana Gulf	Pacific Northwest	Lakes	Atlantic	Rate [a]	River entry point
Eastern Nebraska	1	85.7	---	80.5	---	130.8	Kansas City
	25	75.0	75.9	---	---	---	---
	50	70.8	73.8	---	---	---	---
	75	67.8	70.8	---	---	---	---
Western Iowa	1	75.8	---	49.0	---	78.6	Clinton
	25	69.7	75.9	45.9	---	66.4	Clinton
	50	64.9	73.8	37.3	---	---	---
	75	61.3	70.8	33.3	---	---	---
Eastern Iowa	1	77.2	---	45.7	---	69.8	Clinton
	25	71.0	---	38.2	---	58.3	Clinton
	50	65.3	---	35.1	---	56.5	Clinton

[a] Rail-barge rate is equal to rail rate to river entry point plus contract-barge rate plus 4.9 cents per bushel handling charge.

Table 28. (Continued)

Originating region	Number of rail cars in shipment	Rail rates to port areas: Louisiana Gulf	Pacific Northwest	Lakes	Atlantic	Rail-barge to Gulf ports: Rate[a]	River entry point
Southwest Minnesota	1	90.4	111.2	90.9	---	84.4	Minnea-polis
	25	76.4	76.5	54.6	---	---	---
	50	71.4	---	50.1	---	---	---
	75	67.2	---	46.8	---	---	---
Central Illinois	1	88.6	---	38.1	---	---	---
	65	45.6	---	---	47.4	---	---
	125	44.9	---	---	47.4	---	---
Central Ohio	1	76.3	---	19.3	72.0	---	---
	100	---	---	---	38.2	---	---
Eastern Kentucky	1	48.1	---	---	53.7	---	---
Northeast Mississippi	1	33.4	---	---	---	---	---

Table 29. Selected 1980 rail and rail-barge rates for wheat to port areas by originating region and shipment size in cents per bushel

Originating region	Number of rail cars in shipment	Rail rates to port areas				Rail-barge to Gulf ports	
		Louisiana Gulf	Pacific Northwest	Lakes	Atlantic	Rate[a]	River entry point
Northwest Nebraska	1	136.6	111.2	126.7	---	137.0	Omaha
	50	75.3	85.8	---	---	---	---
Southern Nebraska	1	102.2	130.0	103.6	---	114.0	Omaha
	25	75.0	97.2	---	---	---	---
	50	70.8	94.8	---	---	---	---
	75	67.8	94.8	---	---	---	---
Northern Kansas	1	86.6	108.4	90.8	---	93.1	Kansas City
	50	---	92.7	---	---	---	---
	75	---	92.7	---	---	---	---
Southwestern Minnesota	1	90.4	150.2	84.8	152.6	84.4	Minnea-polis
	25	76.8	---	54.6	---	---	---

[a] Rail-barge rate is equal to rail rate to river entry point plus contract-barge rate plus 4.9 cents per bushel handling charge.

Table 29. (Continued)

Originating region	Number of rail cars in shipment	Rail rates to port areas				Rail-barge to Gulf ports	
		Louisiana Gulf	Pacific Northwest	Lakes	Atlantic	Rate[a]	River entry point
	50	71.4	111.3	50.1	---	---	---
	75	67.2	---	46.8	---	---	---
Northwestern Minnesota	1	146.9	150.2	43.8	166.7	98.5	Minne-apolis
	26	---	122.0	34.8	---	89.5	Minne-apolis
	54	---	111.3	---	---	---	---
Central North Dakota	1	169.6	149.3	69.7	---	121.1	Minne-apolis
	26	---	102.2	60.7	---	112.1	Minne-apolis
	54	---	94.8	---	---	---	---
Central Montana	1	---	102.7	154.6	---	205.9	Minne-apolis
	26	---	76.2	142.5	---	193.9	Minne-apolis

by the St. Louis Merchants Exchange [43]. Freight tariffs, published by a barge firm operating on the Columbia-Snake River [45], were the source of rates for this river segment.

Barge rates on the Mississippi River System are negotiated between shippers and barge owners. There are two types of negotiated rates; contract rates and spot rates. Contract rates are negotiated for a fixed period of time, typically the navigation season, and for a fixed quantity of barge services. Although it is typical for contracting to occur for the length of the navigation season, it is not unlikely that shippers would contract for a period of time longer than the current year. Contracts lasting 30 years are not unheard of.[7] Contracts of this length typically include fuel escalation and waterway user charge clauses.

The spot market for barge services serves three basic functions. First, the spot market behaves as a residual market. Grain shippers who have contracted for barge services may enter the spot market as the exact quantity of barge services needed becomes known to them. If the shipper has contracted for too little barge space, he can purchase additional barge space through the spot market. Conversely, he may sell excess barge space on the spot market. Barge owners may also enter the spot market as the exact availability of barges becomes known. It is unlikely that barge owners would contract 100 percent of their available barge fleet. Adverse river conditions or scheduling problems may prevent barge owners from meeting commitments. Additionally, the flexibility of being

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[7] Based on interviews with barge company executives.

able to shift barge services to other commodities or alternative locations may produce higher revenues [79]. Secondly, trading for spot market barges may not occur at the time of shipment, but months before the shipment. In this respect, the spot market is a forward pricing mechanism. A grain shipper may contract in January for barge services the following October, believing that by October, barge rates will be higher than what he traded for. A barge owner may contract to sell barges in January for October delivery believing that rates will fall. Finally, the spot market serves as a barometer of current market conditions. Spot rates are influential in determining the current day's bid price to producers who use barge services [14].

Until August 1, 1978, there was no record of spot transactions. At that time, the Merchants Exchange of St. Louis initiated a barge freight call session in which barge service for immediate or future delivery are bought and sold. The call session, "conceived by grain merchants in order to create a competitive element in the movement of grain to New Orleans", is participated in by grain interests, barge and towing companies, financial analysts and brokerage firms [42]. From an opening volume of 18 barges traded for August, 1978 delivery, the volume of barges traded peaked in October, 1980 at 855. The volume of barges traded by month exhibits a seasonal pattern as demonstrated by Figure 3. In each of the three years presented in this figure, volume has followed a similar pattern. March through May, which corresponds to the beginning of the navigation season, exhibits the smallest volume. There is a gradual increase in the number of barges traded during the summer quarter

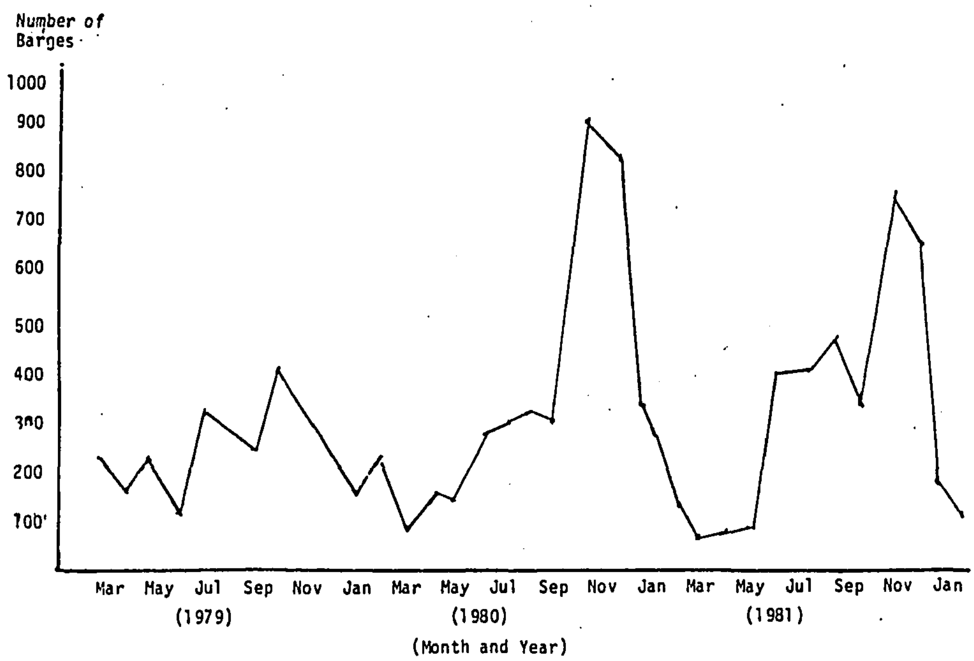

Figure 3. Total number of barges traded for all river segments by month, 1979-1981

Table 30. Average number of barges traded at Merchants Exchange of St. Louis,[a] 1979-1981

River	Average Number	Percent of average
Illinois	125	46
Mississippi:		
Upper	15	6
Middle	84	31
Lower Middle	8	3
Lower	25	9
Ohio	13	5
TOTAL	270	100

[a] Source: [43].

as shippers empty storage to ready for the following harvest. Volume peaks in October and November in each year as the new crop is marketed. Table 30 presents average volume by river segment. Of a total average of 270 barges traded per month, the Illinois river accounts for 46 percent of all trades. The Middle Mississippi River accounts for an additional 31 percent of the average trades per month. The remaining 23 percent is spread among the other four river segments.

Barge rates are quoted at a premium or discount to a standardized tariff. Bargeload Bulk Grain Tariff #7, cancelled in February, 1976, has remained the benchmark for barge rates. Rates in this tariff are termed equal to 100 percent of tariff.

Figure 4 presents the monthly percentage tariff on the Illinois River as estimated from St. Louis Merchants Exchange data. The percent of tariff ranged from 151 percent (May, 1981) to 291 percent (November, 1980) of the benchmark tariff for Illinois river origins. Figure 5 presents the monthly percentage tariffs on the Middle Mississippi River. On this river segment, the percent of tariff ranged from 167 percent (July, 1980) to 312 percent (November, 1979). Table 31 presents the benchmark tariffs for Illinois and Middle Mississippi River origins as found in Bargeload Bulk Grain Tariff #7 in cents per ton. Additionally, the low and high percentage tariff is converted to cents per ton for these origins.

Barge rates as seen in Figures 4 to 5 follow a fairly well-defined seasonal pattern. Rates gradually decline from the level established at the opening of the navigation season. In the third quarter, rates

Table 31. Barge rates at 100 percent of tariff and range of rates for selected points on the Illinois and Middle Mississippi rivers in cents per ton

River	City	100 Percent[a] of tariff	Range[b] low	Range[b] high
Illinois	Seneca, IL	524	793	1527
	Hennepin, IL	507	767	1477
	Peoria, IL	481	728	1401
	Naples, IL	464	702	1352
Middle Mississippi	Dubuque, IA	600	1021	1871
	Clinton, IA	532	905	1659
	Burlington, IA	508	865	1584
	Hannibal, MO	484	824	1509

[a] Source [73].

[b] Source [43].

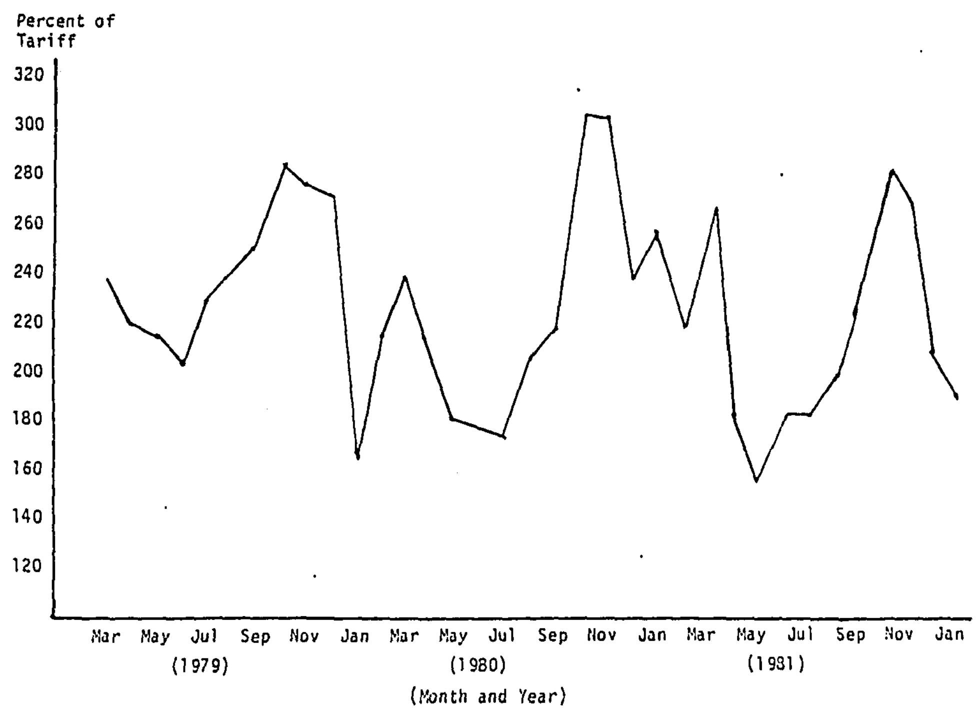

Figure 4. Average percent of tariff for barges traded for Illinois river shipment, 1979-1981

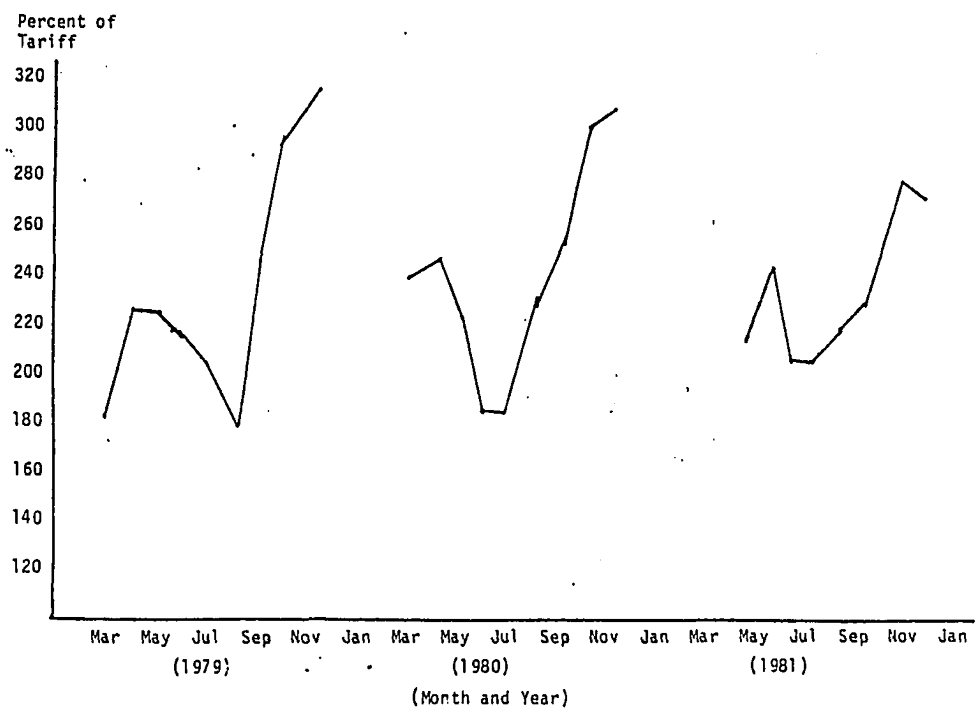

Figure 5, Average percent of tariff for barges traded for Middle Mississippi river shipment, 1979-1981 increase as storage is emptied. Rates peak on both river segments during harvest time.

Table 31 presents the barge rates as a percentage of Tariff #7, as used in this analysis. Two periods, winter (December-February) and non-winter (March-November), are specified. The non-winter barge rates are computed as a simple average of the non-winter quarterly barge rates. The barge rates in cents per bushel of corn and cents per bushel of wheat or soybeans, as used in the model are presented in Table 32. No spot trades on Missouri or Arkansas rivers were made at the St. Louis Merchants Exchange. Barge rates on the Columbia-Snake river system are reproduced directly from Rate Schedule #3 as published by Tidewater Barge Lines, Inc. [45]. The rates in cents per bushel of corn and cents per bushel of wheat or soybeans, for this river segment, are included in Table 33.

Truck rates

Truck rates are equal to estimated truck costs plus a profit margin. The procedure used in estimating the cost of trucking grain in tractor-semi-trailers is outlined in Narigon [34]. A consensus of industry opinion suggested that, for 1980, a two percent profit margin was reasonable.

The components of total annual operating costs for a tractor-semi-trailer are represented by equation (13).

$$TC = FC + VC \cdot M + TR \qquad (33)$$

where

Table 32. Percents of tariff for barge contract rates and quarterly average spot rates by river segment on the inland waterway system to export ports, 1979-1980

River	Segment[a]	Spot rate (1979-1980) Oct-Dec	Jan-Mar	Apr-Jun	July-Sept	Contract rate 1980
Mississippi	Upper	341.50		190.00	253.75	248.75
	Middle	298.25		204.25	215.00	230.00
	Lower Middle	239.50	199.00	200.00	171.75	215.50
	Lower	260.75	163.75	120.25	200.50	200.00
Illinois		274.50	213.75	183.00	191.25	230.00
Ohio		260.00	199.00	128.00	256.00	200.00
Missouri	Upper					258.00
	Lower					265.50
Arkansas						210.00
Columbia-Snake						100.00

[a] River segments are defined as:

Mississippi: Upper -- All inclusive from one mile north of McGregor, IA
Middle -- McGregor, IA to Winfield, MO
Lower Middle -- Alton, IL to one mile north of Cairo, IL
Lower -- Cairo, IL to Gulf Ports

Missouri: Upper -- Sioux City, IA to one mile north of Kansas City, MO
Lower -- Kansas City, MO to junction with Mississippi River.

Table 33. Barge rates by river, origin and type of rate in cents per bushel, 1979-80

River	Origin	Corn			Wheat and soybeans		
		Contract	Winter	Average Spring Summer Fall	Contract	Winter	Average Spring Summer Fall
Mississippi	Minneapolis, MN	43.1	---	45.4	46.2	---	48.6
	Winona, MN	43.1	---	45.4	46.2	---	48.6
	McGregor, IA	38.6	---	40.1	41.4	---	43.0
	Clinton, IA	34.2	---	35.7	36.6	---	38.2
	Burlington, IA	32.7	---	34.1	35.1	---	36.5
	Hannibal, MO	31.4	---	32.1	33.6	---	34.4
	St. Louis, MO	24.1	22.4	22.8	25.8	24.0	24.4
	Cairo, IL	21.3	21.3	23.0	22.8	22.8	24.6
	Portageville, MO	21.3	17.4	20.9	22.8	18.6	22.4
	Osceola, AR	19.6	16.2	18.9	21.0	17.4	20.2
	Memphis, TN	17.4	14.6	17.2	18.6	15.6	18.4
	Helena, AR	16.8	14.0	16.2	18.0	15.0	17.4
	Perthshire, MS	15.1	12.3	14.6	16.2	13.2	15.6
	Greenville, MS	12.9	10.6	12.3	13.8	11.4	13.2
Illinois	Seneca, IL	33.6	31.4	31.9	36.0	33.6	34.2
	Ottawa, IL	32.5	30.2	30.6	34.8	32.4	32.8
	Peoria, IL	30.8	38.6	29.1	33.0	30.6	31.2
	Naples, IA	29.7	28.0	28.0	31.8	30.0	30.0

Table 33. (Continued)

River	Origin	Corn: Contract	Corn: Winter	Corn: Average Spring Summer Fall	Wheat and soybeans: Contract	Wheat and soybeans: Winter	Wheat and soybeans: Average Spring Summer Fall
Ohio	Cincinnati, OH	26.3	26.3	28.2	28.2	28.2	30.2
	Louisville, KY	25.2	24.6	26.7	37.0	26.4	28.6
	Mt. Vernon, IN	22.4	22.4	23.9	24.0	24.0	25.6
Missouri	Sioux City, IA	67.2	---	---	72.0	---	---
	Omaha, NB	57.1	---	---	61.2	---	---
	Kansas City, MO	48.2	---	---	51.6	---	---
Arkansas	Catoosa, OK	33.0	---	---	35.4	---	---
Columbia-Snake	Lewiston, ID	---	11.2	11.9	---	12.0	12.8
	Central Ferry, WA	---	10.6	11.4	---	11.4	12.2
	Lyons Ferry, WA	---	10.1	10.8	---	10.8	11.6
	Windust, WA	---	9.5	10.1	---	10.2	10.8
	Umatilla, WA	---	8.4	9.0	---	9.0	9.6
	Biggs, OR	---	7.3	8.0	---	7.8	8.6
	Dalles, OR	---	7.3	7.8	---	7.8	8.4

TC = Total annual operating costs

FC = Fixed cost per annum

VC = Variable cost per mile

M = Miles traveled in a year

TR = Transfer cost per annum

The components of fixed and variable cost are presented in Table 34. Fixed costs per annum are the addition of depreciation, license and road use taxes (Table 36), maintenance, insurance and administrative overhead. Depreciation expenses are estimated as the annual equivalent cost of the purchase price minus the salvage value over the 5 year expected service life at an interest rate of 13 percent. Variable cost per mile is the addition of fuel cost per mile, tire cost per mile, oil and oil filter cost per mile and wages per mile. Fuel cost per mile is estimated by dividing price per gallon by an assumed average 5.5 miles per gallon over the round trip.[8] Tire and oil and filter cost per mile is equal to the purchase price of these items divided by life expectancy. Wages per mile is equal to wages per hour (Table 36) divided by miles per hour which varies by trip distance as shown in Table 34.

Annual mileage per truck is the product of average distance per trip and the number of trips per year. The number of trips per year is estimated by equation (34).

$$N = \frac{H}{D/S + T} \qquad (34)$$

[8] Fuel consumption is equal to 5 miles per gallon when loaded and 6 miles per gallon empty. An empty backhaul, which approximates current grain trucking practices, is assumed.

Table 34. Major components of estimated trucking costs as received from trucking industry representatives, 1980

Item	
Fixed Cost:	
Purchase price	= $54,043.00
Service life	= 5 years
Salvage value	= $19,248.00
Interest rate	= 13% per annum
License and taxes	Variable by state[a]
Maintenance (5% of purchase price)	= $2,702.15 per annum
Insurance	= $3,722.00 per annum
Overhead (administration)	= $480.00 per annum
Variable Cost:	
Tire cost	
type - 11.00/22.5" 12 ply	
number - 18 tires per truck	
service life - 100,000 miles	
cost per set of tires	= $5,277.00 per set
Oil and oil filter cost	
amount - 42 quarts and filter	
service life - 10,000 miles	
cost per change	= $51.38 per charge
Fuel cost	= $1.173 per gallon
Labor cost	Variable by region[a/]

[a] See Table 36.

where

N = Number of trips per year

H = Total working hours per year (2,200 hours = 225 days)

D = Average round trip distance per trip

S = Speed in miles per hour

T = Transfer time (loading and unloading time = 0.75 hours per trip)

The number of trips per year and estimated annual mileage given the assumed average speed for trips of given distance is presented in Table 35.

Annual transfer costs (TR) are estimated by multiplying the number of trips per year times the transfer time per trip times the hourly wage rate.

Truck cost per hundredweight is the product of average cost per mile times the assumed payload of 275 hundredweight times one-way miles. The relationship of cost per hundredweight to one-way miles is estimated by regression of the estimated cost for each distance presented in Table 34 on one-way miles. The regression coefficients are presented in Table 36. Estimated trucking rates are adjusted to reflect the assumed two percent profit margin. Trucking rates in cents per bushel for distances of 50, 100 and 200 miles for truck movements in the major grain states are presented in Table 37.

Truck rates as used in the L.P. model are based on the mileage computed from the center of the origin region to a destination specified as the center of a deficit region, the export facility, or the river.

Table 35. Average round-trip distance, assumed speed in mph, number of trips per year and annual mileage for grain transportation in a tractor-semi-trailer

Round-trip distance	Speed[a] (mph)	Number of trips per year	Annual mileage
30	35	1,368	41,040
50	35	1,009	50,450
100	40	676	67,600
150	40	488	73,200
200	40	382	76,400
250	45	348	87,000
300	45	296	88,800
350	50	283	99,050
400	50	251	100,400

[a] Speed in miles per hour (mph) incrases with round-trip distance to reflect the diminishing importance of loading and unloading time as trip length increases.

Table 36. Average 1980 hourly wage rates and 1980 license fees in dollars and regression coefficients used to estimate 1980 truck rates by state

	Average hourly wage rate[a]	Annual license fee plus usage tax[b]	Intercept	Slope
Alabama	$7.82	$1,008.0	4.279	.218
Arkansas	7.82	1,380.0	4.321	.219
California	9.70	652.0	4.716	.230
Colorado	9.70	1,501.7	4.807	.232
Florida	7.82	698.0	4.244	.217
Georgia	7.82	936.0	4.271	.217
Idaho	9.70	328.0	4.673	.228
Illinois	9.55	1,788.9	4.802	.232
Iowa	9.55	1,923.0	4.818	.233
Indiana	9.55	728.0	4.681	.229
Kansas	9.55	1,578.0	4.778	.231
Kentucky	7.82	1,068.0	4.286	.218
Louisiana	7.82	1,188.0	4.299	.218
Michigan	9.55	1,093.0	4.722	.230
Minnesota	9.55	1,488.0	4.768	.231
Mississippi	7.82	1,173.4	4.298	.218
Missouri	9.55	1,374.8	4.755	.231
Montana	9.70	2,863.0	4.962	.237
Nebraska	9.55	1,508.0	4.770	.231
North Carolina	7.82	1,028.0	4.281	.218
North Dakota	9.55	1,359.0	4.753	.231
Ohio	9.55	1,055.5	4.719	.230
Oklahoma	7.82	959.0	4.273	.217
Oregon	9.70	443.0	4.686	.229
South Carolina	7.82	855.3	4.261	.217
South Dakota	9.55	1,678.0	4.790	.232
Tennessee	7.82	1,357.9	4.319	.219
Texas	7.82	1,028.0	4.281	.218
Virginia	7.82	1,198.0	4.301	.218
Washington	9.70	1,237.4	4.777	.231
Wisconsin	9.55	1,830.0	4.807	.232

[a] Source [33].

[b] Source: Consultation with representatives of state departments of transportation.

Table 37. Estimated 1980 truck rates for trucking distances of 50, 100, and 200 miles in cents per bushel

State	Truck rates in cents per bushel of corn			Truck rates in cents per bushel of wheat or soybeans		
	50	100	200	50	100	200
Illinois	9.38	16.01	29.28	10.05	17.15	31.37
Iowa	9.40	16.04	29.34	10.07	17.19	31.43
Kansas	9.35	15.96	29.19	10.01	17.10	31.27
Minnesota	9.33	15.94	29.15	10.00	17.08	31.23
Montana	9.60	16.36	29.88	10.28	17.53	32.02
Nebraska	9.33	15.94	29.16	10.00	17.08	31.24
North Dakota	9.31	15.91	29.10	9.98	17.04	31.17
Ohio	9.26	15.83	28.97	9.93	16.96	31.04
Oklahoma	8.66	14.87	27.30	9.27	15.93	29.25
Washington	9.34	15.96	29.19	10.01	17.10	31.27

Handling charges

Handling charges were applied at river terminals to all grain received by truck or rail shipment. Handling charges were applied at a rate of 4.87 cents per bushel of corn and 5.22 cents per bushel of wheat or soybeans. Handling charges were estimated based upon a study completed at the Texas Transportation Institute [18,p.25].

Ocean rates

Ocean-going vessel rates are estimated by calculating the average, weighted by ship payload capacity, of grain rates published by the Journal of Commerce and Commercial [41] for the period October 1979 to September 1980. After reviewing the import ship rates as implied by the 1979-80 average with industry representatives, it was determined that Great Lake rates to Europe were understated by the sample. These rates were adjusted to reflect a $13 dollar per ton differential between Great Lakes and Gulf rates to Europe. Ocean rates are presented in cents per bushel of corn in Table 38. Table 39 presents ocean rates in cents per bushel of wheat or soybeans.

Port capacities

The unloading capabilities of port areas are based on a survey of individual port elevators reported by Dezik and Fuller [18]. Dezik and Fuller report the location, elevator name, storage capacity, ship-loading rate, truck-, rail-, and barge-receiving rates of U.S. export port facilities that handle grain. The receiving rates are reported in bushels per hour.

Table 38. Estimated 1980 ocean grain rates from domestic ports to major foreign demand regions in cents per bushel of corn

	Central and South America	Middle East and Africa	Western Europe	Eastern Europe	Far East
East Coast	78.8	86.5	49.3	84.0	108.8
Gulf	66.8	118.3	43.5	74.0	63.0
Lakes	113.8	97.0	76.0	106.5	131.8
West Coast	65.8	98.0		156.5	51.5

Table 39. Estimated 1980 ocean grain rates from domestic ports to major foreign demand regions in cents per bushel of wheat and soybeans

	Central and South America	Middle East and Africa	Western Europe	Eastern Europe	Far East
East Coast	84.4	92.7	52.8	90.0	116.5
Gulf	71.5	126.7	46.6	79.3	67.5
Lakes	121.9	103.9	81.4	114.1	141.1
West Coast	70.4	105.0		167.7	55.2

Unloading capacities for this study are estimated by port areas, time period, and by transport mode. The port groupings and total bushel unloading capacity per area are presented in Table 40.

Transportation equipment requirements - rail

The following assumptions are the basis for the projected 1990 covered hopper car fleet:

1. The covered hopper car fleet will increase by 5,000 cars per year until 1990.
2. Ninety-five percent of the projected rail car fleet is available at all times. Five percent of the fleet is being repaired at any given time.
3. Sixty percent of the available covered hopper car fleet is used to transport corn, wheat and soybeans.
4. The percentage of the grain fleet used to export corn, wheat and soybeans is equal to 56.6 percent of the available grain fleet. The ratio of export rail-car loadings to total rail-car loadings [2] is the basis for this percentage.

The estimated covered hopper car supply and rail cars available for the export of corn, wheat and soybeans is presented in Table 41. Rail car usage of this available supply is a function of rail turnaround time (RTAT) and the total bushels of grain shipped by rail.

Two constraints imposed on the linear programming model utilize estimated RTAT. First, the available export rail-car days are rationed

Table 40. Unloading capacity by major port areas and transport mode, in thousands of bushels per hour, 1980[a]

Port area	Unloading capacities: Rail	Truck	Barge
East Coast, North of Hatteras	271.5	127.4	---
East Coast, South of Hatteras	50	25	---
Gulf of Mexico	597.2	229.0	496.3
West Coast, California	85.0	93.5	---
West Coast, Oregon and Washington	231.1	73.6	152.7
Great Lakes, Duluth	65	83.7	---
Great Lakes, Chicago	112.4	64.4	---
Great Lakes, Saginaw	25	37	---
Great Lakes, Toledo	70	160	---

[a] Source: [18].

Table 41. Estimated 1990 covered hopper rail car supply and export requirements

	1990
July 1, 1981 Inventory	219,900
Net additions to fleet at 5,000 per year	45,000
Projected inventory	264,900
Projected usable fleet (95%)	251,655
Projected fleet used for corn, wheat and soybeans (60%)	150,993
Projected fleet used for corn, wheat and soybean exports (56.6%)	85,462

among direct-rail export shipments as a function of RTAT in days from origin of export shipment to port. Secondly, the capacity of a region to utilize the less expensive multiple car rates depends upon the total rail-car days assigned to the region. Regional rail-car days are a function of the number and rail-car loading capacity of the multiple car facilities in the region (see Table 42). A multiple car shipment, of any distance, causes the assigned rail-car days to decrease. The decrease in rail-car days for a particular origin-destination pair is a function of the RTAT.

The available data on RTAT consisted of turnaround times recorded by two central Iowa grain shipping firms. These firms have a combined rail-car fleet of approximately 5,000 rail cars. Table 43 presents the average RTAT by size of shipment and one-way miles as collected from these firms. As demonstrated in Table 44, distance traveled has a minimal effect on the difference between RTATs of various shipment sizes. Shipment by a 75-car train will save 8.3 days, at a distance of less than 250 miles, when compared with single-car shipments. This savings increases to 8.8 days for distances greater than 1,000 miles. This suggests that the greatest portion of the time savings is attributable to non-transit factors, such as loading and unloading, switching and yard time. Data on these non-transit factors were unavailable. Consequently, miles traveled, of necessity, became the independent variable for regression estimation of RTAT.

Table 42. Maximum 1980 rail-car loading capacity per facility and number of facilities by state, CRD, and subdivision

State	CRD	Quadrant	Rail-car loading capacity	Number of facilities
ID	7	---	26	6
	8	---	26	6
	9	---	26	9
IL	5	NE[a]	100	4
	5	NE	125	1
	5	NW[b]	125	1
	5	SE[c]	100	2
	6	NE	100	1
	6	NW	100	3
	6	NW	125	4
	6	SE	100	1
	6	SW[d]	100	10
	6	SW	125	2
	40	NE	100	5
	40	W[e]	100	1
	60	NE	65	2
	60	NE	100	2
	60	NE	125	2
	60	NW	65	1
	60	NW	100	2
IN	1	N[f]	65	1
	1	N	100	2
	1	S[g]	65	3
	1	S	100	8
	2	N	100	1
	2	S	100	3
	3	N	100	1

[a]Northeast quadrant of CRD.

[b]Northwest quadrant of CRD.

[c]Southeast quadrant of CRD.

[d]Southwest quadrant of CRD.

[e]Western half of CRD.

[f]Northern half of CRD.

[g]Southern half of CRD.

Table 42. (Continued)

State	CRD	Quadrant	Rail-car loading capacity	Number of facilities
	3	S	100	4
	4	N	100	1
	4	S	100	2
	5	N	100	7
	5	S	65	1
	5	S	100	2
	6	N	100	2
	7	N	65	1
	8	S	100	1
IA	1	NE	25	3
	1	NE	50	4
	1	NE	75	7
	1	NW	25	5
	1	NW	50	2
	1	SE	25	7
	1	SE	50	2
	1	SE	75	6
	1	SW	75	2
	2	NE	25	4
	2	NE	50	2
	2	NW	25	3
	2	NW	50	4
	2	NW	75	5
	2	SE	25	5
	2	SE	50	1
	2	SW	25	7
	2	SW	50	3
	2	SW	75	6
	3	NW	25	1
	3	SW	25	1
	3	SW	50	1
	4	NE	25	4
	4	NE	75	3
	4	NW	25	2
	4	NW	50	1
	4	NW	75	2
	4	SE	25	4
	4	SE	50	1
	4	SW	75	2
	4	SW	25	1
	5	NE	25	4
	5	NW	25	3
	5	NW	50	2

Table 42. (Continued)

State	CRD	Quadrant	Rail-car loading capacity	Number of facilities
	5	NW	75	3
	5	SE	50	2
	5	SE	75	1
	5	SW	25	8
	5	SW	50	3
	5	SW	75	5
	7	NW	25	1
	7	NE	50	1
	8	NW	25	1
	8	SW	25	1
	8	SW	50	1
KS	3	---	50	1
	3	---	75	1
	5	---	75	3
	8	---	75	1
MI	4	---	100	1
	6	---	100	7
	8	S	100	1
MN	1	N	26	7
	1	S	26	1
	1	S	26	1
	4	N	26	5
	4	S	52	3
	4	S	26	1
	4	S	54	1
	5	S	54	1
	7	NE	25	2
	7	NE	75	2
	7	SE	25	4
	7	SE	50	2
	7	SE	75	2
	7	SW	25	3
	7	SW	75	1
	8	NE	25	1
	8	NW	25	3
	8	NW	75	1
	8	SE	25	2
	8	SE	50	3
	8	SE	75	2
	8	SW	75	3
	8	SW	25	1

Table 42. (Continued)

State	CRD	Quadrant	Rail-car loading capacity	Number of facilities
MT	2	---	26	16
	3	---	26	4
	5	---	26	3
	9	---	26	2
NE	1	N	50	2
	1	S	50	1
	2	N	25	2
	2	N	50	1
	3	W	25	2
	3	W	50	1
	3	W	75	2
	5	SE	25	7
	5	SE	50	2
	5	SE	75	3
	5	SW	25	1
	5	SW	50	2
	6	E[h]	25	3
	6	E	50	3
	6	E	75	1
	6	W	25	10
	6	W	50	8
	6	W	75	3
	7	S	50	1
	8	E	25	1
	8	E	50	8
	8	E	75	2
	8	W	50	1
	9	W	25	2
	9	W	50	2
SD	1	---	54	1
	1	---	26	4
	2	---	26	4
	2	---	26	2
	3	---	26	9
	3	---	26	3
	4	---	26	2
	5	---	26	1
	6	---	26	2
	6	---	26	4

[h] Eastern half of CRD.

Table 42. (Continued)

State	CRD	Quadrant	Rail-car loading capacity	Number of facilities
	7	---	26	1
	9	---	26	1
	9	---	52	1
OH	1	NE	65	1
	1	NE	100	4
	1	NW	100	1
	1	SE	100	1
	1	SW	100	2
	2	NE	65	1
	2	NE	100	1
	2	NW	100	1
	2	SE	65	1
	2	SW	65	1
	2	SW	100	1
	4	N	100	5
	4	S	65	1
	4	S	100	3
	5	N	100	4
	5	S	100	3
	6	---	100	1
	7	S	100	1
ND	3	---	54	2
	3	---	26	2
	4	---	26	1
	5	---	26	1
	5	---	52	1
	9	---	26	4

Table 43. Average rail turnaround time in days by size of shipment and miles traveled as collected from grain shipping firms in Iowa, 1977-1980

Size	Number of observations	One-way miles shipped			
		0-249	250-749	750-999	1000 or more
1-15	287	18.3	22.2	27.2	29.8
24-30	875	13.3	17.4	21.4	25.7
50-65	286	12.7	15.2	16.6	21.9
75-125	852	10.0	14.4		21.0

Table 44 presents the alternative functional forms used to estimate RTAT. The choice of functional form for the regression of RTAT on miles was based on a comparison of a linear equation of the type:

$$RTAT = a + b \text{ (one-way miles)} \tag{19}$$

and a logarithmic equation:

$$\ln(RTAT) = a + b \ln(\text{one-way miles}) \tag{20}$$

The choice of the logarithmic equation rests upon some intuitive reasoning. The contribution of non-transit factors to total RTAT will decrease as distance traveled increases, suggesting that RTAT will increase at a decreasing rate as distance increases.[9] This is true for all shipment sizes. Figure 6 presents a plot of the estimated regression equations by shipment size.

Additional input from rail industry sources led to the assumption that existing RTAT can be expected to improve by twenty percent by 1990. This improvement is based upon projected expansion of export facilities, improved main-line track conditions, and increased usage of multiple-car shipments. Table 45 presents projected RTAT, including the projected reduction of 20 percent, from major grain producing regions to selected export ports.

Mileage between origin-destination points is estimated using Rand McNally mappings of railroad mileages [37,38]. The criteria used in route selection are identified in Hauser [21].

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[9] A linear function would require RTAT to increase at a constant rate as distance increases.

Table 44. Regression coefficients, linear and logarithmic transformation used in projecting rail turnaround time by shipment size

Size of shipment	Equation type	Constant	One-way miles	R^2	F
single	linear	12.694 (0.72)	0.1857 (0.001)	0.36	161.0
	log-linear	0.442 (0.15)	0.4321 (0.027)	0.48	263.9
25-car	linear	12.446 (0.44)	0.0113 (0.0004)	0.40	566.8
	log-linear	0.869 (0.09)	0.3296 (0.013)	0.42	616.2
50-car	linear	11:529 (1.13)	0.0089 (0.001)	0.21	76.0
	log-linear	0.950 (0.19)	0.2967 (0.029)	0.27	107.0
75-car	linear	12.008 (1.08)	0.0075 (0.001)	0.08	70.44
	log-linear	0.594 (0.21)	0.3412 (0.029)	0.14	136.11

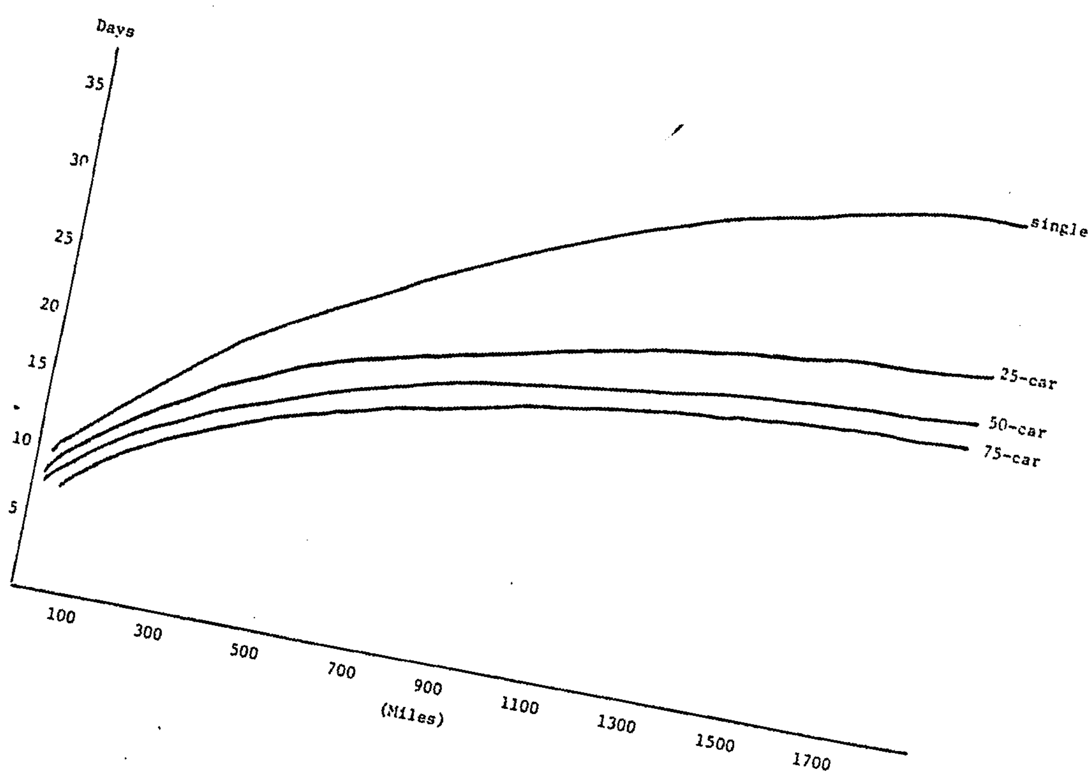

Figure 6. Rail turnaround-time in days for one-way miles travelled

Table 45. Projected 1990 rail turnaround times in days by size of shipment from selected major grain producing regions to point of export

Region	Export locations and shipment size								
	Gulf			Pacific Northwest			Lakes		
	1	25	75	1	25	75	1	25	75
Central Iowa	25.0	18.8	15.5	32.6	23.0	19.1	15.8	13.2	10.8
Central Illinois	22.7	17.4	14.3	34.6	24.1	20.1	8.7	8.4	8.4
Central Nebraska	24.3	18.4	15.1	30.4	21.8	18.1	20.2	16.0	13.1
Central North Dakota	30.8	22.2	18.4	28.5	20.8	17.2	17.5	14.3	11.7
Central Montana	31.4	22.4	18.5	24.2	18.4	15.1	23.5	17.9	14.7

<u>Transportation equipment requirements - barge</u>

The 1990 fleet of covered hopper barges is projected by least squares regression of the historical trend in the number of dry cargo barges, as supplied by the Twin City Shipyard annual industry survey [25]. The regression of the number of covered hopper barges on time was a logarithmic equation of the form:

$$\underset{}{\ln(\text{Barges})} = \underset{(.201)}{3.828} + \underset{(.074)}{1.613} \ln(\text{time}). \qquad (37)$$

The total size of the fleet is projected to be 14,886 barges in 1990. Of this total, 70 percent—10,420 barges--is available to transport corn, soybeans and wheat. Based on industry consultation, it was determined that 80 percent of the available grain barge fleet are committed to long-term contracts. The residual twenty percent is available for spot movements.

Barge usage of this available supply is a function of barge turnaround time (BTAT) and the total bushels of grain shipped by barge. Table 46 presents the estimated barge days (fleet size times days per period) in 1990. A barge shipment, of any distance, decreases the available barge days. The decrease in barge days is a function of the BTAT between river origins and export port.

Barge turnaround times on the Mississippi River system are computed using river speeds (total trip) as supplied by the Army Corps of Engineers and industry estimates of loading, unloading and fleeting time at the origin and the Gulf. Total trip river speeds in miles per hour, as presented in Table 47, includes all intermediate switching. Barge

Table 46. Estimated contract and spot barge days available to transport grain in 1990

	Winter[a]	Non-Winter[b]
Contract-barge days	760,660	2,281,980
Spot-barge days	190,165	570,495

[a] 91.25 days in winter period.

[b] 273.75 days in non-winter period.

Table 47. Miles traveled per day by barges by river segment[a]

	Total-trip[b] (including delay)		Underway (excluding delay)	
River	South	North	South	North
Lower Mississippi	229.4	114.5	279.4	129.4
Upper Mississippi	75.6	69.6	180.2	131.8
Illinois	65.7	60.2	118.6	96.7
Ohio	117.8	92.9	210.7	147.4
Missouri	146.2	84.7	224.2	95.5
Arkansas	101.0	117.4	180.2	146.2

[a] Total-trip miles per day includes delays at locks and dams and intermediate switching.

[b] Source: Army Corps of Engineers.

turnaround times on the Columbia-Snake River system are estimated based on information obtained from a grain transportation consulting firm located in Portland, Oregon. A sample of BTAT are presented in Table 48. Unlike rail, no decrease in BTAT is expected between 1980 and 1990.

Increased Transport Costs Due to User Charges

The level of inland waterway user taxes

The two types of user taxes analyzed in this study are fuel and segment-specific taxes. A fuel tax is simply a tax levied on each gallon of propulsion fuel consumed on the inland waterways and is similar to federal and state highway fuel taxes imposed on fuel consumed by automobiles and trucks. A segment tax is similar to the taxes collected on toll highways. The level of waterway user taxes used in this analysis were taken from a study conducted by Data Resources Incorporated(DRI) [17]. The METHOD OF ANALYSIS Chapter presents the methods used by DRI to determine the systemwide and segment levels of taxation.

The 38.1 cents per gallon fuel tax is converted to origin-specific taxes per bushel of grain on the Mississippi River system. Internal Revenue Service [71] guidelines specify that only propulsion fuel is subject to a tax. In addition, no taxes are collected south of Baton Rouge, Louisiana, or west of The Dalles on the Columbia-Snake River. The procedure utilized to estimate barge fuel consumption on the Mississippi River and tributaries is discussed in the next section. Fuel surcharges on barge traffic on the Columbia-Snake River as specified in barge tariffs [13] are used to determine the fuel tax per bushel of grain on this system.

Table 48. Estimated 1990 turnaround time to New Orleans for barge shipments originating on the Mississippi river system and to Portland on the Columbia-Snake

River	City	Miles to port	Turnaround time (days)[a]
Mississippi	Minneapolis, MN	1,811	60.9
	Clinton, IA	1,471	51.2
	St. Louis, MO	1,128	41.4
	Cairo, IL	954	36.4
	Helena, Ark.	661	32.4
Illinois	Seneca, IL	1,424	51.0
	Peoria, IL	1,330	47.8
Ohio	Cincinnati, OH	1,456	46.4
	Louisville, KY	1,332	44.0
Missouri	Sioux City, IA	1,880	56.7
	Omaha, NE	1,773	54.1
	Kansas City, MO	1,517	49.1
Arkansas	Catoosa, OK	1,040	40.1
Columbia-Snake	Lewiston, WA	475	7.5
	Central Ferry, WA	405	6.8
	Windust, WA	350	6.2
	Biggs, OR	209	3.3

[a] Includes: 7.5 days loading and fleeting at Mississippi River origins, 15 days unloading, switching and fleeting at Gulf, and unforeseen repair delays equal to 4 percent of total TAT.

The segment-specific ton-mile taxes presented in Table 3 are converted to cents per bushel of grain for individual barge loading points by multiplying the tax by the miles traveled on that segment and dividing by the appropriate bushels per ton.

Barge freight fuel consumption

Under P.L. 95-502, fuel taxes are collected on liquid fuels in the propulsion system of commercial waterway transportation vessels. Fuel consumed in the transportation of freight from origin to destination "commercial waterway transportation" includes: the operation of vessels while moving empty of cargo, while awaiting passage through locks, while dislodging vessels grounded on a sandbar, while moving to or from a repair facility, while maneuvering around loading and unloading docks, and while fleeting into a single tow [73]. Fuel consumed in the generation of electricity and heat, if the generator is separate from propulsion engines, is not subject to the tax. Fuel taxes are collected on movements resulting from "commercial waterway transportation" on the following river segments (applicable to grain transportation):

Lower Mississippi River: From Baton Rouge, Louisiana, RM 233.9 to Cairo, Illinois, RM 953.8.

Upper Mississippi River: From Cairo, Illinois, RM 953.8 to Minneapolis, Minnesota, RM 1,811.4.

Missouri River: From junction with Mississippi River at RM 0 to Sioux City, Iowa at RM 734.8.

Illinois River: From junction with Mississippi River at RM 0 to Lockport Lock and Dam at RM 291 (Des Plaines River).

Ohio River: From junction with the Mississippi River at RM 0 to junction of Allegheny and Monongahela at Pittsburgh, Pennsylvania at RM 981.

Arkansas River: From junction with Mississippi River at RM 0 to port of Catoosa, Oklahoma at RM 488.2.

Columbia-Snake Rivers: From The Dalles at RM 191.5 to Pasco, Washington (McNary Pool) at RM 330, Snake River from RM 0 at the mouth to RM 231.5 at Johnson Bar Landing, Idaho [71].

Table 49 presents the source and type of data collected by river segment used to estimate barge freight fuel consumption. Fuel consumption is estimated on data obtained from three basic sources. First, the Army Corps of Engineers provided data on average miles per hour by river segment. Table 47 presents these estimates in miles per day. Data are presented on two speeds for each river segment. The underway miles per day is the average speed on the listed river segment for a barge moving full-speed ahead. The total-trip miles per day is the average speed on the listed river segment including both underway and delay time (delays at locks and dams, all intermediate switching, and the adding on of additional barges).

Secondly, data were collected from four barge companies that monitor actual towboat fuel consumption by horsepower and size of tow. In most cases, fuel consumption data were separable by river segment. Therefore, the greatest proportion of data was collected on the Lower Mississippi River. The importance of this is that all grain shipments on the Mississippi River system move on the Lower Mississippi River regardless of their origination point. The larger number of observations on the Lower Mississippi allowed greater precision in fuel consumption estimation on this segment, and hence on the greatest proportion of grain barge traffic. The origin-destination, horsepower of towboat, typical

Table 49. Source and type of data used in estimating taxable fuel consumption by river segment

River segment	Source	Type
Lower Mississippi	A. C. of E.[a] 3 barge companies	River speeds 22 trips - 516,737 tons Horsepower range (4300-7000)
Upper Mississippi	A. C. of E. 2 barge companies	River speeds 9 trips - 85,357 tons Horsepower range (3200-5600)
Illinois	A. C. of E. 2 barge companies	River speeds 5 trips - 11,607 tons Average consumption Horsepower range (3200-4000)
Ohio	A. C. of E. 1 barge company	River speeds 11 trips - 247,005 tons Horsepower range (4300-5000)
Missouri	A. C. of E. 1 barge company	River speeds July - August average Horsepower range (2200-3300)
Arkansas	A. C. of E.	River speeds Estimated fuel consumption by horsepower of towboat

[a] Army Corps of Engineers.

number and capacity of barges, and average fuel consumption statistics estimated from barge company data are reported in Table 50.

The third type of data is specific to the Columbia-Snake River. Rate Schedule No. 1 as published by Columbia Marine Lines, Inc.[13] includes fuel surcharges by origin. These fuel surcharges were imposed as a result of the four cent per gallon user charge which became effective in October, 1980. These surcharges are reproduced in Table 51 on a cents per ton and cents per bushel basis. By increasing these surcharges proportionately to account for the fuel tax levels in 1990, the need to estimate fuel consumption on the Columbia-Snake River was eliminated.

Fuel consumption from a specific origin on the Mississippi River system to Baton Rouge, Louisiana is equal to fuel consumed on the underway and delay portions of the round-trip. River segment specific round-trip fuel consumption is estimated by the following equation:

$$TFC_{ij} = GPTM_i \cdot M_{ij} \cdot T_i \qquad (38)$$

where

TFC_{ij} = Total fuel consumption on river segment i, from origin j.

$GPTM_i$ = Average gallon per ton-mile fuel consumption on river segment i (from Table 51)

M_{ij} = Miles on river segment i, from origin j.

T_i = Typical tons per grain movement on river segment i (equals the number of barges, which represent the typical size of a tow on each river segment, multiplied by the tons per barge as shown in Table 51).

Table 50. Towboat horsepower, typical number of barges per tow, tons per barge, and fuel consumption by river segment

River	Origin	Destination	Horsepower of towboat	Typical number of barges per tow	Tons per barge	Fuel consumption Loaded south	Empty north	Total	Gallons per ton	Gallons per Ton-mile
Lower Miss.	St. Louis	Baton Rouge	6,500	25	1,475	21,483	42,494	63,977	1.73	.002410
Upper Miss.	Davenport	St. Louis	4,000	12.5	1,475	8,735	10,860	19,595	1.06	.003488
Illinois	Peoria	St. Louis	4,000	12.5	1,475	5,099	8,221	13,320	.72	.003564
Ohio	Owensboro	Cairo	4,000	12.5	1,475	4,915	4,566	9,482	.51	.002327
Upper Missouri	Sioux City	Kansas City	3,200	3	1,200	5,116	6,271	11,387	3.16	.008767
Lower Missouri	Kansas City	St. Louis	3,200	6	1,200	6,955	9,919	16,874	2.34	.006148
Arkansas	Catoosa	Miss.-Ark.	3,200	5	1,200	11,326	9,729	19,884	3.31	.007520

Table 51. Schedule of fuel surcharges on the Columbia-Snake river system[a]

City	Fuel surcharge	
	Cents per ton	Cents per bushel
The Dalles, OR	0	0
Biggs, OR	4.0	0.11
Arlington, OR	4.0	0.11
Pasco, WA	4.0	0.11
Wallula, WA	4.0	0.11
Windust, WA	6.0	0.17
Lyons Ferry, WA	7.0	0.20
Almota, WA	8.0	0.22
Central Ferry, WA	8.0	0.22
Clarkston, WA	10.0	0.28
Lewiston, ID	10.0	0.28

[a] Source: [13].

Taxable fuel consumption by river segment is equal to total fuel consumption as estimated by equation (38) minus generator fuel consumption. Generator fuel consumption varies by horsepower of towboat. Hence, generator fuel consumption varies by river segment. For the horsepower of the towboats assumed for this analysis, as presented in Table 50, the fuel consumed on a daily basis in the operation of the generator is shown in Table 52. This daily rate of generator fuel consumption was estimated from barge company records.

Table 52. Generator fuel consumption by horsepower of towboat

Horsepower	Generator fuel consumption
6,500	324 gallons per day
4,000	192 gallons per day
3,200	192 gallons per day

Using these daily rates of generator fuel consumption, segment specific generator consumption is estimated by equation (39).

$$GFC_{ij} = \sum_k (M_{ij} \div TD_{ijk}) \cdot DG_i \qquad (39)$$

where

GFC_{ij} = Generator fuel consumption on river segment i, from origin j.

TD_{ijk} = Total-trip miles per day on river segment i, from origin j for direction of movement k: k=north or south

DG_i = Daily fuel consumption by generator on river segment

Taxable fuel consumption over the round-trip grain movement is equal to:

$$TTFC_j = \sum_i (TFC_{ij} - GFC_{ij}) \quad (40)$$

where

$TTFC_j$ = Taxable fuel consumption from origin j to Baton Rouge, Louisiana.

Assuming that generator output is constant whether the towboat is underway or delayed, delay-time per trip does not affect taxable fuel consumption. Consequently, the computation of fuel consumed by a typical barge movement while waiting at locks and dams, while switching towboats at intermediate river points, and for other delays is included only for completeness. Delay fuel consumption by river segment is estimated as follows:

$$DFC_{ij} = \sum_k (M_{ij} \div TD_{ijk} - M_{ij} \div UD_{ijk}) \cdot 0.25\ AFC_i \quad (41)$$

where

DFC_{ij} = Total gallons of fuel consumed while delayed on river segment i, from origin j to the confluence with another river segment.

UD_{ijk} = Underway miles per day on river segment i, from origin j, for direction of movement k.

AFC_i = Approximate fuel consumption per day by size of towboat as suggested by the Army Corps of Engineers as presented in Table 53.

Table 53. Approximate fuel consumption by horsepower of towboat

Horsepower	Approximate fuel consumption
6,500	4,875
4,000	3,400
3,200	3,040

Executives of barge companies attributed 25 percent of daily fuel consumption rates to fuel consumption while delayed. The fuel consumed while the tow is delayed is necessary to maintain the position of the tow. Hence, the 0.25 constant in equation (41).

Table 54 presents the breakdown of total fuel consumption by type of barge movement for selected river origins. Note the following points:

1. The distance from Minneapolis, MN to Cairo, IL is approximately 135 miles greater than the distance from Cairo, IL to Baton Rouge, LA. However, the fuel consumed during delay movements is approximately 6.7 times greater on the Minneapolis to Cairo grain movement.[10]
2. The distances between the Gulf ports and Seneca, IL; Cincinnati, OH; Clinton, IA; or Kansas City, MO; are within a 100 mile range. However, differences in fuel consumption attributable to segment characteristics (average speeds, the number of locks and dams, and size of tow) will affect total fuel consumption and

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[10] Delay fuel consumption from Minneapolis to Cairo is equal to 12097-1567.

Table 54. Estimated total and taxable barge fuel consumption by selected origins

River	Origin	Underway: Loaded south	Underway: Empty north	Delay	Total fuel consumption	Generator fuel consumption	Taxable fuel consumption
Upper Miss.	Minneapolis, MN	39,944	67,037	12,097	119,078	7,594	111,484
	Clinton, IA	32,427	56,427	7,925	97,245	5,795	91,450
Middle Miss.	St. Louis, MO	24,818	46,628	3,702	75,148	3,974	71,174
Lower Miss.	Cairo, IL	20,972	41,438	1,567	63,977	3,054	60,923
	Memphis, TN	14,327	28,309	1,070	43,706	2,086	41,620
	Greenville, MS	8,836	17,458	660	26,954	1,287	25,667
Illinois	Seneca, IL	31,969	55,570	7,049	94,588	5,752	88,836
	Peoria, IL	29,665	52,725	6,002	88,392	5,176	83,216
Ohio	Cincinnati, OH	30,536	50,109	4,861	85,506	4,909	80,597
	Louisville, KY	28,173	47,966	4,047	80,186	4,451	75,735
Missouri	Sioux City, IA	34,823	63,432	6,031	104,286	6,706	97,580
	Kansas City, MO	30,326	57,483	5,005	92,814	5,405	87,409
Arkansas	Catoosa, OK	19,313	29,419	2,854	51,586	3,095	48,491

hence, the per bushel fuel tax from these origins to Baton Rouge, LA.

Validation of estimated fuel consumption was a difficult task. Barge company executives suggested that as an average the fuel consumption estimates were on target. A second method of validating the estimates was to convert total fuel consumption to ton-miles per gallon for various length of haul and differential backhaul assumptions, and compare these to available barge company data. The procedure utilized in determining different levels of fuel consumption for various backhaul percentages consisted in estimating the difference in fuel consumption by barge between unit-tow coal movements and barge movements where the number of loaded barges on the backhaul movement was determinable. It was estimated that approximately 21 percent more fuel per barge is consumed over the return trip because of the non-empty backhaul. Table 55 presents the 1977-78 and 1978-79 average ton-miles per gallon for towboats of various sizes as obtained from a barge company. Estimated barge ton-miles by river segment for various backhaul assumptions are presented in Table 56. By comparing Tables 55 and 56, the following conclusions may be drawn:

1. The average barge company data ton-miles per gallon for the horsepower of towboat similar to those assumed in the study for the Upper Mississippi, Ohio and Illinois Rivers (4,000) is 434. This average compares favorably with the estimated ton-miles per gallon in the 25 to 40 range of percentage backhaul on the Upper Mississippi and Illinois Rivers (Table 56).

Table 55. Ton-miles per gallon of fuel used for various horsepower of towboats as supplied by a barge company

Horsepower	Ton-miles per gallon of fuel used 1977-78	1978-79
3,800	467	447
4,200	405	441
4,200	406	437
6,300	437	421
6,600	519	501
7,300	531	558

Table 56. Estimated barge ton-miles per gallon by river segment for selected levels of percentage backhaul

River segment and origin city	Percentage backhaul 0	25	40	50
Upper Mississippi				
Minneapolis	358.8	436.0	480.3	509.0
Davenport	376.1	456.5	502.5	532.4
Lower Mississippi				
Cairo	435.7	526.7	578.4	611.8
Missouri				
Sioux City	229.3	278.2	306.2	324.3
Kansas City	294.6	356.6	293.0	414.9
Illinois				
Seneca	376.0	456.4	502.4	532.2
Peoria	383.1	464.7	511.5	541.7
Ohio				
Cincinnati	449.3	545.7	601.0	636.8
Arkansas				
Catoosa	202.9	247.3	272.8	289.4

2. The average barge company data ton-miles per gallon of fuel consumed for the horsepower of towboat similar to those assumed for the Lower Mississippi (6,500) is equal to 494. This average lies between the estimated ton-miles per gallon in the 0 to 25 range of percentage backhaul on the Lower Mississippi.

Barge company executives suggested that during a given year, between 25 and 40 percent backhaul is a reasonable approximation.

Taxes by river origin

In the preceding section the procedure utilized to estimate barge freight fuel consumption from specific grain origins to Baton Rouge, LA was outlined. Dividing taxable fuel consumption on a particular river segment by the appropriate tonnage for a typical barge movement on that segment yields gallons per ton. For example, as presented in Table 55, taxable fuel consumption for a grain movement from Minneapolis, MN to Baton Rouge, LA is equal to 111,484 gallons. Taxable fuel consumption from Cairo, IL to Baton Rouge, LA is equal to 60,923 gallons. Therefore, taxable fuel consumption for this movement on the Upper Mississippi River is equal to 50,561 gallons. The fuel consumed per ton for the Upper Mississippi River segment movement is equal to 50,561 divided by 18,437.5 tons (12.5 barges x 1,475 tons per barge) or equivalently 2.74 gallons per ton. On the Lower Mississippi portion of this movement gallons per ton is equal to 1.65. Although total fuel consumption on the Lower Mississippi movement is over 10,000 gallons greater, the gallons per ton consumption is less because a typical barge movement on the Lower

Mississippi consists of 25 barges. Total gallons per ton for this movement from Minneapolis, MN to Baton Rouge is equal to 4.39. Multiplying gallons per ton by the appropriate bushels per ton--35.7 for corn, 33.3 for soybeans and wheat--and by the fuel tax of 38.1 cents per gallon yields a tax per bushel of corn of 4.69 cents for the Minneapolis to Baton Rouge grain movement. Similar calculations were performed for the fuel portion of the fuel-segment tax. On the Columbia-Snake River, the fuel surcharges as presented in Table 52 were increased proportionately to the 38.1 cents per gallon tax level. Calculating origin specific segment taxes is simply a matter of multiplying miles traveled on a particular river segment times the tax for that segment and summing over all river segments over the length of the trip. Origin specific fuel and segment taxes in cents per bushel of corn are presented in Table 57. These taxes in cents per bushel of soybeans and wheat are presented in Table 58.

The following conclusions may be drawn from Tables 57 to 58.

1. The per bushel fuel tax varies widely depending on the river and origin on that river. The 1990 fuel tax ranges from 0.7 cents per bushel of corn at Greenville, Mississippi to 7.7 cents per bushel at Sioux City, Iowa.
2. The 1990 segment ton-mile tax with no railroad rate response ranges from 0.4 cents per bushel of corn at Greenville, Mississippi to 8.6 cents per bushel at Sioux City, Iowa.
3. If railroads raise their rates in response to a user tax, the per bushel tax declines on most rivers. The higher rail rates

Table 57. Estimated increase in 1990 cost of barging grain from user taxes, in cents per bushel of corn

River	Origin	Fuel tax[c]	Combination[b] fuel-segment tax	Segment tax[a]: No railroad response	Segment tax[a]: 50 Percent railroad response	Segment tax[a]: 100 Percent railroad response
Mississippi	Minneapolis, MN	4.69	5.37	6.52	6.19	5.97
	Winona, MN	4.21	5.28	5.63	5.43	5.20
	McGregor, IA	3.93	4.28	5.08	4.84	4.66
	Clinton, IA	3.53	3.72	4.34	4.14	3.98
	Burlington, IA	3.12	3.27	3.57	3.47	3.32
	Hannibal, MO	2.82	2.70	3.00	2.89	2.76
	St. Louis, MO	2.36	2.53	2.13	2.08	1.98
	Cairo, IL	1.76	1.18	1.01	1.01	1.01
	Portageville, MO	1.57	1.04	0.90	0.90	0.90
	Osceola, AR	1.34	0.90	0.77	0.77	0.77
	Memphis, TN	1.20	0.80	0.69	0.69	0.69
	Helena, AR	1.05	0.70	0.60	0.60	0.60
	Perthshire, MS	0.90	0.60	0.52	0.52	0.52
	Greenville, MS	0.74	0.50	0.43	0.43	0.43
Illinois	Seneca, IL	3.38	3.25	3.61	3.44	3.23
	Ottawa, IL	3.33	3.19	3.54	3.38	3.18
	Peoria, IL	3.05	2.88	3.16	3.03	2.86
	Naples, IL	2.73	2.51	3.17	2.63	2.49

[a] Segment taxes: see Table 3.

[b] Fuel tax = 9.9 cents per gallon.

[c] Fuel tax = 38.1 cents per gallon.

Table 57. (continued)

River	Origin	Fuel tax[c]	Combination[b] fuel-segment tax	Segment tax[a] No railroad response	Segment tax[a] 50 Percent railroad response	Segment tax[a] 100 Percent railroad response
Ohio	Cincinnati, OH	2.90	1.79	1.43	1.53	1.49
	Louisville, KY	2.62	1.64	1.33	1.41	1.37
	Mt. Vernon, IN	2.11	1.36	1.14	1.19	1.15
Missouri	Sioux City, IA	7.74	7.40	8.61	7.76	7.08
	Omaha, NE	6.85	6.60	7.68	6.94	6.35
	Kansas City, MO	4.65	4.67	5.45	5.00	4.60
Arkansas	Catoosa, OK	4.23	6.27	8.43	7.60	7.03
Columbia-Snake	Lewiston, ID	2.67	2.90	3.51	3.31	3.21
	Central Ferry, WA	2.13	2.29	2.77	2.61	2.53
	Lyons Ferry, WA	1.86	1.79	2.52	2.38	2.30
	Windust, WA	1.60	1.17	2.18	2.05	1.99
	Umatilla, WA	1.06	0.70	1.42	1.33	1.29
	Biggs, OR	1.06	0.70	0.68	0.64	0.62
	Dalles, OR	0.00	0.31	0.49	0.46	0.45

Table 58. Estimated increase in 1990 cost of barging grain from user taxes, in cents per bushel of wheat or soybeans

River	Origin	Fuel tax[c]	Combination[b] fuel-segment tax	Segment tax[a]		
				No railroad response	50 Percent railroad response	100 Percent railroad response
Mississippi	Minneapolis, MN	5.02	5.76	6.99	6.63	6.39
	Winona, MN	4.54	5.66	6.08	5.78	5.57
	McGregor, IA	4.21	4.59	5.45	5.19	4.99
	Clinton, IA	3.78	3.99	4.65	4.44	4.26
	Burlington, IA	3.36	3.51	3.87	3.71	3.56
	Hannibal, MO	3.02	2.89	3.22	3.10	2.96
	St. Louis, MO	2.53	2.71	2.28	2.23	2.12
	Cairo, IL	1.89	1.26	1.08	1.08	1.08
	Portageville, MO	1.69	1.11	0.96	0.96	0.96
	Osceola, AR	1.44	0.96	0.82	0.82	0.82
	Memphis, TN	1.29	0.86	0.74	0.74	0.74
	Helena, AR	1.12	0.75	0.64	0.64	0.64
	Perthshire, MS	0.97	0.64	0.55	0.55	0.55
	Greenville, MS	0.80	0.54	0.46	0.46	0.46
Illinois	Seneca, IL	3.62	3.48	3.87	3.68	3.46
	Ottawa, IL	3.56	3.42	3.80	3.62	3.40
	Peoria, IL	3.27	3.09	3.39	3.25	3.06
	Naples, IL	2.93	2.69	2.92	2.82	2.67

[a] Segment taxes: see Table 3.

[b] Fuel tax = 9.9 cents per gallon.

[c] Fuel tax = 38.1 cents per gallon.

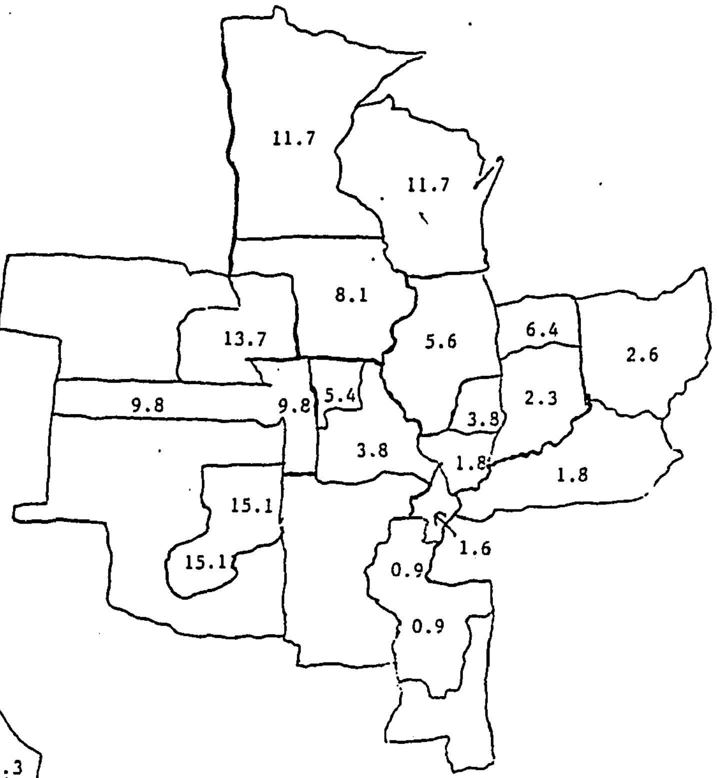
Table 58. (continued)

River	Origin	Fuel tax[c]	Combination[b] fuel-segment tax	Segment tax[a]		
				No railroad response	50 Percent railroad response	100 Percent railroad response
Ohio	Cincinnati, OH	3.11	1.92	1.53	1.64	1.59
	Louisville, KY	2.81	1.76	1.42	1.51	1.47
	Mt. Vernon, IN	2.26	1.46	1.22	1.28	1.23
Missouri	Sioux City, IA	8.29	7.93	9.23	8.31	7.58
	Omaha, NE	7.34	7.07	8.23	7.44	6.80
	Kansas City, MO	4.98	5.00	5.84	5.35	4.93
Arkansas	Catoosa, OK	4.54	6.72	9.03	8.14	7.53
Columbia-Snake	Lewiston, ID	2.86	3.11	3.76	3.54	3.44
	Central Ferry, WA	2.29	2.45	2.96	2.79	2.71
	Lyons Ferry, WA	2.00	1.92	2.70	2.55	2.47
	Windust, WA	1.72	1.25	2.33	2.20	2.13
	Umatilla, WA	1.14	0.75	1.52	1.43	1.38
	Biggs, OR	1.14	0.75	0.73	0.69	0.67
	Dalles, OR	0.00	0.33	0.52	0.49	0.48

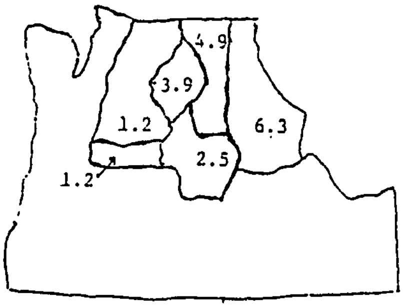
drive grain traffic back to barges. Since the public cost of the inland waterways are largely fixed in any one year, the higher level of barge traffic results in a lower tax.

4. The per bushel fuel tax is lower than the segment tax on some rivers and higher on other rivers. The fuel tax is cheaper on the Illinois, Missouri, Arkansas, Columbia-Snake and on the Upper Mississippi north of Hannibal, Missouri. The segment tax is cheaper on the Ohio and the Mississippi River south of Burlington, Iowa.

Rail rate responses to the user charges are estimated by adding 50 percent and 100 percent of the appropriate per bushel segment tax to export bound rail rates. The appropriate user tax for a specific grain supply region is the tax charged to the lower cost contract barge rate alternative available to that supply region. The specific 100 percent rail responses per hundredweight by region are presented in Map 7. Rail rates to Gulf ports were increased in central United States. Rail rates to East Coast ports were increased in Illinois, Indiana, Ohio and Kentucky. Rail rates to Pacific Northwest ports were increased in Washington, Idaho and Oregon. Rail responses were not determined for grain movements to Great Lakes ports. Fifty percent rail responses are approximately 1/2 the rail responses as presented in Map 7.



Central United States



Northwest United States

Map 7. Estimated 100 percent railroad rate response to river segment specific ton-mile user charges by region in cents per hundredweight

CHAPTER V. RESULTS

Introduction

Five user charge solutions are modelled. In each user charge scenario, the transportation cost structure of the base solution is modified by adding user charges (Table 57 to 58) to barge rates. The user charges are designed to recover 100 percent of inland waterway operations, maintenance, repair and construction (OMRC) from all river traffic, including grain shipments. In two user charge scenarios, railroad rates are changed to simulate a possible competitive reaction to the increased barge rates. In these solutions, railroad rates are increased to Gulf and East Coast export regions from states bordering the Mississippi, Illinois, Ohio, Missouri and Arkansas Rivers. Rates to West Coast ports are increased from states bordering the Columbia-Snake River. The rail rate increases for a particular area are equal to 50 and 100 percent of the segment tax applicable at a nearby river loading point. Domestic rail rates, non-water competitive export rates, truck rates, handling charges and ocean freight rates remain constant in all tax scenarios.

The following user charge scenarios are modelled for 1990.

1. a system-wide fuel tax equal to 38.1 cents per gallon and no rail response.
2. a river-segment specific tax per ton-mile and no rail response.
3. a combination system-wide fuel tax and river segment specific ton-mile tax and no rail response.
4. a river segment specific ton-mile tax combined with a railroad rate response of 50 percent of the segment tax. In this

scenario the tax level on each river segment is lower than the tax level in the segment tax - no response solution reflecting that increased rail rates will cause a greater volume of barge traffic. Hence, given a fixed level of expenditure recovery, a lower per unit tax.

5. a river segment specific ton-mile tax combined with a railroad rate response of 100 percent of the segment tax. In this scenario the tax level on each river segment is lower than both the segment tax-no response and segment tax - 50 percent response tax levels.

This chapter is divided into two major sections. In the first section, the 1990 base--no user charge--computer solution is examined. The second section is concerned with the implication of user charge imposition for the base solution results.

1990 Base Solution

Movements of corn to export regions

Approximately 2,985 million bushels of corn are projected to move to exporting ports during the 1989-1990 crop year. Of this total, it is estimated that direct rail shipments will account for 40.8 percent, barge shipments will equal 48.5 percent and direct truck shipments will equal 10.7 percent. As seen in Table 59, these percentages correspond closely to the 1977 percentages as determined by Hill, Leath and Fuller (HLF) [22].

Approximately 76 percent of total export shipments to the Gulf ports are by barge (HLF estimate 77.6 percent). Eighty percent of the total barge shipments to Gulf ports originate in Illinois and Iowa. An additional 18.5 percent originate in Indiana and Minnesota. Of the 443 million bushels shipped by direct rail to Gulf ports, 347 million--about

Table 59. Base solution corn flows to export regions by originating state and mode in millions of bushels

Originating state	Export region	Transport mode			Total
		Rail	Barge	Truck	
Alabama	Gulf	0	0	8.93	8.93
Florida	Gulf	1.03	0	0	1.03
Georgia	Gulf	2.07	0	0	2.07
Illinois	Atlantic	11.05	0	0	11.05
	Gulf	123.12	589.96	0	713.08
	Lakes	0	0	46.77	46.77
Indiana	Atlantic	327.96	0	0	327.96
	Gulf	0	118.09	0	118.09
Iowa	Gulf	177.59	565.17	0	742.76
	Pacific	22.02	0	0	22.02
Kansas	Gulf	28.12	0	0	28.12
Michigan	Atlantic	53.91	0	0	53.91
	Lakes	0	0	106.43	106.43
Minnesota	Gulf	46.49	150.35	0	196.84
	Lakes	46.37	0	0	46.37
	Pacific	1.80	0	0	1.80
Missouri	Gulf	0	1.26	0	1.26
Nebraska	Gulf	50.94	0	0	50.94
	Pacific	179.74	0	0	179.74
North Carolina	Atlantic	0	0	6.83	6.83
Ohio	Atlantic	132.26	0	0	132.26
	Lakes	0	0	0.96	0.96
South Carolina	Atlantic	0	0	4.69	4.69
Texas	Gulf	14.42	0	0	14.42
Virginia	Atlantic	0	0	3.29	3.29
Wisconsin	Gulf	0	23.50	0	23.50
	Lakes	0	0	140.19	140.19
All States	Gulf	433.78	1,448.33	8.93	1,901.04
	Atlantic	525.18	0	14.81	539.99
	Lakes	46.37	0	294.35	340.72
	Pacific	203.56	0	0	203.56
Total		1,218.89	1,448.83	318.09	2,985.31
1990 Percent of Total		40.8	48.5	10.7	100.0
1977 Percent of Total[a]		36.7	50.3	11.2	98.2

[a] Source: [22].

78 percent--originate in Illinois, Iowa, and Minnesota. This represents a slight decline from the 84.8 percent of all direct rail shipments originating in these states as determined by HLF. The difference may be accounted for by the greater percentage of rail shipments originating in Nebraska by 1990--11.5 percent compared to 7.3 percent in HLF.

The Atlantic ports are served primarily by multiple car rail shipments originating in Indiana and Ohio. The Pacific ports are served primarily by multiple car shipments originating in Nebraska. Lake ports are served primarily by direct truck shipments originating in Minnesota and Wisconsin.

Hill, Leath and Fuller determine that the five leading corn exporting states (Illinois, Iowa, Indiana, Ohio and Minnesota) originate 84.5 percent of total corn exports. This study indicates that export shipments among these states will decline slightly to 79 percent by 1990. However, if Nebraska shipments are included, the concentration of export shipments originating in these six states is estimated at almost 87 percent of total 1990 corn exports.

Movements of soybeans to export regions

There is considerable difference between the modal split of total soybean export shipments as projected by this study and the modal split as determined by Leath, Hill, and Fuller (LHF) [26]. As presented in Table 60, LHF attribute 23.1 percent of soybean export shipments to rail and 61.1 percent to barge. In this analysis, the rail share increases to

Table 60. Base solution soybean flows to export regions by originating state and mode in millions of bushels

Originating state	Export region	Transport mode: Rail	Barge	Truck	Total
Alabama	Gulf	4.65	0	24.66	29.31
Arkansas	Gulf	0	17.10	0	17.10
Florida	Gulf	9.94	0	0	9.94
Georgia	Atlantic	2.48	0	6.44	8.92
	Gulf	14.07	0	0	14.07
Illinois	Gulf	25.95	155.63	0	181.58
	Lakes	0	0	1.95	1.95
Indiana	Atlantic	38.22	0	0	38.22
	Gulf	0	15.38	0	15.38
Iowa	Gulf	55.87	102.30	0	158.17
	Pacific	17.24	0	0	17.24
Kentucky	Gulf	0	25.99	0	25.99
Louisiana	Gulf	0	14.48	76.67	91.15
Michigan	Atlantic	30.87	0	0	30.87
Minnesota	Gulf	44.84	64.73	0	109.57
	Lakes	0	0	18.90	18.90
Mississippi	Gulf	26.76	11.02	15.73	53.51
Missouri	Gulf	0.01	86.05	0	86.06
Nebraska	Gulf	6.14	5.69	0	11.83
	Pacific	12.44	0	0	12.44
North Carolina	Atlantic	3.93	0	16.24	20.17
Ohio	Atlantic	81.82	0	0	81.82
	Gulf	0	31.77	0	31.77
	Lakes	0.25	0	0	0.25
South Carolina	Atlantic	3.87	0	5.27	9.14
Tennessee	Gulf	47.47	0	0	47.47
Texas	Gulf	0	0	14.62	14.62
Wisconsin	Lakes	0	0	9.14	9.14
All States	Gulf	235.70	530.14	131.68	897.52
	Atlantic	161.19	0	27.95	189.14
	Lakes	0.25	0	29.99	30.24
	Pacific	29.68	0	0	29.68
Total		426.82	530.14	189.62	1,146.58
1990 Percent of Total		37.2	46.2	16.6	100.0
1977 Percent of Total[a]		23.1	61.1	15.8	100.0

[a] Source: [26].

37.2 percent while the barge share declines to 46.2 percent of total shipments.

The increase in the rail share is attributable to two factors. First, by 1990 an increased share of total soybean exports is projected to originate in Minnesota and Nebraska. In LHF these two states account for 5.4 percent of total soybean export shipments. In this analysis, approximately 11.7 percent of soybean shipments originate in these two states. Forty-one percent of the estimated 1990 soybean shipments originating in Minnesota are transported in multiple car trains. LHF estimate that rail shipments account for only 14 percent of the total 1977 soybean shipments originating in Minnesota. Similarly the rail share of export shipments originating in Nebraska increases from 60 percent in LHF to about 77 percent in this study. Secondly, estimated 1990 rail shipments of soybeans to Pacific Northwest account for approximately 7 percent of total rail shipments (3 percent of all soybean export shipments). These soybeans are transported on multiple-car rates from Iowa and Nebraska. These rates were not available during the 1977 period studied by LHF. In LHF, rail shipments to Pacific Northwest ports account for less than 1 percent of total soybean rail shipments and only about 0.2 percent of total soybean exports.

Movements of wheat to export regions

As is the case with soybean flows, this analysis indicates a greater percentage of wheat rail movements to export regions and a smaller barge share than does Leath, Hill, and Fuller [27]. Table 61 presents the

Table 61. Base solution wheat flows to export regions by originating state and mode in millions of bushels

Originating state	Export region	Transport mode: Rail	Barge	Truck	Total
Arkansas	Gulf	0	26.38	0	26.38
California	Pacific	0	0	54.82	54.82
Colorado	Pacific	42.32	0	0	42.32
Idaho	Pacific	57.36	11.87	0	69.23
Illinois	Gulf	1.58	25.11	0	26.69
	Lakes	0.09	0	0	0.09
Indiana	Atlantic	21.66	0	0	21.66
Kansas	Gulf	160.96	33.61	0	194.57
	Pacific	18.44	0	0	18.44
Michigan	Atlantic	6.81	0	0	6.81
	Lakes	0	0	3.75	3.75
Minnesota	Gulf	0.08	12.58	0	12.66
	Lakes	52.28	0	48.10	100.38
Missouri	Gulf	0	62.38	0	62.38
Montana	Pacific	106.02	49.29	0	155.31
Nebraska	Gulf	16.68	6.17	0	22.85
	Pacific	43.78	0	0	43.78
North Dakota	Lakes	153.94	0	52.64	206.58
	Pacific	32.57	0	0	32.57
Ohio	Atlantic	48.44	0	0	48.44
	Gulf	0	0.87	0	0.87
Oklahoma	Gulf	248.99	0	0	248.99
	Gulf	0	25.90	0	25.90
Oregon	Pacific	16.73	14.33	17.60	48.66
South Dakota	Gulf	0	17.40	0	17.40
	Pacific	4.65	0	0	4.65
Texas	Gulf	104.12	0	0	104.12
Washington	Pacific	1.71	105.02	26.06	132.79
All States	Gulf	532.41	210.40	0	742.81
	Atlantic	76.91	0	0	76.91
	Lakes	206.31	0	104.49	310.80
	Pacific	323.58	180.51	98.48	602.57
Total		1,139.21	390.91	202.97	1,733.09
1990 Percent of Total		65.7	22.6	11.7	100.0
1977 Percent of Total[a]		58.0	29.4	12.6	100.0

[a] Source: [27].

wheat flows to export regions by state as projected in this analysis. The five leading wheat producing states in 1977 and 1990 (Kansas, North Dakota, Oklahoma, Minnesota and Montana) account for 48 percent of total wheat production in 1977. By 1990, it is projected that these states will account for approximately 52 percent of total wheat production. Given the absence of barge competition in these wheat producing states, and the multiple-car rate structure included in the 1990 analysis[1] the rail share can be expected to increase.

The relative share of barge traffic between the two major river segments remains nearly constant between 1977 and 1990. In 1977 the Mississippi River System commanded a 53.2 percent share of total wheat barge shipments. The Columbia-Snake River accounted for 46.8 percent of the total barge shipments on these two rivers. In 1990, the Mississippi River accounts for 53.8 of total barge shipments of wheat. The Columbia-Snake accounts for the residual 46.2 percent.

Multiple car rail shipments to export regions

Rail shipments of corn, soybeans and wheat to export regions are projected for 25 states. As Table 62 indicates, only 12 of these states have access to multiple-car rate structures. Of the total bushels

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[1] Multiple car rates only recently became effective in the Northern Plain States to Pacific Northwest and Lake Ports. The first such rate was instituted by the Union Pacific in 1979.

Table 62. Rail movements of grain to export regions by originating state and shipment size in millions of bushels[a]

Originating state	Export region	Size of shipment 100-125	65-75	50-55	25-26	Single	Total
Alabama	Gulf	0	0	0	0	4.65	4.65
Colorado	Pacific	0	0	0	0	42.32	42.32
Florida	Gulf	0	0	0	0	10.97	10.97
Georgia	Atlantic	0	0	0	0	2.48	2.48
	Gulf	0	0	0	0	16.14	16.14
Idaho	Pacific	0	0	0	23.28	17.27	40.55
Illinois	Atlantic	11.05	0	0	0	0	11.05
	Gulf	149.07	0	0	0	3.16	152.23
	Lakes	0	0	0	0	0.09	0.09
Indiana	Atlantic	364.02	23.68	0	0	5.46	393.16
Iowa	Gulf	0	190.42	29.87	11.79	2.76	234.84
	Pacific	0	28.71	17.08	4.02	0	49.81
Kansas	Gulf	0	0	0	0	189.08	189.08
	Pacific	0	18.44	0	0	0	18.44
Michigan	Atlantic	89.97	0	0	0	3.23	93.20
Minnesota	Gulf	0	61.76	28.89	35.52	0	126.17
	Lakes	0	0	17.36	32.10	73.92	123.38
	Pacific	0	0	1.80	0	0	1.80
Mississippi	Gulf	0	0	0	0	26.76	26.76
Missouri	Gulf	0	0	0	0	0.01	0.01
Montana	Pacific	0	0	0	69.54	36.48	106.02
Nebraska	Gulf	0	8.22	17.51	0	103.51	129.24
	Pacific	0	71.23	91.16	39.59	67.96	269.94
North Carolina	Atlantic	0	0	0	0	3.93	3.93
North Dakota	Lakes	0	0	0	36.51	117.43	153.94
	Pacific	0	0	4.56	56.02	0	60.58
Ohio	Atlantic	231.66	30.76	0	0	0.30	262.72
	Lakes	0	0	0	0	0.25	0.25
Oklahoma	Gulf	0	0	0	0	248.99	248.99
Oregon	Pacific	0	0	0	0	16.73	16.73
South Carolina	Atlantic	0	0	0	0	3.87	3.87
South Dakota	Pacific	0	0	3.29	1.36	0	4.65
Tennessee	Gulf	0	0	0	0	47.47	47.47

[a] In general, rail shipments to the Gulf are 125, 75, 50 or 25 car shipments; rail shipments to the Atlantic are 100 or 65 car shipments; and rail shipments to the Pacific and Great Lakes ports are 75, 54, 52 or 26 car shipments.

Table 62. (continued)

Originating state	Export region	Size of shipment					Total
		100-125	65-75	50-55	25-26	Single	
Texas	Gulf	0	0	0	0	118.54	118.54
Washington	Pacific	0	0	0	0	1.71	1.71
All States	Gulf	149.07	260.40	76.27	47.31	772.04	1,305.09
	Atlantic	696.70	54.44	0	0	19.27	770.41
	Lakes	0	0	17.36	68.61	191.69	277.66
	Pacific	0	118.38	117.89	193.81	182.47	612.55
Total		845.77	433.22	211.52	309.73	1,165.47	2,965.71
Percent of Total		28.5	14.6	7.1	10.4	39.3	100.0

shipped by rail, 28.6 percent -- 846 million bushels -- are carried in either 100 or 125 car shipments. Only single car shipments account for a greater percentage -- 39.3 percent -- of the total bushels of export grain shipped by rail. The greatest percentage of total rail shipments is to Gulf ports. However, of multiple car shipments, the Atlantic ports receive a greater percentage than Gulf ports. Approximately 42 percent of the bushels shipped by multiple car trains are bound for the Atlantic ports (30 percent to Gulf ports).

Grain shipped to Atlantic ports by multiple car shipment originates in Indiana, Ohio, Michigan and Illinois. About 87 percent of all multiple car shipments to the Atlantic ports originate in Indiana and Ohio. Single car shipments to Atlantic ports are predominant in Southeastern United States. However, in these states -- Georgia, North Carolina, and South Carolina -- truck shipments remain the major means of moving grain to export. About 40 million bushels are carried by truck to export whereas only 10 million bushels are carried by single-car rail shipments in these three states.

Grain shipped to Gulf ports in multiple-car shipments originates in Illinois, Iowa, Minnesota and Nebraska. Approximately 44 percent of the multiple car shipments to Gulf ports originates in Iowa. Illinois and Iowa combine for a 72 percent share of these shipments. The greatest percentage of the bushels shipped by multiple car shipment to Gulf ports -- 77 percent -- is moved on the largest available train size in these states.[2] About 59 percent of the total rail shipments to Gulf ports are by single-car. Kansas, Nebraska, Oklahoma and Texas account for the bulk of these shipments.

All but three states that ship to Pacific ports have multiple-car rate structures available for these movements. It is not surprising, therefore, that multiple car shipments account for 70 percent of all rail shipments to Pacific ports. Single car shipments are the predominant means of shipping grain to Lake ports. However, as is the case with the Southeast flows to Atlantic ports, truck remains the principal means of transporting grain to Lake ports.

Barge shipments to export regions

During the three year period of 1978 to 1981, barge shipments of corn, soybeans and wheat on the inland waterways averaged about 1,694 million bushels [51] per year. Barge shipments of these grains during the 1989-1990 crop year are estimated at 2,369 million bushels, or an increase of 28.5 percent.

Table 63 presents the 1978-1981 average and projected 1990 barge shipments by crop and river segment. Barge shipments of corn are projected to increase by approximately 56 percent over the 1978-1981 average. The projected increase is attributable to the large growth of corn shipments on the Upper Mississippi. Total corn shipments on this segment averaged 364.5 million bushels during the 1978-1981 period.

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[2] 125-car in Illinois, 75-car in Iowa, Minnesota and Nebraska.

Table 63. Actual 1978-81 average[a] and estimated base solution barge shipments of corn, soybeans and wheat by river segment in millions of bushels

River	Corn		Soybeans		Wheat	
	1978-81 Average	1990	1978-81 Average	1990	1978-81 Average	1990
Upper Mississippi	364.5	782.4	108.5	202.3	62.1	39.1
Middle and Lower Mississippi	54.8	51.3	138.6	162.5	90.8	88.1
Illinois	408.8	461.9	86.7	71.3	11.3	3.6
Ohio	99.2	105.6	59.8	83.6	19.8	1.7
Missouri	3.7	2.1	4.7	10.4	31.8	52.1
Arkansas-Catoosa	b	0	b	0	b	25.9
Columbia/Snake	0	0	0	0	148.4	180.5
Total	931.0	1,448.3	398.2	530.1	364.6	390.9

[a] Source [52, 53, 54].

[b] Included in Lower Mississippi average.

Projected 1990 corn shipments on the Upper Mississippi equal 782.4 millions bushels, or an increase of 45.0 percent.[3] Moderate increases in barge corn shipments are projected for the Illinois and Ohio Rivers.

Total 1990 soybean shipments are projected to increase by 33 percent over the 1978-1981 average. Most of the increase is projected to be on the Upper Mississippi River. The 1990 soybean traffic on this segment is projected to increase by 86.5 percent over the 1978-1981 average. A sizeable increase of 17.2 percent is projected for soybean shipments on the Middle and Lower Mississippi. Approximately 24 million bushels is the expected gain for the Ohio River. Illinois River shipments of soybeans are down slightly.

Total 1990 barge shipments of wheat are projected to be about 7.2 percent above the 1978-81 average shipments by barge. This relatively small projected growth in barge movements is due to several factors: 1) much of the wheat is produced in regions located away from the inland waterways, 2) the high level of 1978-81 barge shipments were partially caused by rail car shortages and 3) the current rail car surpluses and the introduction of low cost unit train rates on wheat to West Coast and Great Lakes ports has made the inland waterways less competitive on wheat movements. Only the Missouri and the Columbia-Snake Rivers are projected

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[3] Although the 1990 projection may seem to be large, barge shipments on the Upper Mississippi were almost 500 million bushels during the 1980-1981 crop year [54]. Secondly, between 1978 and 1981 barge shipments on this segment increased an average 94 million bushels per year [51].

to have a greater volume of wheat barge shipments by 1990. Both of these rivers are located close to major wheat producing areas.

Table 64 presents the total projected 1990 bushels of grain shipped on the inland waterways and percentage shipments originating by state on each river segment. In total, 15 states originate grain shipped on the Mississippi River System. Four states originate grain shipped on the Columbia-Snake River System. Illinois ships the greatest quantity -- 713 million bushels on the Mississippi River and tributaries. Illinois has access to the Upper and Middle Mississippi, Illinois and Ohio Rivers. The second leading state to utilize barges is Iowa -- 667 million bushels. Together, Illinois and Iowa account for 66 percent of all grain shipped on the Mississippi River and tributaries. Wheat shipments on the Columbia-Snake River originate in 4 states. About 58 percent -- 105 million bushels -- is from Washington. An additional 50 million bushels of wheat originates in western Montana.

Sixty-four percent of the grain shipped on the Upper Mississippi River (72 percent of corn, 48 percent of soybeans) originates in Iowa. Approximately 41 percent of the 661 million bushels on the segment from Iowa are delivered to barge terminals by multiple-car rail shipments. In total, 28 percent of all barge shipments from the six states that ship on the Upper Mississippi River are combined rail-barge movements.

Middle Mississippi River barge shipments originate in three states. Lower Mississippi barge shipments originate in three states. Almost 57 percent of all shipments on the Ohio River originate in Indiana. Illinois, Kentucky and Ohio also originate grain that travels the Ohio.

Table 64. Projected 1990 bushels of corn, soybeans, and wheat shipped on the inland waterways and percentage bushels by state

River	Million bushels shipped	State and percentage[a]
Upper Mississippi	1,023.9	Iowa (64.5), Minnesota (22.2), Illinois (5.0), Missouri (4.2), Wisconsin (2.3), South Dakota (1.7)
Middle Mississippi	232.9	Illinois (53.2), Missouri (40.4), Kentucky (6.4)
Lower Mississippi	69.0	Arkansas (63.0), Louisiana (21.0), Mississippi (16.0)
Illinois	536.8	Illinois (100.0)
Ohio	235.8	Indiana (56.6), Illinois (24.8), Ohio (13.9), Kentucky (4.7)
Missouri	64.6	Kansas (52.0), Missouri (19.0), Nebraska (18.4), Iowa (10.5)
Arkansas	25.9	Oklahoma (100.0)
Total Mississippi System	2,188.9	Illinois (32.5), Iowa (30.5), Minnesota (10.4), Missouri (6.8), Indiana (6.1), Arkansas (1.9), Kansas (1.5), Ohio (1.5), Kentucky (1.2), Oklahoma (1.2), Wisconsin (1.1), South Dakota (0.7), Louisiana (0.7), Nebraska (0.5), Mississippi (0.5)
Columbia-Snake System	180.5	Washington (58.2), Montana (27.3), Oregon (7.9), Idaho (6.7)

[a] Percentage of total shipments on river segment in parentheses.

Kansas wheat accounts for 52 percent of Missouri River traffic. The Illinois and Arkansas Rivers are supplied by one state each.

<u>Grain movements from export to foreign demand regions</u>

Total 1990 corn, soybean, and wheat exports are projected at 5,866 million bushels. As presented in Table 65, Gulf ports originate 60.4 percent of total grain exports. The Atlantic, Lakes, and Pacific ports originate 13.7, 11.6 and 14.3 percent of grain exports respectively. The Far East is projected to be the leading grain importing region by 1990 -- 32.1 percent. Western and Eastern Europe (including USSR) each demand about 26 percent of U.S. exports. The Middle East (including Africa) and South America (including Mexico and Central America) demand 6.8 and 8.3 percent of U.S. exports respectively. Compared to actual percentages by export port and importing region for 1980, as presented in Table 66, the model performs quite well. The largest error in port shares -- 3.7 percent -- occurs with shipments originating at Gulf ports. There are slight differences in the percentage share attributed to Lakes and Atlantic ports. The share of exports attributed to Pacific ports is virtually the same in both years.

By importing region, the 1990 projections estimate a larger share of export shipments for Eastern Europe (including USSR) and the Far East. Two factors account for these differences. First, the grain embargo on USSR grain shipments occurred during 1980. Second, expansion of trade with China, and renewed agreements with the USSR would indicate that exports to these regions may increase in the next decade.

Table 65. Projected 1990 corn, soybean, and wheat exports in millions of bushels and percent of exports shipped by export region and foreign demand region

Foreign demand region	1990 Exports		Export region			
	Total	Percent	Gulf	Atlantic	Lakes	Pacific
Western Europe	1,560	26.6	34.5	45.6	20.0	0
Eastern Europe[a]	1,539	26.2	95.5	0	4.5	0
Middle East[b]	396	6.8	0	23.7	76.3	0
Far East	1,883	32.1	55.6	0	0	44.4
South America[c]	488	8.3	100.0	0	0	0
	5,866	100.0	60.4	13.7	11.6	14.3

[a] Includes USSR.

[b] Includes Africa.

[c] Includes Mexico and Central America.

Table 66. Percent of 1979-1980 corn, soybean, and wheat exports shipped by export region and foreign demand region[a]

Foreign demand region	1980 Exports Percent	Export region Gulf	Atlantic	Lakes	Pacific
Western Europe	37.1	63.6	20.2	16.2	0
Eastern Europe[b]	18.9	69.4	17.7	8.4	4.5
Middle East[c]	4.8	56.1	9.0	27.2	7.7
Far East	25.5	47.2	2.8	1.8	48.2
South America[d]	13.7	92.6	0.6	0	6.8
Total	100.0	64.1	12.1	9.4	14.4

[a] Source [54].

[b] Includes USSR.

[c] Includes Africa.

[d] Includes Mexico and Central America.

Exports from individual export regions to foreign demand regions in the computer solutions are based upon the assumptions that ocean rates remain constant over the entire time period, import demand by region is fixed and simultaneously satisfied by time period, and shippers simultaneously are motivated to minimize the total cost of all shipments. Given these rather restrictive assumptions, it is not surprising that some differences exist between the projected 1990 (Table 65) and actual 1980 (Table 66) percentage shipments by export and importing region. The most significant error occurs with shipments to Western Europe. The predicted Gulf share overestimates the actual share of shipments by almost 30 percent. Similarly, the predicted Atlantic share is underestimated by a like amount. The port share predicted for Middle East shipments differ from actual shares. However, the Middle East accounts for only about 5 percent of total U.S. exports in 1990. The port shares predicted for shipments to Eastern Europe, the Far East, and South American shipments are very reasonable given the actual 1979-1980 percentages.

1990 User Charge Solutions

Systemwide cost and taxes collected

The total cost and the user taxes collected in transporting corn, wheat and soybeans under the base solution and each user charge scenario for 1990 is presented in Table 67. Under the fuel tax scenario, the increase in the total cost of transporting corn, wheat, and soybeans caused by user charges is about $70.4 million. The combination

Table 67. Estimated total grain transportation and handling costs and user taxes collected by type of user charge, in millions of dollars, 1990

Solution	Total cost	Change in total cost	Taxes collected	Taxes collected as a percent of change in cost
Base	$8,352.7	---	---	---
Fuel Tax: 38.1¢/gallon	8,423.1	$70.4	$60.7	86
Combination Fuel-Segment Tax	8,421.6	69.2	59.3	86
Segment Tax: No Railroad Response	8,429.0	76.3	65.5	86
Segment Tax: 50 Percent Rail-road Response	8,453.9	101.2	64.8	64
Segment Tax: 100 Percent Rail-road Response	8,472.2	119.5	67.0	56

fuel-segment tax results in a total cost increase of about $69.2 million. The segment tax with no rail response results in a total cost increase of $76.3 million. Increased costs due to the 50 and 100 percent rail rate increases are $101.2 and $119.5 million respectively. In these two scenarios, both rail and barge export shipments originating in water competitive areas are transported at higher rates.

The fuel tax generates about $60.7 million of tax revenue whereas the combination tax and the segment tax generate $59.3 and $65.5 million respectively. In these three solutions, which assume no railroad rate response, 86 percent of the change in total cost is attributable to the collected taxes. The remaining 14 percent of indirect costs are caused by changes in transport modes and origin-destination combinations. Indirect costs increase considerably when rail rates increase in response to user charges. About $36.4 and $52.5 million of indirect costs to the shippers are collected by competing modes when railroad rates are increased by 50 and 100 percent of the user tax. In addition to this significant increase in indirect costs, the tax generated from grain shipments increase slightly over that generated by the segment tax - no response solution, even though the origin-specific tax levels are lower. Table 68 will explain why this is so. In particular, consider the bushels of grain hauled by barge. In the segment tax - no response solution, 1,959 million bushels are hauled by barge. As railroads respond to the user tax by increasing rates, barge traffic increases. In effect, the lower tax levels combined with a larger taxable barge shipment base generates an increased level of tax revenue.

Table 68. Estimated total and per bushel user taxes collected by type of user tax, 1990

Solution	User taxes collected	Bushels of grain hauled by barge	User taxes in cents per bushel
Fuel Tax: 38.1¢/gallon	$60,667,006	1,960,390,000	3.10
Combination Fuel-Segment Tax	59,304,773	1,981,170,000	2.99
Segment Tax: No Railroad Response	65,537,831	1,959,860,000	3.35
Segment Tax: 50 Percent Railroad Response	64,786,088	2,019,600,000	3.21
Segment Tax: 100 Percent Railroad Response	67,030,982	2,118,120,000	3.19

Table 68 is also instrumental in comparing the two types of tax structure considered in this analysis. The segment tax with no rail response causes the greatest decline in barge shipments from the base solution results.[4] Simultaneously, this tax generates the highest level of tax revenue from grain shipments given no rail response. Consequently, the weighted average per bushel tax -- equal to taxes collected divided by bushels shipped -- is the highest. The average tax generated in the segment tax with no response solution is 3.35 cents per bushel. The fuel tax results in an average per bushel tax of 3.10 cents. In the rail response solutions the average tax generated is equal to 3.21 and 3.19 cents per bushel for a 50 and 100 percent rail response respectively.

An additional point to consider is that these per bushel taxes collected are lower than the level of taxes imposed as presented in Tables 57 and 58. There are two reasons why the average taxes collected are lower than the taxes imposed. First, the high taxes imposed cause some high taxed grain to be diverted to railroads. Secondly, the average tax collected is a weighted average tax collected from grain which is not diverted from barges. Thus, the average tax collected will be lower than the average tax imposed because the high tax grain will not be included in the collected taxes.

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[4] As indicated on page 187, barge shipments equal 2,369 million bushels in the base solution.

Modal shares, revenues and average transport costs

Table 69 shows the estimated bushels of export corn, wheat, and soybeans transported by barge, truck, and rail. Total barge shipments in the 1990 base solution are projected to be about 2.37 billion bushels. This is about 22.1 percent above the record 1.94 billion bushels transported by barge during April 1, 1980 to March 31, 1981. The projected 1990 barge bushels are 41.1 percent above the 1.68 billion bushels transported by barge from April 1, 1979 to March 31, 1980 [53].

Barge shipments decline under all user charge scenarios. Assuming no railroad rate response, the fuel tax and the segment tax result in a diversion of 17.3 percent of base traffic to railroads and trucks. The combination fuel-segment tax causes a diversion of 16.4 percent to other modes. In the fuel and segment tax scenarios, total barge shipments decline to about 1.96 billion bushels. This is approximately equal to the record barge shipments of 1980-81 and it represents an increase of approximately 16.7 percent above the 1979-80 levels. Barges regain about 60 and 159 million bushels of traffic if railroad rates are increased by 50 and 100 percent of the segment tax respectively.

Direct rail shipments to export ports in 1990 under the base solution are projected to be about 2.79 billion bushels. This is 10.3 percent above the 2.54 billion bushels of all grains shipped in 1980 [2]. Direct rail shipments to export ports increase under all user charge scenarios as user charges shift grain to direct railroad and truck movements. Export bound rail shipments increase between 9.4 and 10.7 percent under the segment and fuel tax scenarios with no railroad rate response.

Table 69. Estimated bushels and percent change in export corn, wheat and soybeans transported by truck-barge, rail-barge, barge, rail and truck, millions of bushels, by computer solution, 1990

Mode	Base solution	Fuel tax	Segment tax	Segment Tax: No railroad response	Segment Tax: 50 Percent railroad response	Segment Tax: 100 Percent railroad response
Truck-barge						
Bushels	2,078.5	1,812.1	1,836.0	1,830.7	1,873.9	1,932.9
Percent change	---	(-12.8)	(-11.7)	(-11.9)	(-9.8)	(-7.0)
Rail-barge						
Bushels	290.8	148.3	145.1	129.1	145.8	185.3
Percent change	---	(-49.0)	(-50.1)	(-55.6)	(-49.8)	(-36.3)
Total barge						
Bushels	2,369.3	1,960.4	1,981.2	1,959.9	2,019.7	2,118.1
Percent change	---	(-17.3)	(-16.4)	(-17.3)	(-14.8)	(-10.6)
Rail (direct)						
Bushels	2,785.8	3,084.9	3,048.1	3,048.1	2,978.3	2,840.2
Percent change	---	(10.7)	(9.4)	(9.4)	(6.9)	(1.9)
Truck (direct)						
Bushels	710.6	819.7	835.8	857.1	867.2	906.8
Percent change	---	(15.4)	(17.6)	(20.6)	(22.0)	(27.6)

Railroads then begin to lose some of their new traffic if railroad rates increase in response to user charges. About 70 million bushels shift to barges and trucks if railroads increase their rates by 50 percent of the user tax. If railroads respond by increasing rates by 100 percent of the user tax, 208 million bushels are shifted to barges and trucks. This reduces the gains in rail traffic over base solution rail traffic levels, to 6.9 and 1.9 percent, respectively. Of the 70 million bushels lost by railroads if rail rates are increased by 50 percent of the segment tax, 86 percent shifts to barges and 14 percent to trucks. Of the 208 million lost if rail rates are increased by 100 percent of the segment tax, 76 percent shifts to barges and 24 percent to trucks.

Railroad shipments to barge loading elevators decline under all user charge scenarios. Rail shipments to these elevators decline by about 49 percent under the fuel tax and by over 55 percent under the segment tax with no railroad response. The losses to barge loading elevators moderate to 36 percent if export rail rates are increased by 100 percent of the segment taxes. The net effects of the railroad gain in direct traffic to export ports and the losses in traffic to barge loading elevators is that total rail traffic increases by 5.1 percent under the fuel tax and 3.3 percent under the segment tax with no rail rate response. If rail rates are increased by 50 and 100 percent of the segment tax, the net effect of the railroad gains and losses in traffic is that net rail bushels increase 1.5 percent over the base solution levels if rail rates are increased 50 percent but decline by 1.6 percent of the base solution if rates are increased 100 percent of the segment tax.

Total export bound truck shipments increase under all user tax scenarios. The smallest increase in truck traffic is 15.4 percent under the fuel tax; the largest increase is almost 27.6 percent under the segment tax and a 100 percent rail rate response. However, truck traffic to barge loading elevators declines under all user tax scenarios. The largest reductions in truck traffic are under user taxes with no rail rate response. If rail rates increase, trucks, along with barges, regain part of their lost traffic. The net effect of the truck gains and losses are as follows:

Tax Scenario	Net gain(+) or loss(-) in truck grain traffic
Fuel tax	-157 million bushels
Fuel-segment tax	-116 million bushels
Segment tax	
No rail response	-101 million bushels
50 percent rail response	-48 million bushels
100 percent rail response	+51 million bushels

Thus, total truck bushels decline under all user tax scenarios except under the segment tax with a 100 percent railroad rate response.

Table 70 presents the estimated 1990 barge, rail, truck and ocean vessel revenues for each user charge scenario. These estimated revenues exclude user taxes and transfer costs. The estimates also combine the net effect of reduced rail-barge and truck-barge traffic with gains in rail and truck export bound traffic.

Table 70. Estimated rail, truck, barge and ocean vessel revenues for export grain by computer solution in millions of dollars, 1990

Solution	Barge		Railroad		Truck		Ocean vessel	
	Revenue	Percent change	Revenue	Percent change	Revenue	Percent change	Revenue	Percent change
Base	$725	---	$1,668	---	$391	---	$4,369	---
Fuel tax	575	-20.7	1,794	7.5	396	1.3	4,419	1.1
Fuel-segment tax	578	-20.3	1,795	7.6	407	4.1	4,424	1.3
Segment tax no railroad response	569	-21.5	1,769	6.1	416	6.4	4,432	1.4
Segment tax 50 percent railroad response	587	-19.0	1,757	5.3	421	7.7	4,435	1.5
Segment tax 100 percent railroad response	627	-13.5	1,680	0.7	452	15.6	4,452	1.9

The greatest losses in barge revenue occur with the segment charge with no rail rate response. Under this solution, barge companies lose about 21.5 percent of their 1990 base solution revenues. They lose about 20.7 percent of their 1990 base solution revenues under the fuel tax and 20.3 percent under the combination fuel-segment tax. They regain part of their lost revenue if rail rates increase by 50 and 100 percent of the segment tax. Total barge revenue is 19.0 and 13.5 percent below the base revenues under these solutions. Barge companies regain this revenue because higher rail rates drive some grain back to the rivers. The higher tax revenues from the increased grain traffic result in lower user taxes required to recover the 100 percent of OMRC. The lower per unit tax further increases the amount of barge grain traffic.

Rail revenues for export bound traffic are above base solution revenues under all user charge scenarios. However, the rate of growth in rail revenues is not as high as the rate of growth of bushels of direct rail shipments. The difference in these growth rates represents a loss in rail shipments to barge loading facilities when user taxes are imposed. Railroads gain 6.1 percent in revenues under the segment tax with no rail rate response; they gain 10.7 percent in bushels hauled direct to exports under the same solution. Railroad revenues increase only 5.3 and 0.7 percent above the base solution if rail rates are increased by 50 and 100 percent of the segment tax because the higher rail rates cause a shift of grain to trucks and barges.

Trucks incur net increases in revenue under all 1990 user tax scenarios. The gains in revenues from export bound grain shipments more than offset the losses in truck traffic to barge loading points.

Ocean vessel revenues increase 1.1 percent above the base solution under the fuel tax and 1.9 percent under the segment tax with a 100 percent rail rate response. Ocean vessel revenues rise under all user tax scenarios because the user taxes and rail rate increases to Gulf, East Coast, and West Coast ports will result in more grain moving to Great Lakes ports.

Table 71 presents the 1990 average cost for transporting corn, wheat, and soybeans by barge, rail, truck, ocean vessel, and for the entire system. This table includes all the costs of export and domestic grain shipments in the model as well as all collected user taxes. The average cost per bushel to transport these grains by barge in the base solution is 48.8 cents per bushel. The average cost is slightly higher under the fuel tax and the segment tax with a 100 percent rail rate response but it declines under the combination fuel-segment tax and segment tax with no rail rate response. Two forces tend to moderate average barge costs. First, the user taxes tend to cause the high cost barge movements to shift to rail or truck. This lowers the average barge cost per bushel. Secondly, if railroad rates increase by 50 and 100 percent of the segment tax, the higher rail rates force some but not all of previously diverted grain back to barges. The increased barge traffic lowers the per bushel user tax required to recover the fixed cost of OMRC.

Table 71. Estimated average and percent change in transportation and handling cost in cents per bushel by barge, railroads, truck, ocean vessel and for the total system, by type of user charge, 1990[a]

Solution	Barge[b]	Rail	Truck	Ocean	Total system
Base	48.8¢	59.8¢	19.1¢	74.5¢	98.5¢
Fuel tax: 38.1¢/gallon	48.9 (0.2)	59.2 (-1.0)	20.7 (8.4)	75.3 (1.1)	99.4 (0.9)
Combination fuel-segment tax	48.6 (-0.4)	59.4 (-0.7)	20.9 (9.4)	75.4 (1.2)	99.3 (0.8)
Segment tax: no railroad response	48.5 (-0.6)	59.5 (-0.5)	21.1 (10.5)	75.6 (1.5)	99.4 (0.9)
Segment tax: 50 percent rail-road response	48.4 (-0.8)	60.2 (0.7)	21.2 (11.0)	75.6 (1.5)	99.7 (1.2)
Segment tax: 100 percent rail-road response	49.7 (1.8)	60.0 (0.3)	21.4 (12.0)	75.9 (1.9)	99.9 (1.4)

[a] Includes handling costs and user charges where applicable.

[b] Includes truck-barge and rail-barge revenues.

There is very little change in average rail costs per bushel for the three user charges with no rail rate response. Grain shifting from barge to rail has little effect on average rail costs. Moreover, a significant portion of the increased rail traffic moves shorter distances to Lakes ports. The lower rates on these shorter distance rail movements tend to hold down average rail costs.

Average rail costs increase 0.4 and 0.2 cents per bushel when rates are increased by 50 and 100 percent of the segment tax. The higher rates apply to Gulf, East Coast, and Pacific export grain. These increases, averaged with all other export and domestic rail grain, result in only a small increase in average rail costs with a rail rate increase of 100 percent of the segment tax.

The average truck cost is 19.1 cents per bushel under the base solution. Truck costs increase under all user tax scenarios. The user taxes significantly reduce the amount of relatively short distance trucking to barge loading elevators; however, the taxes increase the amount of longer distance truck shipments to export ports. Therefore, average truck costs increase between 8.4 to 12 percent in the user charge scenarios.

Ocean freight costs average 74.5 cents per bushel under the base solution. The average ocean cost per bushel increases between one and two percent under all solutions. These increases are due mainly to shifts to the relatively high cost Lake ports under each user charge scenario.

The average system-wide grain transportation system cost is 98.5 cents per bushel under the base solution. The 98.5 cent per bushel cost is lower than the sum of barge-ocean and rail-ocean costs because the total system includes shipments to feed manufacturers and industrial processors that have no ocean freight costs. The average cost increases slightly under all user tax scenarios. The largest increase is 1.4 percent -- also 1.4 cents per bushel -- if rail rates are increased 100 percent of the segment tax. The impact of user charges is relatively small when averaged over the entire system.

Bushels of corn diverted from river segments

Table 72 shows the bushels of corn shipped by barge on each river. It also presents the percent of corn diverted to other modes by user charges. In total, 1,448.3 million bushels of corn are shipped on the inland waterways in the base solution. The Mississippi River System accounts for all corn barge shipments. Diversions of corn to other modes induced by user charges range from 16.1 percent under the fuel tax to 9.8 percent under the segment tax with a 100 percent rail response.

The estimated diversion of corn on the Upper Mississippi is 21.6 percent under the fuel tax and 23 percent each under the combination fuel-segment tax and the segment tax with no rail rate response. Diversion of corn on the Upper Mississippi River declines slightly to 22.2 and 16.0 percent under the segment tax with a 50 and 100 percent rail rate response. In the fuel tax solution, a total of 168 million bushels are diverted. Sixty-two percent of this diversion is from rail-barge combination movements. In Central Iowa, the corn shipped by rail-barge is diverted to multiple-car Gulf shipments. In Northwest Iowa, the corn is

Table 72. Estimated 1990 corn barge shipments and percent diverted by river and computer solution, in thousands of bushels

River	Base solution	Fuel tax	Fuel-segment tax	Segment tax: No railroad response	Segment tax: 50 Percent railroad response	Segment tax: 100 Percent railroad response
Upper Mississippi	782,440	613,680 (21.6)	598,440 (23.0)	598,440 (23.0)	608,890 (22.2)	643,740 (17.7)
Middle and Lower Mississippi	51,260	31,200 (39.1)	31,200 (39.1)	31,200 (39.1)	51,250 (0.0)	51,260 (0.0)
Illinois	461,930	442,320 (4.2)	442,310 (4.2)	442,320 (4.2)	458,840 (0.7)	458,830 (0.7)
Missouri	2,140	2,140 (0.0)	2,140 (0.0)	2,140 (0.0)	2,140 (0.0)	2,140 (0.0)
Ohio	150,560	125,550 (0.0)	150,560 (0.0)	150,560 (0.0)	150,560 (0.0)	150,560 (0.0)
Snake/Columbia	0	0	0	0	0	0
Arkansas-Catoosa	0	0	0	0	0	0
Total	1,448,330	1,214,890 (16.1)	1,224,650 (15.4)	1,224,660 (15.4)	1,271,680 (12.2)	1,306,520 (9.8)

diverted to domestic shipments. This corn displaces base solution domestic shipments from other regions. The displaced corn is then shipped to the Gulf. An additional 31 percent of the corn diverted under the fuel tax originates in Minnesota. Corn from Minnesota transported by barge in the base solution is diverted to Lake Ports for export. The corn originating in Northwest Iowa and Minnesota does not return to barge shipments when rail rates increase. The Lakes remain in a favorable export position for Minnesota corn because Lake rail rates are not increased in the rail response solution. All rail-barge combination shipments originating in Central Iowa in the base solution and diverted in the no rail response solutions, return to the river when rail rates are raised to 100 percent of the segment tax.

About 20 million bushels of corn are diverted from the Middle and Lower Mississippi River under the user charge scenarios with no rail rate response. However, this corn reverts back to the river if rail rates are increased 50 and 100 percent of the segment tax. About 4 percent of the Illinois River corn diverts to Lake shipment under the three user charge scenarios with no rail rate response. Most of this corn reverts back if rail rates are increased. The only diversion on the Ohio River -- 16 percent to Atlantic ports -- occurs under the fuel tax.

There is no diversion of corn on the Missouri River. However, the only corn moving on the Missouri River under all computer solutions is that amount delivered directly to river elevators by farmers. Under all 1990 scenarios, the Missouri River is not competitive for corn that is received by a country elevator and then trucked to a river elevator to be loaded into barges. Thus, barge loading elevators on the Missouri River perform the same function as country elevators.

Bushels of soybeans diverted from river segments

Table 73 presents the bushels of soybeans shipped by barge on each river and the percent of soybeans diverted to other modes under each user charge scenario. In total, 530.1 million bushels of soybeans are shipped on the inland waterways in the base solution. Diversions of soybeans to other modes range from 19.8 percent under the fuel tax to 13.4 percent under the segment tax with a 100 percent rail response.

Soybean shipments on the Upper Mississippi account for 38 percent of total base solution soybean shipments. However, most of the soybean diversion caused by user charges occurs on the Upper Mississippi River. Assuming no rail rate response, 40 percent of the base solution barge soybean traffic is diverted to other modes under the fuel, combination fuel-segment and segment tax scenarios. Barges regain about 4.6 and 12 million bushels respectively if rail rates are increased 50 and 100 percent of the segment tax, but diversion remains at 34 and 37 percent. Under the fuel tax a total of 81.2 million bushels are diverted. Sixty-six percent of this diversion is Minnesota soybeans directed to Lake shipment. Thirty-four percent are rail-barge shipments in Iowa directed to single-car Gulf shipment. Similar diversions occur in the fuel-segment and segment tax solution with no rail response. As is the case with corn, there is partial return to the river of the rail-barge diversions as rail rates increase. However, the Minnesota soybeans do not return to

Table 73. Estimated 1990 soybean barge shipments and percent diverted by river and computer solution, in thousands of bushels

				Segment tax		
River	Base solution	Fuel tax	Fuel-segment tax	No railroad response	50 Percent railroad response	100 Percent railroad response
Upper Mississippi	202,340	121,130 (40.1)	121,450 (40.0)	121,450 (40.0)	126,130 (37.7)	133,590 (34.0)
Middle and Lower Mississippi	162,490	162,490 (0.0)	162,490 (0.0)	162,490 (0.0)	162,490 (0.0)	162,490 (0.0)
Illinois	71,270	71,270 (0.0)	71,270 (0.0)	65,980 (7.4)	71,270 (0.0)	71,270 (0.0)
Missouri	10,420	0 (100.0)	0 (100.0)	0 (100.0)	2,320 (77.7)	8,010 (23.1)
Ohio	83,620	70,220 (16.0)	83,610 (0.0)	83,610 (0.0)	83,610 (0.0)	83,610 (0.0)
Snake/Columbia	0	0	0	0	0	0
Arkansas-Catoosa	0	0	0	0	0	0
Total	530,140	425,110 (19.8)	438,820 (17.2)	433,530 (18.2)	445,820 (15.9)	458,970 (13.4)

river shipment. Soybean shipments originating in Illinois and Missouri on the Upper Mississippi River are not diverted in any tax solution.

No soybeans are diverted from the Middle and Lower Mississippi River. A relatively small amount is diverted to Lake shipment from the Illinois River under the segment tax with no rail rate response but this is regained when rail rates are increased. About 16 percent of the soybeans originating in Kentucky are diverted to domestic processing from the Ohio River under the fuel tax but none are diverted under any segment tax. These are low cost rivers and soybean traffic under the base solution originates close to the river.

The Missouri River loses all of its soybeans under the fuel tax, the combination fuel-segment tax, and the segment tax with no rail rate response. Soybeans are diverted to multiple-car shipments to the Pacific Northwest. It regains 23 and 77 percent of its base solution soybeans if railroads raise their rates by 50 and 100 percent of the segment tax. This suggests that the Missouri River will have difficulty competing for soybeans except when rail-barge relationships are near those in the base solution.

Catoosa, Oklahoma is the only originating point on the Arkansas River that is included in this analysis. All soybeans moving on the Arkansas River normally originate on the Lower Arkansas and White Rivers. These soybeans were included in the Lower Mississippi segment because of the short distance they would move on the Arkansas and White Rivers.

Bushels of wheat diverted from river segments

Table 74 shows the bushels of wheat shipped by barge from each river along with the percent of wheat diverted to other modes under each user charge scenario. In total, 390.9 million bushels of wheat are shipped on the inland waterways in the base solution. The Columbia-Snake accounts for 46 percent of all wheat barge shipments. Diversion of wheat to other modes induced by user charges range from 22.8 percent under the segment tax with no rail response to 9.8 percent under the segment tax with a 100 percent rail response.

The Upper Mississippi River is estimated to have about 29 percent of its wheat diverted to railroads and trucks under the fuel tax, about 36 percent under the combination tax and over three-fourths under all segment tax scenarios. This river does not regain its lost wheat traffic if rail rates are increased 50 and 100 percent. In the base solution, 76 percent -- 29.9 million bushels -- of the wheat shipped on the Upper Mississippi is shipped by rail-barge combination from Minnesota and South Dakota. Thirty-eight percent of these shipments are diverted to single-car Lake movements in the fuel tax solution. In the segment tax solutions, 100 percent of these rail-barge movements are diverted to Lake shipment. No wheat is diverted from the Middle and Lower Mississippi, Illinois, and Ohio Rivers under any user charge scenario.

The Missouri River loses slightly over half of its wheat traffic in all user charge scenarios except under the segment tax with a 100 percent rail rate response. The Arkansas River wheat traffic follows a similar pattern. Eighty-three percent of the base solution wheat traffic is

Table 74. Estimated 1990 wheat barge shipments and percent diverted by river and computer solution, in thousands of bushels

River	Base solution	Fuel tax	Fuel-segment tax	Segment tax: No railroad response	Segment tax: 50 Percent railroad response	Segment tax: 100 Percent railroad response
Upper Mississippi	39,110	27,840 (28.8)	25,150 (35.7)	9,130 (76.7)	9,130 (76.7)	9,130 (76.7)
Middle and Lower Mississippi	88,080	88,080 (0.0)	88,080 (0.0)	88,080 (0.0)	88,080 (0.0)	88,080 (0.0)
Illinois	3,560	3,560 (0.0)	3,560 (0.0)	3,560 (0.0)	3,560 (0.0)	3,560 (0.0)
Missouri	52,090	25,230 (51.6)	25,230 (51.6)	25,230 (51.6)	25,230 (51.6)	52,090 (0.0)
Ohio	1,660	1,660 (0.0)	1,660 (0.0)	1,660 (0.0)	1,660 (0.0)	1,660 (0.0)
Snake/Columbia	180,510	169,600 (6.0)	169,600 (6.0)	169,600 (6.0)	170,020 (6.0)	172,200 (4.6)
Arkansas-Catoosa	25,900	4,420 (82.9)	4,420 (82.9)	4,420 (82.9)	4,420 (82.9)	25,900 (0.0)
Total	390,910	320,390 (18.0)	317,700 (18.7)	301,680 (22.8)	302,100 (22.7)	352,690 (9.8)

diverted from the river in all but the 100 percent rail response solution. In both cases, the wheat shipments are diverted to single-car rail shipments to Gulf ports.

The Columbia River loses about 6 percent of its projected wheat traffic under all user charge scenarios except the segment tax with a 100 percent railroad rate response; it loses only 4.6 percent when rail rate increases match the segment tax. In each solution, almost all the diverted wheat originates in Central Washington. After user charges are imposed, this wheat travels to Pacific ports by single-rail shipment. Wheat shipments originating in Idaho and Montana are not diverted from the Columbia-Snake River. In effect, the recently established multiple-car rates have already diverted much of the Montana Columbia-Snake River traffic. For instance, the 1975 export shipments from the Great Falls, Montana area consisted of 40 percent truck-barge and 60 percent single-car shipments to Pacific Northwest ports. However, as reported in Baumel and Beaulieu [4], by 1982 truck-barge shipments have declined to about 5 percent of total shipments and direct multiple-rail car shipments account for the remaining 95 percent. This analysis incorporated many of these multiple-car rate structures available in the Northwest.

Grain shipped and taxes paid by state

Table 75 presents the number of bushels of corn, wheat, and soybeans shipped by barge from each state. It also shows the number and percent of total bushels diverted by user charges from barges to railroads and trucks. Illinois and Iowa originate almost 61 percent of all corn,

Table 75. Estimated bushels and percent of corn, wheat and soybeans diverted from barge shipments by state, 1990

State	Base solution	Fuel tax at 38.1 cents per gallon		Segment tax-no response		Segment tax 100% response	
	Bushels shipped by barge (000,000)	Bushels diverted from barges (000,000)	Percent of barge shipments diverted	Bushels diverted from barges (000,000)	Percent of barge shipments diverted	Bushels diverted from barges (000,000)	Percent of barge shipments diverted
Arkansas	43.5	0	0	0	0	0	0
Idaho	11.9	0	0	0	0	0	0
Illinois	770.7	44.6	5.8	49.9	6.5	5.3	0.7
Indiana	133.5	27.2	20.4	0	0	0	0
Iowa	667.5	142.4	21.3	143.4	21.5	86.4	12.9
Kansas	33.6	26.0	77.4	26.0	77.4	0	0
Kentucky	26.0	11.2	43.1	0	0	0	0
Louisiana	14.5	0	0	0	0	0	0
Minnesota	227.7	117.3	51.5	133.9	58.8	133.9	58.8
Mississippi	11.0	0	0	0	0	0	0
Missouri	149.7	0	0	0	0	0	0
Montana	49.3	0.4	0.8	0.4	0.8	0	0
Nebraska	11.9	6.6	55.5	6.6	55.5	0	0
Ohio	32.6	0	0	0	0	0	0
Oklahoma	25.9	21.5	83.0	21.5	83.0	0	0
Oregon	14.3	0	0	0	0	0	0
South Dakota	17.4	1.4	8.0	17.4	100.0	17.4	100.0
Washington	105.0	10.5	10.0	10.5	10.0	8.3	7.9
Wisconsin	23.5	0	0	0	0	0	0
Total	2369.4	409.0	17.3	409.5	17.3	251.3	10.6

wheat, and soybeans moving by barge in the base solution; Minnesota, Missouri, Indiana and Washington ship an additional 26 percent; the remaining 13 percent is shipped by 13 other states.

The largest diversions in the fuel tax solution occur in Iowa and Minnesota. These large shifts of 142.4 and 117.3 million bushels respectively, are in part, the result of the longer distances barges must travel on the Upper Mississippi and Missouri Rivers. These long distances place a heavier fuel tax burden on these shipments. In addition, these two states have well-developed unit grain train systems which make it cheaper to shift relatively large amounts of grain to another mode versus incurring the additional cost of the fuel user tax. About 51 percent of the Minnesota base solution barge grain and over 21 percent of the Iowa barge grain is diverted to rail or truck. Illinois, which has the largest amount of barge grain in the base solution, has only 5.8 percent of its barge grain diverted to other modes. This relatively small diversion of Illinois grain is due to: 1) low user charges on the Illinois River, 2) a large part of the Illinois grain is grown in areas close to either the Illinois, Upper Mississippi and Ohio Rivers which have no well developed competitive alternatives, and 3) Illinois barge grain travels fewer miles to Mississippi River export elevators than Iowa or Minnesota grain. The result is that the truck-barge combination rates with user charges are still relatively low for much of the Western Illinois grain.

Eight of the 19 states with barge shipments of corn, wheat, and soybeans have no diversion in the fuel tax solution.

While the remaining states ship only a small percent of total barge movements, several of these states have a high percent of their total barge shipments diverted by other modes. These states include Kansas, Kentucky, Nebraska and Oklahoma. Three of these states ship on the relatively high cost Missouri and Arkansas Rivers.

The diversions under the segment tax with no railroad rate response are similar to those under the fuel tax. The total diversion is 17.3 percent under the fuel tax and the segment tax solutions. Minnesota and Iowa experience greater diversion under the segment tax than under the fuel tax. Oklahoma, South Dakota and Kansas also have a high percent of their barge shipments diverted to other modes. These three states ship by barge on the relatively high cost Missouri and Arkansas Rivers. The diversion to other modes reduces the amount of tax paid by these states.

Total diversion under the segment tax with 100 percent rail rate response falls to 10.6 percent of total barge shipments in the base solution. South Dakota is the only state that has all of its barge grain diverted to other modes. Thirteen states have no diversion and Illinois has less than one percent diverted under the 100 percent rail rate response. The largest diversion in this solution occurs in Minnesota and Iowa.

Table 76 shows the taxes collected and percent of total user taxes paid by states. Under the fuel tax solution, Illinois ships 37 percent of the total barge grain and pays 34.7 percent of the total fuel taxes. However, Iowa and Minnesota pay more taxes relative to the amount of grain shipped. Iowa ships 26.8 percent of the barge grain and pays 32.4

Table 76. Total and percent of total user taxes collected by states, in thousands of dollars, 1990

State	Base solution	Fuel tax at 38.1 cents per gallon		
	Percent of total barge shipments	Percent of total barge shipments	Taxes collected	Percent of total taxes collected
Arkansas	1.8	2.2	$593	1.0
Idaho	0.5	0.6	339	0.6
Illinois	32.5	37.0	21,047	34.7
Indiana	5.6	5.4	2,464	4.1
Iowa	28.2	26.8	19,627	32.4
Kansas	1.4	0.4	379	0.6
Kentucky	1.1	0.8	248	0.4
Louisiana	0.6	0.7	115	0.2
Minnesota	9.6	5.6	5,156	8.5
Mississippi	0.5	0.6	88	0.1
Missouri	6.3	7.6	3,783	6.2
Montana	2.1	2.5	1,396	2.3
Nebraska	0.5	0.3	389	0.6
Ohio	1.4	1.7	1,014	1.7
Oklahoma	1.1	0.2	201	0.3
Oregon	0.6	0.7	164	0.3
South Dakota	0.7	0.8	805	1.3
Washington	4.4	4.8	1,757	2.9
Wisconsin	1.0	1.2	1,102	1.8
Total	100.0	100.0	60,662	100.0

Segment tax– no railroad response			Segment tax– 100% railroad response		
Percent of total barge shipments	Taxes collected	Percent of total taxes collected	Percent of total barge shipments	Taxes collected	Percent of total taxes collected
2.2	$339	0.5	2.1	$339	0.5
0.6	447	0.7	0.6	408	0.6
36.8	20,914	31.9	36.1	20,176	30.1
6.8	1,651	2.5	6.3	1,690	2.5
26.7	24,623	37.6	27.4	24,917	37.2
0.4	446	0.7	1.6	1,658	2.5
1.3	278	0.4	1.2	280	0.4
0.7	66	0.1	0.7	66	0.1
4.8	6,050	9.2	4.4	5,532	8.3
0.6	50	0.1	0.5	50	0.1
7.6	3,461	5.3	7.1	3,194	4.8
2.5	1,838	2.8	2.3	1,693	2.5
0.3	436	0.7	0.6	807	1.2
1.7	500	0.8	1.5	520	0.8
0.2	399	0.6	1.2	1,951	2.9
0.7	217	0.3	0.7	198	0.3
0.0	0	0.0	0.0	0	0.0
4.8	2,288	3.5	4.6	2,149	3.2
1.2	1,534	2.3	1.1	1,402	2.1
100.0	65,538	100.0	100.0	67,031	100.0

percent of the total fuel taxes. Minnesota ships 5.6 percent of the barge grain and pays 8.5 percent of the total fuel taxes. Iowa and Minnesota pay more taxes relative to the amount of grain shipped because they are located further distances from Baton Rouge, Louisiana. Missouri, on the other hand, ships 7.6 percent of the barge grain and pays 6.2 percent of the total fuel taxes. These four states -- Illinois, Iowa, Minnesota and Missouri -- ship 77 percent of all 1990 barge grain and pay 81.8 percent of the total fuel taxes. The remaining 15 states ship 23 percent of the barge grain and pay 18.2 percent of the fuel taxes.

Under the segment tax solution with no railroad rate response, Iowa pays 37.6 percent of the segment taxes but ships only 26.7 percent of the barge grain. Minnesota ships 4.8 percent of the total barge grain but pays 9.2 percent of the total segment taxes. Thus, Iowa and Minnesota pay a large percent of the total segment taxes collected relative to the amount of grain shipped because of the longer distances to Baton Rouge and the higher cost of the Upper Mississippi River. Illinois, on the other hand, ships 36.8 percent of the total barge grain but pays only 31.9 percent of the total segment taxes. A large portion of the Illinois grain is shipped on the lower cost Illinois and Ohio Rivers. Moreover, much of Illinois is located closer to Baton Rouge, Louisiana. The segment tax forces South Dakota grain to be diverted to truck and rail.

Grain movements from export to foreign demand regions

Table 77 presents the estimated percent change in total corn, wheat, and soybean exports by export port in 1990. The Gulf share declines

Table 77. Estimated 1990 percent of exports of corn, wheat and soybeans by port areas and solution

Solution	Port area				
	Lakes	Atlantic	Gulf	Pacific	Total
Base	11.6	13.7	60.4	14.3	100
Fuel tax	13.8	14.4	57.4	14.3	100
Fuel-segment tax	14.1	14.0	57.6	14.3	100
Segment tax no railroad response	14.5	14.0	57.2	14.3	100
Segment tax 50 percent railroad response	14.7	13.9	57.1	14.3	100
Segment tax 100 percent railroad response	15.4	13.9	56.7	14.1	100

three percentage points under the fuel tax scenario. Slightly larger losses occur under other user tax scenarios. The largest loss is 3.7 percentage points under the segment tax with a 100 percent rail rate response. The East Coast port share of total exports increase above the base level unless Gulf and East Coast port rail rates are increased 50 and 100 percent of the user charges. Great Lakes ports share of total exports would increase rather sharply as a result of the user charges under the assumption that rail rates to these ports do not increase with the user charges.

User charges have little net effect on the West Coast share of base solution exports. While user charges divert some wheat from the Columbia River, increased exports from the Upper Great Plains states to West Coast ports as a result of user charges create little change in the West Coast share of total exports. However, the West Coast share of total exports declines slightly if rail rates are increased 100 percent of the segment tax.

Table 78 presents the estimated bushels of corn, soybeans, and wheat and percent shipped from export regions to foreign demand regions in the base, fuel, segment-no response and segment-100 percent rail response solutions. By design, foreign demand in total and by regions is constant in all solutions. However, percentage shipped from U.S. export region to individual foreign demand regions varies by computer solution.

The most dramatic shift in export flows occurs in shipments to Eastern Europe. Gulf shipments to Eastern Europe decline by 105 bushels in the fuel tax solution, and almost 150 million bushels under the

Table 78. Estimated 1990 corn, soybean, and wheat exports in millions of bushels and percent of exports shipped by export region and foreign demand region in different computer solutions

Foreign demand region	Export region	Base	Fuel tax	Segment tax: No railroad response	Segment tax: 100 percent railroad response
Western Europe	Gulf	536.3 (34.5)	471.8 (30.2)	452.1 (30.0)	458.2 (29.4)
	Atlantic	712.3 (45.6)	752.3 (48.2)	728.2 (46.7)	718.9 (46.1)
	Lakes	311.4 (20.0)	335.9 (21.5)	379.7 (24.3)	382.9 (24.5)
Eastern Europe[a]	Gulf	1470.5 (95.0)	1365.6 (88.7)	1371.1 (89.1)	1322.3 (85.9)
	Lakes	68.6 (4.5)	173.5 (11.3)	167.9 (10.9)	216.8 (14.1)
Middle East[b]	Atlantic	93.8 (23.7)	93.8 (23.7)	93.8 (23.7)	93.8 (23.7)
	Lakes	301.9 (76.3)	301.9 (76.3)	301.9 (76.3)	301.9 (76.3)
Far East	Gulf	1047.2 (55.6)	1043.5 (55.4)	1043.5 (55.4)	1056.9 (56.1)
	Pacific	835.9 (44.4)	839.6 (44.6)	839.6 (44.6)	826.2 (43.9)
South America[c]	Gulf	487.9 (100.0)	487.9 (100.0)	487.9 (100.0)	487.9 (100.0)

[a] Includes USSR.

[b] Includes Africa.

[c] Includes Mexico and Central America.

segment tax with a 100 percent rail response. Conversely, Lake exports are increased by the same amount as the Gulf losses in shipments to Eastern Europe. Since individual flows from grain surplus origin to foreign destination are not modelled, it is impossible to analyze the exact shifting in export flows. However, it is very plausible that barge shipments diverted to Lake ports under the user charge scenarios account for the increase exports to Eastern Europe.

Shipments to Western Europe from Gulf ports decline to about 30 percent of total shipments to Western Europe under all tax solutions. A more interesting feature of Western European exports is the trade-off between the Atlantic and Lake ports. As seen in Tables 72 to 73, the only diversion of corn and soybeans from the Ohio River occurs under a fuel tax. The segment tax, which is lower than the fuel tax on the Ohio, is not sufficiently high enough to divert grain from the Ohio. Under the fuel tax, grain is diverted to multiple-car rail shipments to Atlantic ports. Again, it is plausible that this grain is shipped to Western Europe. Under the segment tax, there is no grain diverted from the Ohio and the barged grain is exported through Gulf ports.

The share of exports to the Far East between Gulf and Pacific ports remains fairly stable in all solutions. The Gulf share decreases slightly in the no response solutions, but increases as rail rates increase. There is no change in export flows to the Middle East or South America.

Elasticity of Demand for Barge Service

Elasticity of demand is an important concept indicating the responsiveness in quantity demanded of a product to a change in the price of the product all else held constant. In this case, the product of concern is barge services and the price is the barge rate. The change occuring in the barge rate is the increase in the rate due to user charges. The general formula for calculating elasticity coefficients is:

$$E = \frac{\Delta Q}{\Delta P} \frac{P}{Q} \tag{42}$$

where

E = own price elasticity of quantity demanded for the product

Q = quantity demanded of the product

P = price of the product

The magnitude of the computed elasticity coefficient is significant in a number of ways. Consider the importance to barge owners and operators. If the elasticity coefficient is less than a minus one, demand is defined to be elastic. A price (rate) increase will reduce total revenue received by the barge operator because the gain in total revenue associated with the increase in rate is less than the loss in revenue associated with the decline in the quantity of barge services demanded. If the elasticity coefficient is greater than a minus one demand is inelastic. A rate increase will increase total revenue.

Koo [28] and Hauser [21] have estimated the elasticity of demand for barge services. Koo estimates a system-wide elasticity of demand given a proportional change in all barge rates. As determined by Koo, the elasticity of demand for barge services is equal to 3.52, 2.43 and 2.27 when barge rates are increased by 10, 20 and 30 percent respectively. As indicated by Table 79 however, the imposition of user charges will not increase barge rates by a constant percentage at all grain origins. In 1990, the fuel tax ranges from 23.1 percent of the barge rate at Lewiston, Idaho to 6.3 percent at Greenville, Mississippi. The segment tax as a percent of the barge rate ranges from 30.4 to 3.6 percent at Lewiston, Idaho and Greeneville, Mississippi respectively. Hauser determines elasticities given the differential percentage increase in rates due to the fuel and segment taxes projected for 1985. The elasticity coefficient represents an average — weighted by quantity shipped through particular origins on a given river segment -- elasticity by river segment. The elasticity coefficient is computed as:

$$Es = \sum_i \frac{\Delta Q_i}{\Delta P_i} \cdot \frac{P_i}{Q_i} \frac{Q_i}{Q_s} \qquad (43)$$

where

E_s = own price elasticity of barge services demanded on river segment s

Q_i = quantity demanded of barge services in the base solution at river origin i

P_i = price of barge services in the base solution at river origin i

Q_s = quantity demanded of barge services in the base solution on river segment s

Utilizing this formula, elasticity coefficients were calculated by river segment given the increase in barge rates due to the imposition of

Table 79. User charges as a percent of barge rates by type of tax, origin, and river, 1990

River	Origin	Fuel tax	Segment tax
Mississippi	Minneapolis, MN	10.6	14.8
	Clinton, IA	10.2	12.5
	St. Louis, MO	10.2	9.2
	Memphis, TN	7.4	4.2
	Greenville, MS	6.3	3.6
Illinois	Seneca, IL	10.5	11.2
	Peoria, IL	10.4	10.7
	Naples, IL	9.6	9.6
Ohio	Cincinnati, OH	10.8	5.3
	Mt. Vernon, IN	9.2	5.0
Missouri	Sioux City, IA	11.5	12.8
	Kansas City, MO	9.7	11.2
Arkansas	Catoosa, OK	12.8	25.5
Columbia/Snake	Lewiston, ID	23.1	30.4
	Windust, WA	16.4	22.4
	Biggs, OR	14.0	16.0

1990 user charges. The calculated elasticities are presented by river segment in Table 80.

As indicated in Table 80, the demand for barge services is elastic in total and on the Upper Mississippi, Missouri and Arkansas Rivers. The demand for barge services is inelastic on the Lower Mississippi, Illinois and Columbia-Snake. The results for the Ohio River indicate that elasticities are only valid over a particular range of prices. For a relatively small increase in price the demand for Ohio River barge traffic is perfectly inelastic. Given the relationship between revenue generated and the magnitude of the elasticity coefficient, barge owner revenue would increase upon the Lower Mississippi, Illinois and Columbia-Snake rivers. On the Upper Mississippi, Arkansas, and Missouri barge revenue would decline. The effect on the revenue generated from Ohio River shipments is dependent upon type of tax implemented.

A major determinant of the magnitude of the elasticity coefficient is the availability of substitutes. In the context of this study substitution may occur between modes and between origin-destination pairs. The ability of inland shippers to substitute direct rail service for combination rail-barge or truck-barge service will influence the elasticity for barge services. Similarly, the ability of inland shippers to substitute shipments to processing locations for export shipments or between exporting ports will affect the magnitude of the elasticity coefficient. Substitution between transport modes and destinations, however, does not occur at the river origin. Substitution would occur at the inland grain origin elevator. The grain shipper substitutes the combined truck-barge

Table 80. Elasticity estimates resulting from imposition of 1990 user charges and average tax per bushel of corn by river segment

River segment	Fuel tax		Segment tax	
	Elasticity[a]	Average tax per bushel (cents/bushel)	Elasticity[a]	Average tax per bushel (cents/bushel)
Upper Mississippi	2.41	3.72	2.06	4.69
Lower Mississippi	0.72	1.37	0.80	0.88
Ohio	1.62	2.54	0.00	1.30
Illinois	0.35	3.12	0.43	3.37
Missouri	5.61	6.41	4.84	7.25
Arkansas	6.46	4.23	3.25	8.43
Columbia-Snake	0.46	1.48	0.35	1.70
Total	1.94		1.37	

[a] Signs have been charged from negative to positive.

or rail-barge movement with a direct rail or truck shipment to inland processing or exporting ports. Therefore, estimation of elasticity coefficients at the grain origin elevator would seem more appropriate.

Table 81 presents elasticity coefficients estimated at the grain origin elevator for the regions depicted by Map 8. The method of calculation, similar to equation (43), may be represented as follows:

$$E_r = \sum_a \frac{\Delta Q_{ia}}{\Delta P_{ia}} \frac{P_{ia}}{Q_{ia}} \frac{Q_{ia}}{Q_r} \quad (44)$$

where

E_r = own price elasticity of barge services demanded at region r.

Q_{ia} = quantity demanded, at origin elevator a, of a combined mode i - barge movement in the base solution; i - truck, single or multiple car rail.

P_{ia} = Price, including handling charges, at origin elevator a, of a combined mode i - barge movement in the base solution.

Q_r = total quantity of barge services demanded by shipments originating at region r.

The estimated elasticity coefficients range from 0.0 in regions C, G, J, L, O and R to 18.4[5] in region D; northwestern Iowa. Perfect inelasticity of demand for combined truck- or rail-barge movements would indicate that user charges at the level specified in this analysis are insufficient to cause diversions to direct truck or rail movements. The

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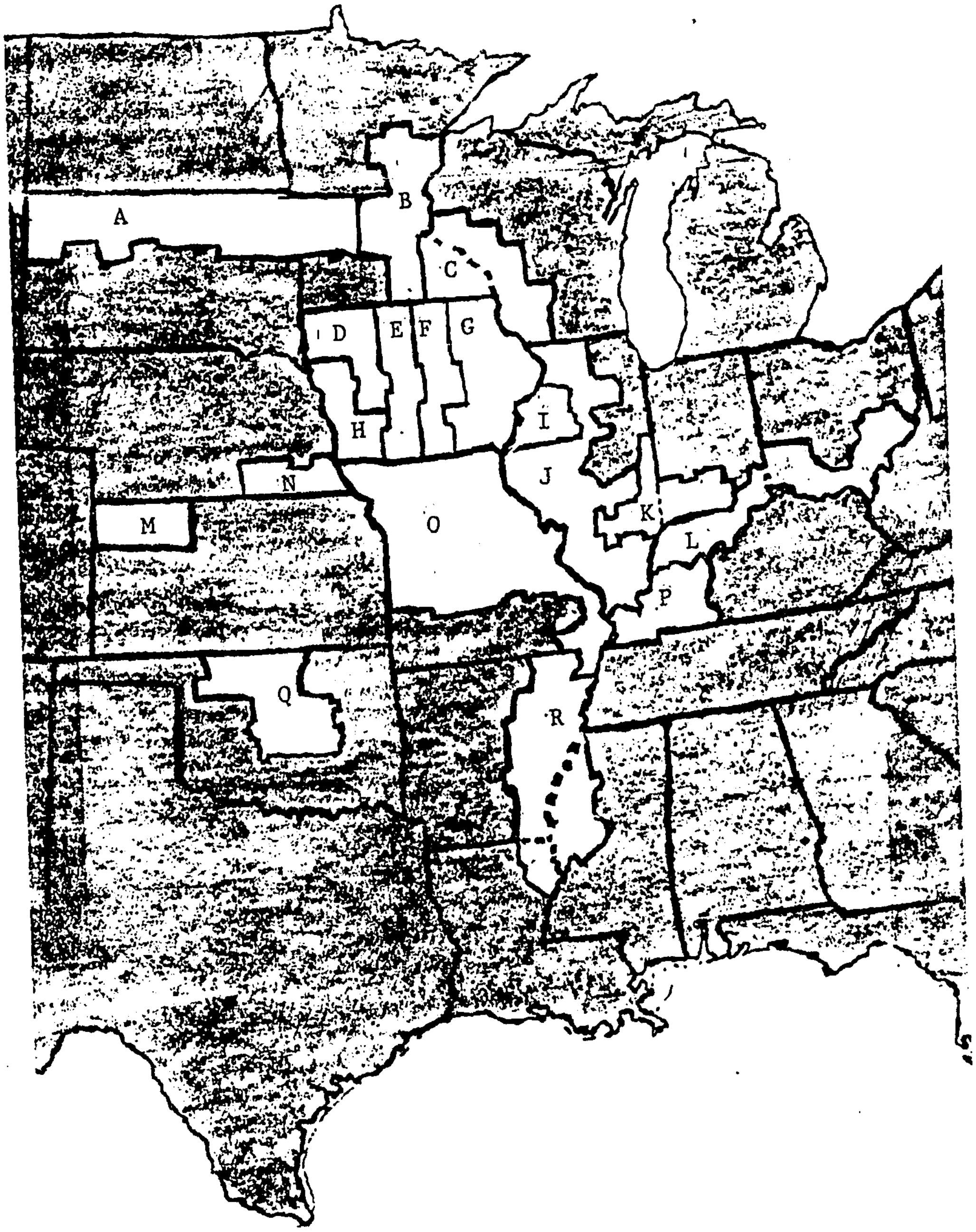
[5] Sign of elasticity coefficient changed from negative to positive.

Table 81. Elasticities of demand for barge transportation computed from 1990 user charges by decision point regions

Region	State	Elasticity of demand for barge transportation: Fuel tax	Segment tax
A	SD,MN	5.2	12.1
B	MN	12.4	10.0
C	MN,WI	0.0	0.0
D	IA	18.4	14.5
E	IA	5.8	4.8
F	IA	1.2	1.0
G	IA	0.0	0.0
H	IA	6.4	5.4
I	IL	1.6	1.8
J	IL	0.0	0.0
K	IL,IN	10.1	7.1
L	IN,OH	0.0	0.0
M	KS	16.9	14.4
N	NE	5.7	5.0
O	MO	0.0	0.0
P	KY	6.7	0.0
Q	OK	10.3	5.2
R	AR,MI,LA	0.0	0.0



Map 8. Water competitive regions in the Mississippi River basin[1]

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[1]No barge shipments originate in shaded areas

regions, characterized by a perfectly inelastic demand are in general located in very close proximity to the river. In these regions, the combined truck- or rail-barge rates remain cheaper than the next-best alternative after user charges are imposed. The exceptions to this close proximity-perfect inelasticity rule are the entire state of Missouri, region I (Illinois) and region P (western Kentucky). In Missouri, the absence of water-competitive rail rates favors the continued use of barge transportation after user charges are imposed. Regions I and P although in close proximity to the river are characterized by an elastic demand for barges. User charges divert grain from export shipment to regional processing locations.

In the remaining regions, both distance to barge loading points and availability of alternative means of transportation become crucial to the determination of the elasticity coefficient. Iowa is an excellent example. Region G is characterized by perfect inelasticity of demand to barge services. This region is in close proximity to the river and the rate on substitute transportation, i.e. rail rates, does not become competitive even after user charges are imposed. Region F shows a slightly elastic demand for barge services. Region E is characterized by an even greater elasticity of demand for barge services. In both regions E and F multiple-car rates to the Gulf become competitive with rail-barge and truck-barge rates after user charges are imposed. In addition, these regions are located at a greater distance from the river making the total rate to export larger. Regions D and H are located in close proximity to the Missouri River. Per bushel user charges on the Missouri River, however, are relatively larger than on other river segments. The large increases in barge transportation rates readily causes grain to divert from barge shipment to truck or rail shipment.

In summary, although river segment elasticities, as presented in Table 80 indicate that in total the demand for barge services is elastic, there are additional factors to consider.

1) Empirically estimated elasticities are valid only for the range of rate increases under analysis. The elasticity coefficients estimated for the Ohio River origins are an excellent example. The elasticity coefficient computed on the basis of the segment tax would suggest a perfectly inelastic demand for barge services on the Ohio River. However, this conclusion would not be supported if rate increases of the magnitude caused by the fuel tax were imposed. Given the fuel tax, the demand for Ohio River barge services is elastic.

2) Elasticity coefficients computed at river origins, although indicative of the directional change in barge owner revenues given a change in barge rates, do not fully approximate the responsiveness of barge traffic to a change in barge rates. Barged grain originates at an inland grain elevator. It is at the inland grain origin elevator that the decision to utilize barges or ship direct by rail or truck is made. These results strongly suggest that the elasticity of demand for barge transportation varies considerably depending upon the origin of the grain shipped.

Barge Share of Traffic in Water-Competitive Areas

Table 82 presents the available surplus destined for processing or export shipment and export shipments in millions of bushels by region as dillineated in Map 8. Additionally, this table presents the market share held by barge shipments of these categories by region.

In total, barges command an 84 percent share of export bound shipments in the base solution in the water competitive regions in the Mississippi River basin. Of the available surplus, barges command a 59 percent share. Under the fuel and segment tax scenarios, the barge share of export bound shipments declines to about 70 percent.

Regionally, barges maintain a 100 percent share of export shipments in regions G (eastern Iowa), L (southern Indiana and Ohio), O (Missouri) and P (western Kentucky). In region C (Minnesota and Wisconsin), J (Illinois), and R (lower Mississippi basin) a constant but less than 100 percent share of export shipments is held by barge in all solutions. Except in the case of region P, these regions are characterized by a perfectly inelastic demand for barge services at the rate relationships existing during the time period covered in this analysis.

The barge share of export shipments declines dramatically in regions A (South Dakota, Minnesota), B (Minnesota), D (Northwest Iowa), H (Southwest Iowa), M (Kansas), and N (Nebraska). These regions are all located near rivers upon which taxes are high because of distance from ports, capacity per barge tow or projected operation, maintenance and construction costs.

Table 82. Projected 1990 available surplus and export shipments in millions of bushels by region and percentage barge share of available surplus and export shipments by computer solution

		Base solution				Percentage share			
		Bushels		Percentage share		Fuel tax		Segment tax	
Region	State	Total surplus	Exports	Total surplus	Exports	Total surplus	Exports	Total surplus	Exports
A	SD,MN	55.2	29.4	54.3	100.0	33.0	85.0	0.0	0.0
B	MN	154.2	147.7	74.1	77.6	4.4	4.6	4.4	4.6
C	MN,WI	128.5	128.5	91.2	91.2	91.2	91.2	91.2	91.2
D	IA	318.5	202.9	30.5	48.0	0.1	0.2	0.1	0.2
E	IA	273.2	187.0	27.2	39.7	15.7	22.0	15.6	22.0
F	IA	218.2	94.0	36.4	84.6	33.1	83.3	33.4	83.7
G	IA	468.9	387.5	82.6	100.0	82.6	100.0	82.6	100.0
H	IA	160.7	62.1	11.5	29.8	5.3	14.1	5.3	14.1
I	IL	277.2	211.6	76.3	100.0	66.6	89.3	64.7	89.0
J	IL	646.1	522.9	77.3	96.0	77.3	96.0	77.3	96.0
K	IL,IN	304.9	158.9	39.0	75.0	23.1	57.8	31.2	64.8
L	IN,OH	115.8	100.0	86.3	100.0	84.5	100.0	86.3	100.0
M	KS	60.1	33.6	56.0	100.0	12.6	22.6	12.6	22.6
N	NE	54.2	22.5	21.9	52.8	9.8	23.6	9.8	23.6
O	MO	188.0	149.7	79.6	100.0	79.6	100.0	79.6	100.0
P	KY	133.3	26.0	19.5	100.0	11.1	100.0	11.1	100.0
Q	OK	39.6	39.6	65.4	65.4	45.7	45.7	45.7	45.7
R	AR,MI,LA	84.8	69.0	81.3	81.3	81.3	81.3	81.3	81.3
Total		3681.6	2572.9	58.8	84.1	47.7	70.2	47.8	69.8

Implications of Constraints

The shadow price of a constraint employed in the model indicates the reduction in total transportation costs if the specific constraint is increased by one unit. The most significant cost reductions would result from an increase in multiple-car loading facilities. Table 83 presents the base solution shadow prices averaged by state and time period and percent utilization of available multiple rail-car capacity for the shipment sizes available in the state. The average shadow prices range from \$0.00 for 75-car shipments in Illinois and 50-car shipments in Kansas to \$66.65 for 50-car shipments in North Dakota. Together with the information provided on percent utilization the shadow prices indicate the states with potential for multiple-car facility expansion and reduction in transportation costs.

On average, 71.5 percent of available multiple rail-car capacity, as measured by percent utilization of available rail-car days, are used in the U.S. On a state basis, however, the utilization of rail-car days varies. In general, the northern plain states exhibit the greatest percent utilization of available capacity. Multiple-car rate facilities are a recent development in these states. The remaining states, except Illinois, exhibit percent utilization in the range of 60 to 80 percent. Similarly, the average shadow prices for the rail-car constraints in the northern plain states are consistently higher relative to other regions. This information suggests that the greatest reduction in total transport costs would result from the expansion of multiple-car facilities in this area.

Table 83. Average shadow prices of base solution regional rail-car day constraints and percent utilization of multiple rail-car capacity by size of shipment and state

State	Size of shipment	Average shadow price in dollars	Percent utilization of available multiple-car capacity
Idaho	26	12.63	100
Illinois	75	0.00	0
	100,125	9.58	22
Indiana	65	13.61	46
	100	21.83	82
Iowa	25	11.67	65
	50	10.85	61
	75	11.31	92
Kansas	50	0.00	0
	75	6.51	80
Michigan	100	29.75	67
Minnesota	26	21.57	47
	50	4.98	76
	75	14.23	100
Montana	25	54.42	100
Nebraska	25,26	16.52	100
	50,54	27.76	100
	75	27.23	100
North Dakota	26	26.88	94
	54	66.65	100
Ohio	65	6.54	66
	100	19.38	55
South Dakota	26	16.27	20
	54	9.09	100

Table 84 presents the utilization of covered hopper cars designated for export shipment. The highest utilization rate occurs with the fuel tax. In this solution, 61,738 covered hopper cars -- 72 percent of the projected export fleet -- are utilized.

The only effective barge day constraint is the constraint that limits spot barge movements during the winter period. The shadow price for this constraint equals $26.48 in the base solution. A positive shadow price indicates that the constraint is effective and an increase of one spot-barge-day would decrease total cost by $26.48. As would be expected the shadow price declines when taxes are imposed and the demand for barges decreases. The shadow price for winter spot-barge-days is equal to $9.93 and $12.85 in the fuel and segment tax solutions respectively. As railroads respond to user charges, the demand for barge increases, and similarly the shadow price increases to $23.55 and $26.50 in the segment tax with a 50 percent and 100 percent response, respectively.

Map 9 indicates the base solution shadow prices resulting from the inventory constraints imposed upon the southeastern states. Shadow prices range from 0.00 -- indicating an ineffective constraint -- in Alabama to $16.70 in south central Georgia. The other solution's shadow prices increase only slightly for these constraints.

Table 84. Rail car requirements for export shipments of grain and percent utilization of available fleet by tax solution

Solution	Rail-car usage	Percent used[a]
Base	53,369	62.4
Fuel tax	61,738	72.2
Fuel-segment tax	61,727	72.2
Segment tax		
No rail response	61,449	71.9
50 percent rail response	59,194	69.3
100 percent rail response	58,646	68.6

[a] Based on available fleet equal to 85,462 cars.

CHAPTER VI. LIMITATIONS AND SIGNIFICANCE OF RESULTS

The results of this analysis depend upon the linear programming model and assumptions outlined in the METHOD OF ANALYSIS chapter. A key assumption is that user charges are passed back to commodity shippers. By design, therefore, user charges are equivalent to an increase in barge transport costs; commodity shippers respond by shifting from barge transport to alternative modes or destinations. As a tax, however, user charges are an arbitrarily imposed increase in transport costs. The issue of incidence, therefore, is an important one. The fact that commodity shippers are a diverse group consisting of grain producers, country elevators, and river elevators complicates this issue.

A second point of concern is that, of necessity, taxes are imposed ceteris paribus. Linear programming requires that the production and demand for commodities remain fixed. Additionally, except in assumed rail rate response scenarios, rail and truck rates do not respond to an increase in barge rates. This chapter will consider the sensitivity of production, demand for commodities, and transport rates to user charges. Since the impact of user taxes on the assumed fixed quantities and rates may effect the incidence of user taxes, the issue of price sensitivity will be considered first.

Impact of User Charges on the Producer

Inland waterway user charges, if passed back to producers, are equivalent to a decrease in the price received for grain at inland terminals. Assuming that producers maximize profits, their response will be to decrease the rate of input utilization in grain production, decrease the quantity of grain produced for export markets, and alter the combination of activities which make up the farm enterprise.

Figure 7 is a convenient means of representing a change in input utilization, and consequently, a change in commodity production, resulting from a decrease in commodity price. The curve labeled TPP, represents the total physical productivity of a variable input, nitrogen, in corn production. The TPP curve is a graphic depiction of the production function relating the quantity of corn produced per acre to different levels of nitrogen used per acre, assuming all other inputs are held fixed. The slope of the TPP curve, at a particular point, that is, at a particular level of nitrogen utilization, is equivalent to the marginal productivity of nitrogen (MPP_N) in corn production. Nitrogen is applied up to the point where MPP_N is equal to the ratio of the price of nitrogen to the price of corn (point A in Figure 7)[1]. At the profit maximizing level of nitrogen utilization, ON_1, the quantity, OC_1, of corn

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[1]An equivalent condition would require that the value of the marginal product of nitrogen (VMP) equal the price per unit of nitrogen. For example, if at the current rate of output, the application of a pound of nitrogen increased corn yield by ½ bushel per acre (i.e., MPP = ½) and corn sells for $3.00, VMP is equal to $1.50. If the price of nitrogen is equal to $1.50 per pound, the producer is maximizing the profits obtainable from nitrogen utilization.

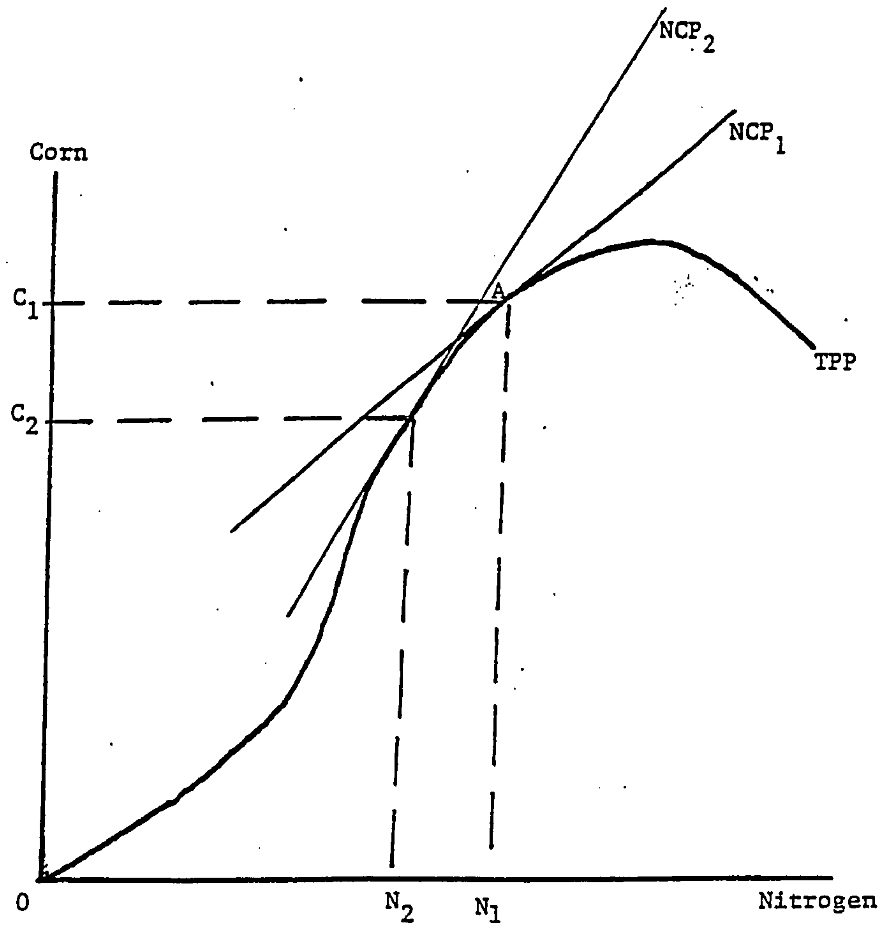

Figure 7. Impact of an increase in barge rates on corn production

per acre is produced. A decrease in the price of corn will increase the nitrogen-corn price ratio as represented by a shift in the price ratio line from NCP_1 to NCP_2. The level of nitrogen utilized in the production of corn decreases from ON_1 to ON_2 and consequently, corn production per acre decreases (OC_1 to OC_2).

Reduced grain production is one response to a decrease in price received for grain. An alternative response is the channeling of grain into alternative outlets. Grain, especially corn, may be utilized in livestock enterprises. As the price of corn decreases, other inputs, such as protein supplements, become relatively more expensive in the livestock feed ration.

The least cost combination of corn and protein inputs is determined, for a particular level of livestock output, when the returns from a dollar invested in corn equals the returns from a dollar invested in protein.[2] A decrease in the price of corn would increase the returns from corn as an input into livestock production and cause a substitution away from protein. In addition, since the total variable cost of producing livestock has decreased, the quantity of livestock produced will increase. This process is demonstrated in Figure 8.

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[2]An equivalent statement is that the ratio of the marginal productivity of each input to the price of the input are equal, for all inputs. The profit maximizing output level, given the least cost combination of inputs for each output level, is determined at the output level for which the value of the marginal product of each input is equal to its price.

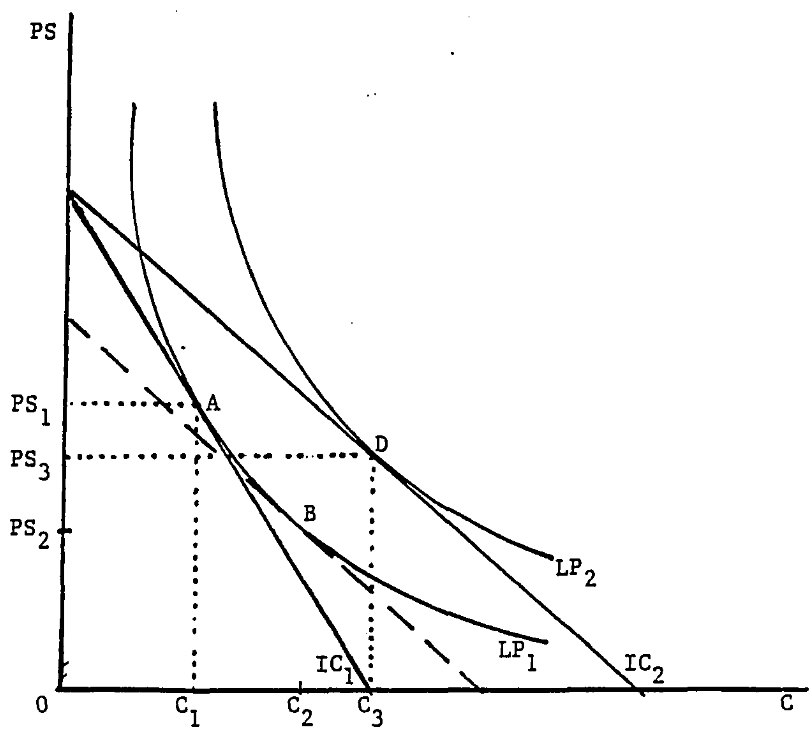

Figure 8. Impact of an increase in barge rates on livestock production

An isoquant, labeled LP_1 specifies the degree to which protein supplements (PS) may be substituted for corn (C) while maintaining a constant level of livestock output (LP_1). An increase in the quantity of livestock produced would be represented as a shift in the isoquant from LP_1 to LP_2. The slope of the isoquant is equal to the ratio of the marginal productivity of corn to the marginal productivity of protein supplements in the production of livestock. An isocost line, labeled IC_1, specifies the degree to which corn and protein supplements may be substituted while maintaining a constant total cost. The slope of the isocost line is equal to the ratio of the price of corn to the price of protein supplements. A decrease in the price of corn would shift the isocost line from IC_1 to IC_2. The least cost combination of corn and protein, given LP_1 and IC_1, is determined at the point of tangency between the isoquant and isocost line (at point A).

The likely first response of producers to a decrease in the price of corn is to substitute corn for protein, holding livestock production constant. Corn utilization increases from OC_1 to OC_2 and protein utilization decreases from OPS_1 to OPS_2. However, given the decrease in the price of corn, and consequently, the decrease in livestock production cost, profits would increase by increasing the quantity of livestock produced to LP_2. At the new tangency, point D, corn utilization is equal to OC_3, protein utilization is equal to OPS_3.

The profit maximizing producer may also alter the combination of activities which make up the farm enterprise. For a given level of inputs, the producer will equate the ratio of the marginal productivity of the inputs in alternative production enterprises to the product price ratio. As an example, the producer may produce corn or livestock given a fixed level of management and labor resources. If the price of corn decreases, the value of these fixed inputs in the production of corn will decrease. Resources will be shifted to livestock production. Figure 9 depicts this process. From a fixed level of management and labor resources, OX units of corn and no livestock or OY units of livestock and no corn could be produced. The curve labeled PP, represents the production possibilities of the farm. The ratio of output prices equals the slope of the line labeled CL_1. At the tangency of CL_1 and PP (point A), OB_1 units of corn and OD_1 units of livestock are produced. A decrease in the price of corn would alter the output price ratio as represented by a shift from CL_1 to CL_2. Corn production decreases to OB_2 and livestock production increases to OD_2. A greater proportion of the fixed input base would be utilized in livestock production. The production of livestock would increase. The production of corn would decrease.

The response, therefore, of producers to a decrease in the price received for corn will likely be a reduction of the farm gate marketing of corn. These reduced marketings may result from a decrease in production or increased usage of corn, on the farm, as an input into livestock production. The extent of this adjustment depends upon the extent to which corn prices decrease in the grain origin region. The extent to which the price of corn decreases depends, in part, the response of transportation rates to user charges.

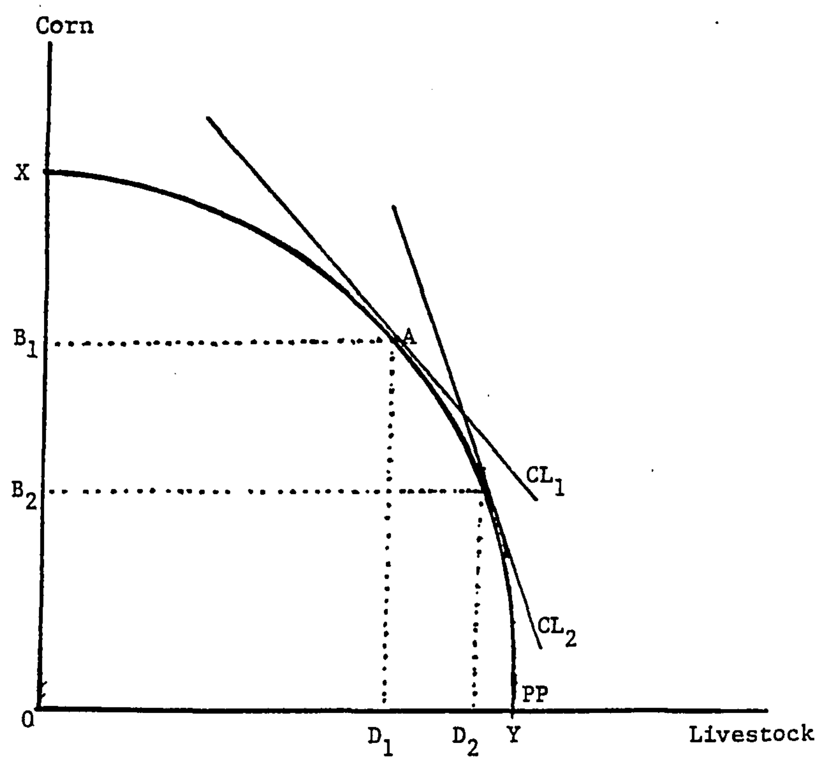

Figure 9. Impact of an increase in barge rates on farm production activities

Competition in the Grain Origin Region

Transporting grain by rail or truck to export ports or shipping to processing facilities and livestock feed deficit areas are alternatives to shipping grain by barge. The results of this analysis suggest that inland elevator operators respond to increased barge rates by diverting grain from barges to these alternative outlets. In this analysis, barge shipments decline by 17.3 percent in both the fuel and segment-specific tax solutions with no rail response. Direct rail shipments increase by about 10 percent in both tax solutions. Direct truck shipments increase by 15.4 and 20.6 percent in the fuel and segment specific tax solutions, respectively.

Alternative outlets, however, are not available uniformly throughout barge competitive regions. In the base solution, the boundary of the area in which barge shipments originate is defined at a distance from the river at which the truck rate, as a function of miles, plus the barge rate and handling cost equals the direct rail rate. Rail-barge, if available, increases the size of the barge drawing area. As indicated in Map 5 (p. 40) the barge drawing area will shrink as barge rates increase relative to alternative rates. Beyond the isorate line, at which the total cost of shipping by barge is now greater than alternatives, inland elevator managers respond by diverting traffic from barges to other modes or markets.

In both the base and tax solutions, the decision criteria of the least cost rate alternative is chosen. However, user charges will cause the rate advantage held by barge in the base solution to be eliminated in some regions. In other regions, barge rates remain the least costly mode even after user charges are imposed. In eastern Iowa and all of Missouri, as demonstrated in the discussion of elasticities and barge traffic share (p. 228-239), barges maintain a 100 percent share of export grain originating in these regions. In other areas, west-central Iowa, for example, the barge share decreases. The important point, given that alternative rates remain constant, is that the price received by producers may decrease by an amount equivalent to the user tax only in regions where alternative grain outlets remain uncompetitive with barges after taxes are imposed. In other regions, the maximum decrease in the price received by producers is equivalent to the rate advantage held by barge in the base solution.

Transportation rates remain constant in this analysis, except in assumed rail response solutions. In the base solution, barge rates increase by the amount of the user tax. The base rate, however, is unchanged. In actuality, barge rates are negotiated between barge owners and commodity shippers. A combination of factors, including the supply and demand for transportation services, the supply and demand for the commodity shipped by barge and the level of competing transport rates influence these negotiations. Given a reasonably fixed short-run capacity of barge space, the increase in barge rates resulting from user charges would cause barge utilization to decline. In addition, as discussed in the RESULTS chapter, barge revenues decline by about 20 percent if barge rates increase by an amount equal to the taxes used in this analysis. To avoid this decline in utilization and revenues, barge owners may decrease rates to encourage continued use of barges.

The response of alternative transportation rates to user charges depends, in part, on the response of barge owners to a decline in traffic share and revenue. If barge owners decrease rates sufficiently to maintain pretax rate relationships, no response in alternative rates may be forthcoming. A more interesting case is the response of alternative modes given an increase in barge rates.

Alternative transportation services may complement or substitute for barge services. Direct rail or truck service to export ports are a substitute to barge transportation. A substitute relationship implies a direct relationship between the directional change in barge rates and the quantity demanded of alternative transportation. In this analysis, rail and truck shipments direct to export increase in response to an increase in barge rates. The rail and truck portions of a combined rail-barge or truck-barge movement complements barge movements. A complementary relationship implies an inverse relationship between the quantity demanded of alternative transportation and the directional change in barge rates. In this analysis, rail traffic that feeds barge declines by 49.0 and 55.6 percent, from base solution traffic levels, as barge rates increase by the amount of the fuel and segment-specific taxes, respectively. Truck-barge traffic declines by about 12 percent in both solutions.

Alternatively, as presented in Figure 10, truck and rail rates may change in response to an increase in barge rates. The impact on barge rates and quantity demanded of barges is presented in diagram (a). The response of direct rail or truck rates and quantity demanded of direct rail or truck services is represented in the center diagram (b). The response in rates and quantity demanded of rail and truck services that complement barge services is presented in diagram (c).

In the base solution, barge, rail and truck services are priced at P_e.[3] An increase in barge rates from P_e to P_t would decrease the quantity demanded of barge services (Q_e to Q_t). The demand curve for substitute transportation would shift right from D_0 to D_1 in diagram (b) and the demand curve for complement transportation would shift left from D_0 to D_2 in diagram (c). The extent of the change in rail or truck rates depends on the slope of the supply curve.

In diagrams (b) and (c), the supply curve labeled S_0 is horizontal. Implied by the shape of this supply curve is unlimited rail or truc capacity at P_e, interchangeability between direct and barge connected services, and an inability of competing rail or truck firms to impact the price of services by increasing or decreasing the quantity of services offered. Given S_0, the price of direct and barge connected services remain the same after user charges are imposed. The utilization of direct services increases (to Q_x). The utilization of barge connected services decreases (to Q_a). The opposite extreme is represented by the

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[3]It is not implied that the scale on the price and quantity axis are meant to be the same, therefore, P_e is not the same in each diagram.

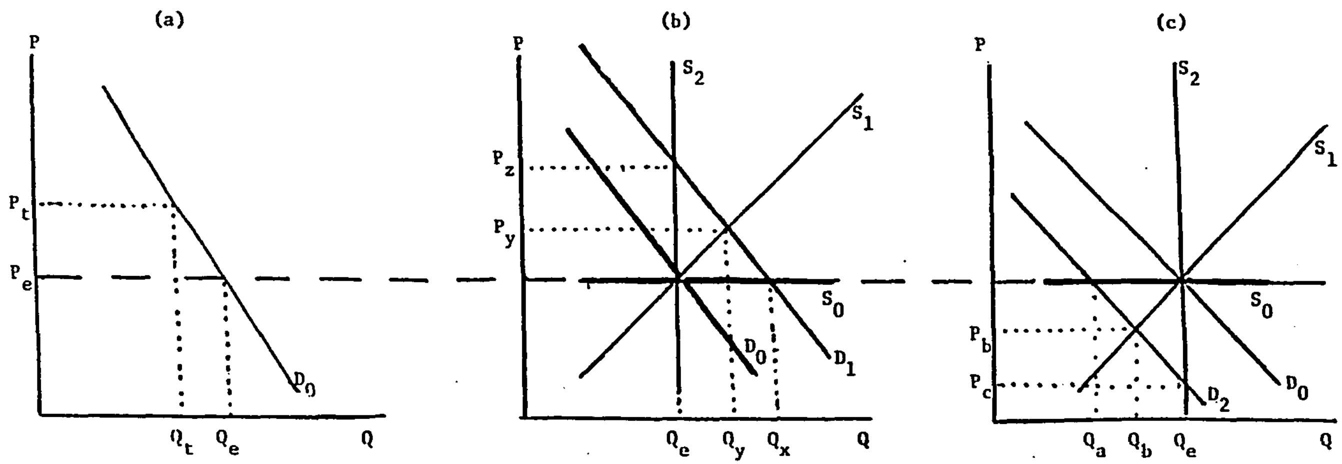

Figure 10. The response of barge substitute and barge complementary traffic rates and utilization to an increase in barge rates

supply curve labeled S_2 in diagrams (b) and (c). Implied by this vertical supply curve is a fixed capacity of dedicated direct and barge connected services. Given S_2, the quantity of direct or barge connected services remains the same after user charges are imposed. The price of direct service increases to P_z. The price of barge connected service decreases to P_c. The curve labeled S_1 in both diagrams represents an intermediate case. For substitute transportation both quantity utilized and the price of direct services increase (to Q_y and P_y). For complement transportation, both quantity and price of barge connected services decline (to Q_b and P_b).

Finally, alternative destinations, such as processing facilities, are alternatives to transporting commodities to export ports by barge. As noted in the LITERATURE REVIEW, Conley and Hill [14] suggest that bids offered to farmers by processors will adjust in the same direction as the bids received from barge transportation. If all else remains constant and barge owners are able to pass back the increase in barge rates to commodity shippers, the price received from exporting grain will decline in grain origin regions. Commodity shippers may then respond by shifting grain to alternative outlets. Given, as assumed by Conley and Hill, processing managers do not wish to alter plant utilization, the increased supply of grain directed at processing facilities would allow processing managers to decrease the price offered for grain. If the price offered at processing plants declines in proportion to the price offered from barge loading facilities, the advantage of shifting grain from barges to processors will be eliminated.

The Question of Incidence Revisited

In this analysis, the assumption of a horizontal barge service supply schedule illustrates the possibility that user charges will be passed back to commodity shippers. As noted in the preceding sections of this chapter, however, the individuals that compose the group of commodity shippers are diverse in numbers and motivation. In addition, it was recognized that barge owners may renegotiate barge rates to maintain market share. A decrease in barge rates would, in essence, be the same as partial absorption of user charges by barge owners. If barge rates were not decreased, the following conclusions concerning incidence may be inferred:

1. If alternative transportation rates remain the same, the price received from exporting grain may decrease only until the rate advantage held by barges, in the absence of user charges, is eliminated. In general, if the price received from exporting grain by barge decreases to a level below the next best alternative, commodity shippers will shift to that alternative. This would be more common at the boundary of the barge competitive area than in areas closer to the river.
2. In areas where alternative transportation and outlets do not become competitive with barges after user charges are imposed, the response of producers to a decrease in price received for grain would be to decrease the marketing of the commodity which

was barged. Grain usage as an input into livestock operations may increase or alternative farming enterprises may substitute for grain production. In either case, the individual producer will avoid the incidence of user charges by avoiding barge transport.

3. Transport rates on alternative direct to export shipments may remain the same or increase. However, transport rates on barge connected services may decrease. A decrease in barge connected transportation rates would be the same as partial absorption of the tax by alternative modes.

4. In addition, at each break in the transportation channel, that is, at the inland elevator or river terminal elevator, the price of incoming grain differs from the price of outgoing grain by the elevator margin. If inland elevators are located on barge connected routes, the elevators complement barge service. All river elevators complement barge service. An increase in the price of barge services implies a decrease in the demand for elevator service. Therefore, to encourage continued use of the elevator, elevator managers have the option of decreasing margins received from grain transactions.

In this analysis, the primary impact of inland waterway user charges is on the domestic grain distribution network. The incidence of user charges is absorbed by domestic commodity shippers. The international grain distribution network is affected only to the extent that user charges may change the originating export port for international shipments. Regional import demands remain fixed throughout the entire analysis. Foreign purchasers of U.S. commodities absorb none of the tax.

Baumel [3] and Binkley and Sharples [8], as discussed in the METHOD OF ANALYSIS chapter (p. 43-47), suggest that given particular market conditions, a significant portion of the incidence of user charges may be absorbed by foreign purchasers of U.S. grain.[4] The mechanics of how user charges may be passed forward from the domestic to the foreign market may be illustrated with a simple graphical depiction of foreign trade [44].

Consider a closed economy, as depicted in diagram (a) of Figure 11. In this country, equilibrium is established at a price equal to P_e and quantity at Q_e. At a price below P_e, an excess demand for grain is created. For example, at P_1, the excess demand is equivalent to the horizontal distance between the demand and supply curves, that is, the line segment $\overline{ab}$. If the price is equal to P_2 excess demand would be larger. If this country were allowed to trade at a price equal to P_1, or P_2, the excess domestic demand would translate into an import demand schedule (ID) as depicted in diagram (b) of Figure 11. At a price of P_e, the import demand curve intersects the vertical axis, that is, import demand would equal zero. At prices below P_e, the import demand is equivalent to the domestic excess demand. In a similar fashion, if the country is allowed to trade at prices above P_e, the

[4]Baumel suggests that a combination of strong import demand and excess demand for grain transportation will cause importers to absorb user taxes. Binkley and Sharples suggest that an inelastic import demand would be sufficient.

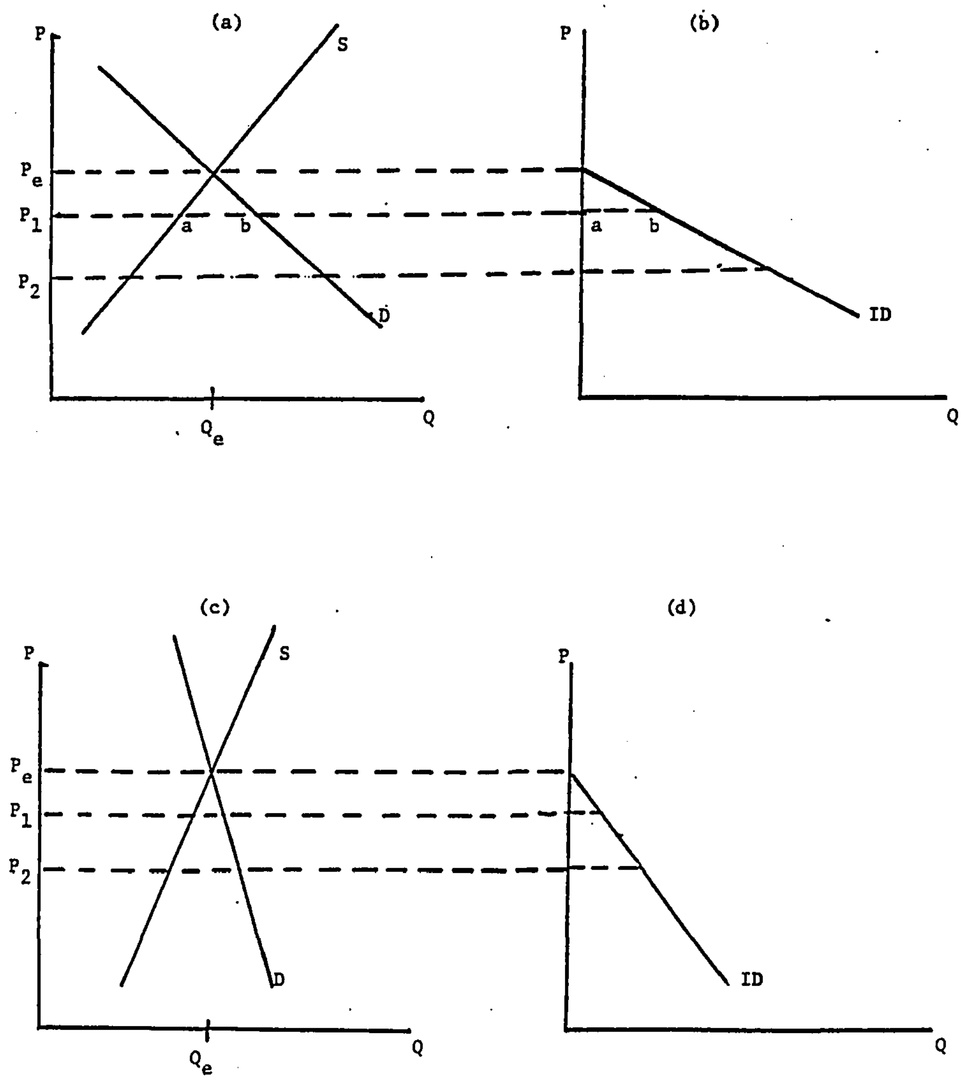

Figure 11. The derivation of the import demand schedule

excess domestic supply would be equivalent to this country's export supply.

The above derivation of the import demand schedule suggests that the quantity imported is dependent upon the domestic price in relation to the world price and the slopes of the domestic demand and supply schedules. A steeper slope of the domestic demand (supply) schedule indicating, by comparison, a more inelastic demand (supply), would translate into a more inelastic import demand curve. This proposition is demonstrated in diagrams (c) and (d) of Figure 10. A relatively more inelastic import demand schedule would imply that the quantity imported is less responsive to a change in world price.

This information may be extended to a three diagram depiction of world trade as presented in Figure 12. By definition, if there is no trade, the potential exporter would reach equilibrium quantity sold at a lower price than the potential importing country. In Figure 12, the exporting country (the United States) is depicted in diagram (a), the importing country in diagram (c), the and world market in diagram (b). If trade is allowed, assuming no transportation costs, trade will occur at the intersection of the export supply curve (ES) and import demand (ID) in diagram (b). The quantity OQ_w will be traded at a price of P_w. Furthermore, the quantity traded is equal to the excess supply at P_w ($\overline{ab}$) in the exporting country and the excess demand ($\overline{cd}$) in the importing country.

Transportation charges impact the quantity traded by increasing the price paid for imports and lowering the price received for exports. In

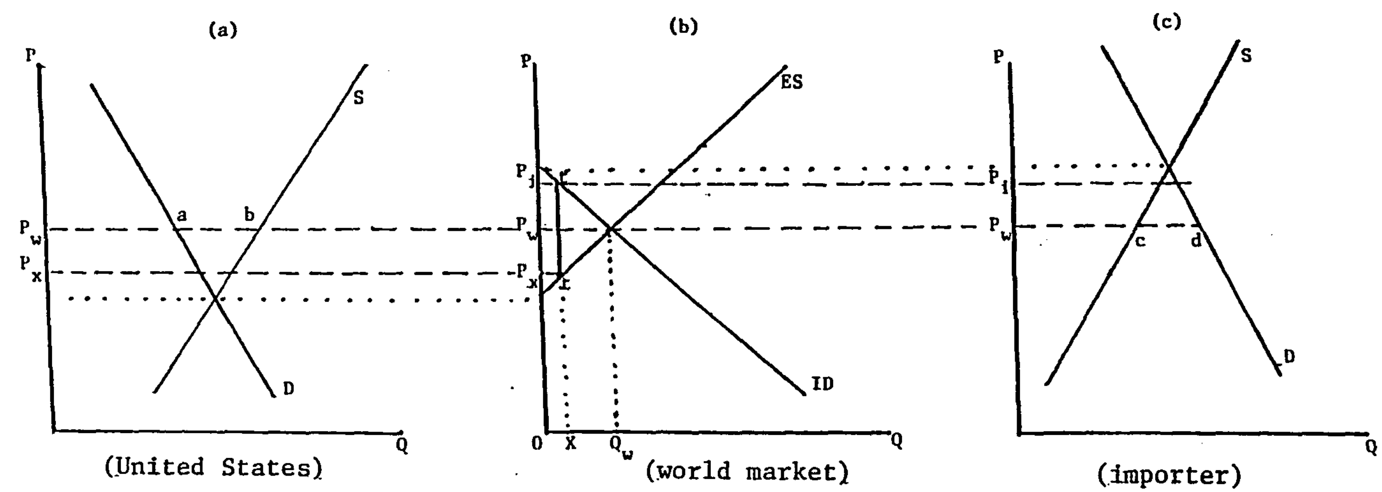

Figure 12. The distribution of transportation charges between the United States and an importing country

diagram (b) of Figure 12, transportation charges are equivalent to the difference between the price received by exporters (P_x) and the price paid by importers (P_i), as represented by the line labeled $\overline{tt}$. Note that the quantity traded decreases from OQ_w to OX. More interesting, however, is the distribution of transportation charges between the importing and exporting country. The portion of the price difference, due to transportation charges absorbed by the exporter would equal P_w-P_x. Importers would absorb P_i-P_w. If the slopes of the export supply and import demand schedules were of equal but opposite value, charges would be shared equally. However, if the slopes differed, the portion of the transportation charges absorbed by each trading partner would differ as illustrated in Figure 13.

In Figure 13, the import demand curve is more inelastic than the export supply curve. As discussed previously, this would result from a relatively more inelastic domestic demand and/or supply schedule in the importing country than presented in Figure 12. As in the previous figure, the introduction of trade would result in the quantity OQ_w being traded at a world price of P_w. The introduction of transportation charges, equal to $\overline{tt}$, would lower the price received in the exporting country from P_w to P_x and raise the price in the importing country from P_w to P_i. However, the distribution of the charges is no longer the same. The importing country absorbs P_i-P_w, which is now much greater than P_w-P_x, the portion absorbed by the exporting country.

The increase in transportation charges due to the imposition of user charges would, if passed forward to the international market, shift the line labeled $\overline{tt}$ toward the vertical axis of diagram (b) in Figures 12 and

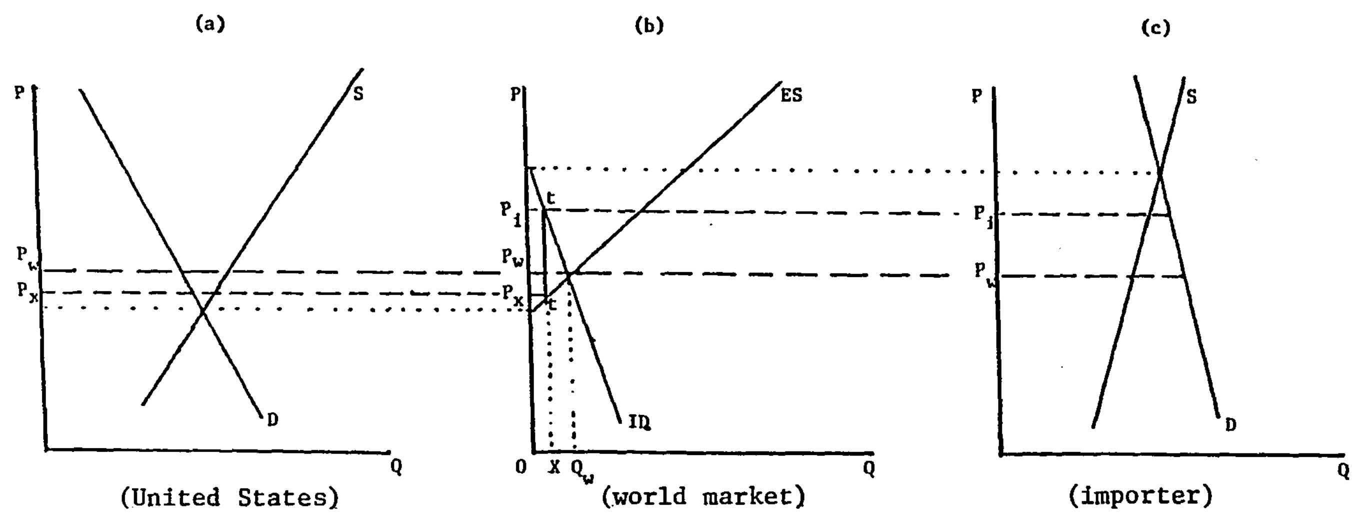

Figure 13. The distribution of transportation charges between the United States and an importing country given an inelastic import demand schedule

13. From the previous discussion it is apparent that the greater the inelasticity of import demand, or elasticity of export supply, the more significant the portion of user charges that would be absorbed by foreign purchasers of U.S. grain.

The critical issue is whether barge companies can pass user charges forward to exporters and exporters pass the tax forward to foreign purchasers. Certainly an inelastic import demand and a shortage of transportation equipment would allow barge owners to pass the user charges forward to importing countries. These conditions, however, will likely encourage increased investment in barge equipment. Over-time, the increased supply of barges will offset the conditions which encouraged the investment in barge equipment and allow user charges to be passed forward.

An Alternative to Linear Programming

A linear programming model requires that transport rates and the supply of and demand for commodities remain fixed in a particular solution. As a result, a solution which simultaneously results in the optimal shipment pattern and recognizes the variety of shipper responses to increased barge rates is not obtainable. Quadratic programming, while incorporating specific shipper responses to a change in barge rates, requires a significantly greater degree of complexity in data specification. This section will present the conceptual framework and data requirements of quadratic programming.

Takayama and Judge [44] have demonstrated the applicability of quadratic programming within a spatial equilibrium context. The conceptual framework of their argument is demonstrated in figure 14. The similarity between figure 14 and diagram (b) in either figure 12 or 13 is apparent. The only notable difference is definitional. The export supply (ES) or import demand (ID) schedules are representative of exports and imports between any two modeled regions and, therefore, may be used to analyze shipments, between domestic regions, as well as international shipments.

In figure 14, P_d and P_s are equilibrium prices in the deficit and surplus regions, respectively. As in figures 12 and 13, these prices correspond to the prices established in the deficit and surplus regions in the absence of trade. P_t and Q_t are the equilibrium price and quantity given trade between the two regions and no transportation costs. Transportation charges equal to $\overline{tt}$ would lower the price received in the exporting region from P_t to P_x, increase the price paid in importing regions from P_t to P_i, and decrease the quantity traded from OQ_t to OX. The objective of quadratic programming is to maximize the benefits from trade. In the absence of transportation charges, these benefits are equivalent to the area defined by the triangle aed. Given the cost of transportation between the two regions, the net benefits of trade are equivalent to the area afgd minus the transportation charges bfgc.

The net benefits from trade, or net social payoff [44], is dependent upon the slopes of the ES and ID curves and the cost of transportation between the two regions. The non-linearity of the objective function results because export supply and import demand, or more appropriately,

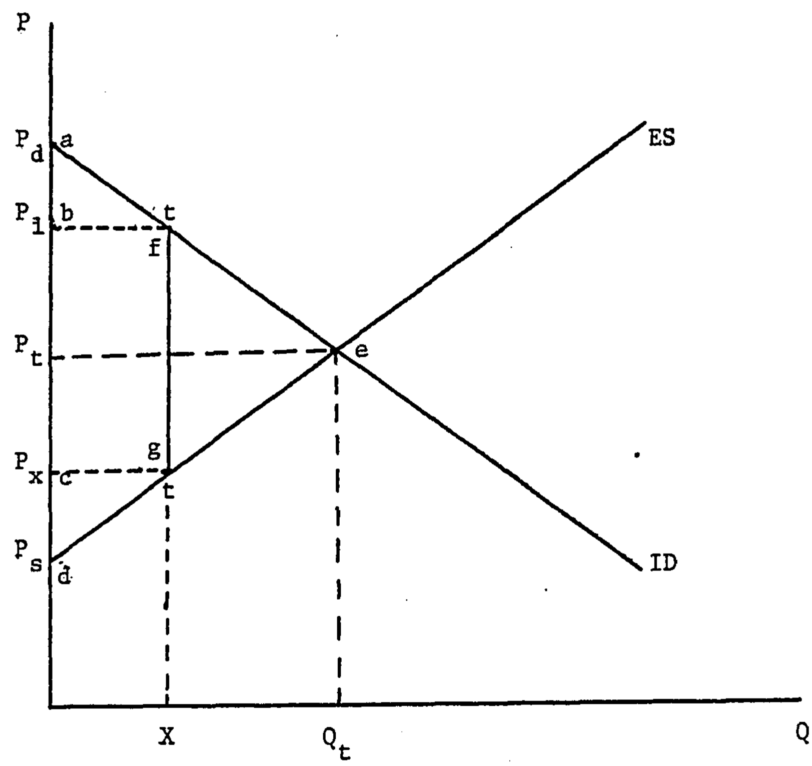

Figure 14. Derivation of the net social payoff function

the underlying supply and demand in the surplus (deficit) region, are a function of the price received (paid) for the traded commodity. In addition, the cost of transportation between the two regions may be a function of the quantity traded.

The critical data requirement of the quadratic model is the correct specification of the export supply and import demand schedules. The derivation of these schedules depends upon the change in the magnitude of the excess demand (excess supply) in the deficit (surplus) region in response to a change in price. Empirically, the export supply and import demand schedules may be estimated, given the elasticity of export supply and elasticity of import demand. These elasticities may be approximated, given the region's own elasticity of demand (E_d), the region's own price elasticity of supply (E_s), an historical average of regional commodity consumption (Q_d), an historical average of regional commodity production (Q_s), average exports (Q_e), or imports (Q_i) as follows [29]:

$$E_m = \frac{Q_d}{Q_m} \left| E_d \right| + \frac{Q_s}{Q_m} E_s \qquad (45)$$

and

$$E_x = \frac{Q_s}{Q_e} E_s + \frac{Q_d}{Q_e} \left| E_d \right| \qquad (46)$$

where

E_m = elasticity of import demand

E_x = elasticity of export supply

It is the relationship, implied by equations (45) and (46), of the traded commodity market elasticities to the regional commodity elasticities, production, and consumption which determines the linkage between regional markets and the market in which commodities are traded. It is also this relationship which would be the most difficult to estimate, given the purpose of this analysis. This analysis required, given transport rates which vary with the distance from the river, that regional areas be well-defined and decrease in size the closer the shipping point to river elevators. An adequate specification of a quadratic model would require the estimation of the factors determining E_x and E_m for each region.

Additionally, as discussed in the previous sections of this chapter, the rate response of competitive modes to user charges is critical in determining the incidence of the tax. If the transport sector responds to user charges by adjusting rates, the quantity traded and cost of exchange will be impacted. In order to measure the response of the transport sector to declining or increasing traffic volume, a function relating transport rates to the quantity traded between regions would be required. The elasticity of barge demand coefficients, presented in this analysis, are a step in the right direction. However, it must be noted that these elasticity coefficients are valid only for the rates and taxes as used in this analysis. In addition, deregulation of the rail industry and the consequent increased freedom to set rates in response to traffic levels is a recent phenomenon. At this time, the required time series of data necessary to measure rate response are unavailable.

CHAPTER VII. CONCLUSIONS

Implications for Agricultural Shipments

The impact of inland waterway user charges on projected 1990 corn, soybean and wheat flows and transport costs is dependent upon the type of tax implemented. A linear programming model was used to project the impacts of a fuel tax, a river segment specific ton-mile tax, and a combination fuel-river segment specific ton-mile tax on inland waterway grain shipments. Additionally, separate rail rate responses in water-competitive regions of 50 and 100 percent of the segment specific ton-mile tax were analyzed. The major assumption of this analysis is that user charges will be absorbed by commodity shippers. The implications of inland waterway user charges are the following:

- The 1990 systemwide transportation costs are projected at $8.35 billion dollars. The greatest increase in systemwide cost--1.43 percent--is projected under a segment tax accompanied by a 100 percent railroad rate response. In this solution, both direct rail and barge export shipments originating in water competitive regions are transported at higher rates. In the solutions that are not accompanied by a railroad rate response, the segment-specific ton-mile tax causes the greatest increase in systemwide cost. The increase in cost, however, is less than one percent of the systemwide costs projected in the base solution.
- In total, the combination fuel-segment specific tax results in the minimal amount of tax revenue--$59.3 million--generated from

corn, soybean, and wheat traffic. The segment tax with a 100 percent rail response results in the largest tax revenue—$67.0 million--generated. In this solution, although origin-specific tax rates are lower than with the segment-tax with no rail response mechanism, the increase in direct rail export rates is sufficient to force an additional 158 thousand bushels back to barge transportation. The fuel tax and segment tax with no rail response result in $60.7 million and $65.5 million in tax revenue generated from grain shipments, respectively.

- The weighted average per bushel user tax generated from grain shipments ranges from 2.99 cents per bushel in the combination fuel-segment tax solution to 3.35 cents per bushel in the segment tax with no rail response solution. The weighted average per bushel user tax generated by the fuel tax is 3.10 cents per bushel. Given no rail response, both the total tax generated and per bushel increase in transportation costs are greater with the segment tax than either the fuel or combination fuel segment taxes.
- Iowa and Minnesota originate about 32 percent of all grain shipped on the inland waterways. These two states account for 40.9 percent of the total fuel tax generated and 46.8 percent of the segment tax generated from grain shipments. In the case of the fuel tax, the longer distances from Baton Rouge, Louisiana that grain originating in these two states must travel, explain the disproportionate share of tax burden. In the case of the

segment tax, the longer distances combined with the high operating, maintenance and construction costs of the Upper Mississippi River, contribute to the relatively higher tax burden. Illinois and Missouri originate about 44 percent of all grain shipped on the inland waterways. These two states, however, account for only 40.9 and 37.2 percent of tax revenue generated under the fuel and segment taxes, respectively. It is the relatively shorter distances to Baton Rouge that grain from these states travels and the lower operations, maintenance and construction costs of the Illinois and Lower Mississippi Rivers that explains the smaller percentage of the total taxes paid by these two states.

- In the absence of inland waterway user charges, grain barge traffic in the 1989-1990 crop year is projected at 2.4 billion bushels. This total represents a 40 percent increase in traffic over average annual grain barge shipments of 1.7 billion bushels during the 1978 to 1981 period and a 22 percent increase over the 1.9 billion bushels shipped between April 1, 1980 and March 31, 1981.
- In total, grain diversions from barge traffic range from 10.6 percent under a segment tax with 100 rail response to 17.6 percent under both the fuel and segment tax with no rail response solutions. Total grain barge shipments in the solutions with the greatest diversions represent an increase of 15.3 percent over the average annual barge shipments in the 1978-1981 period.

- The greatest increase over 1978-1981 average bushels shipped by river segment occurs on the Upper Mississippi River--about 488.3 million bushels. The Upper Mississippi is also most affected in terms of absolute diversions. The greatest diversions--294.8 million bushels--occur with the segment tax-no rail response solution. Even when railroads respond by raising competitive export rates by 100 percent of the user charge, diversions remain at 237.5 million bushels. Export shipments through Great Lakes ports and shipments to interior processing points increase in this solution.
- Total diversions from Illinois River traffic are largest in the segment tax-no rail response solution--about 25 million bushels. This relatively smaller amount of diversions is indicative of the fact that there are few alternatives to barge transportation in water competitive areas served by the Illinois River.
- The Ohio River exhibits an interesting pattern of diversions. Diversions occur only under a fuel tax mechanism. Indicated by this pattern is the discrepancy between segment specific recovery of expenditures and systemwide recovery. Under a fuel tax, the user tax on the Ohio River ranges from 2.9 cents per bushel of corn at Cincinnati, Ohio to 2.1 cents per bushel at Mount Vernon, Indiana. This increase in barge rates is significant enough to divert barge shipments to multiple-car rail export shipments to Atlantic Coast ports. Under a segment tax, rates to the Atlantic coast do not become competitive.

- The Missouri and Arkansas Rivers exhibited the greatest percentage diversions in all solutions excluding the 100 percent rail response solution. However, the total number of bushels diverted on these rivers--60 million bushels--is small compared to the diversions on the Upper Mississippi.
- Projected revenues generated by the 2.37 billion bushels shipped by barge in the base solution equal $725 million. Barge revenues decline by about 20 percent in all solutions except the segment tax-100 percent rail response solution. In general, given that user charges are applied as rate increases, the decline in barge revenues suggest that the demand for barge services in total is elastic.
- The elasticity of demand for barge transportation, given the rates and barge transportation increases as utilized in this analysis, although elastic in total, is not elastic for all river segments. The Lower Mississippi, Illinois and Columbia-Snake exhibit an inelastic demand. Additionally, if the elasticity coefficient is computed at the inland grain origin, elasticity coefficients vary from 0.0 to -18.4. Distance from the river and availability of substitute transportation contribute to this range in the estimated elasticity coefficients.
- Direct rail shipments to export ports increase under all tax mechanisms. The largest increase occuring because of the fuel tax--about 10.7 percent. Rail shipments to barge loading facilities decline considerably in all user tax solutions. The

greatest decrease in rail-barge traffic--approximately 56 percent--occurs in the segment tax-no rail response solution. The total effect of user charges on rail shipments is an increase in bushels shipped in all solutions except the segment tax-100 percent rail response solution. In this solution, total bushels shipped decline slightly. Rail revenues, however, increase in all user charge scenarios. In all tax solutions, the gain in rail revenues is greater than the percentage change in bushels shipped. The difference reflects that direct rail shipments, usually long-haul grain movements, are the most important determinant of rail revenue.

- The most significant reduction in transportation costs, as measured by the shadow prices associated with model constraints, would occur with an increase in multiple-car rail facilities. For the effective constraints, shadow prices range from $4.98 for 50-car rail facilities in Minnesota to $66.65 for 54-car facilities in North Dakota. In general, the states exhibiting the greatest deficiency in multiple-car facilities are Nebraska, Montana, Idaho, and North Dakota. Increased multiple-car capacity in these states would significantly reduce systemwide transport costs.
- The greater percentage of truck shipments is truck-barge combination shipments. These shipments decline under all user charge solutions. Direct truck shipments to export ports increase under all user charge solutions. The net effect of user charges on

truck shipments is a decrease in bushels shipped in all but the segment tax - 100 percent rail rate response. Truck revenues increase under all user charge solutions. Again, as with rail shipments, the increase in revenues reflect the importance of the longer-haul direct to export grain shipments.

Suggestions for Additional Work

By construct, input to the linear programming model is fixed. Production levels and foreign demand are the most noteworthy. Production of corn, soybeans and wheat is variable between years. The effect of uncontrollable factors such as the weather, or government interference in the production decision can greatly effect the volume of grain available for transport. In some areas, Nebraska for example, a decrease in the grain available for transport may free up multiple-car rail capacity and divert grain shipments transported by barge in this analysis. On the other hand, since 100 percent of multiple car capacity is utilized in Nebraska (Table 62), production at a level greater than that specified in this analysis would in all likelihood mean a greater volume of barge shipments. Certainly, Nebraska represents the most significant case in point. However, the effect of varying production levels may have more subtle effects as processing demands are filled from nearby locations again allowing more distant grain to move to export by barge or rail shipment.

Foreign demand was also held constant in this analysis. Grain movements through the Pacific Northwest ports enjoy a relative advantage in exporting to the Far East over export shipments through the Gulf ports. This is especially true given the recent increases in multiple-car rail rates to Pacific ports. A change in the distribution of foreign demand as utilized in this analysis may have a dramatic impact on domestic grain flows.

In addition to these two suggested areas, a number of other changes would seem appropriate and would certainly be enlightening. In this analysis, storage was not considered, that is, by construct, available supplies equalled total demand. A change in either supplies or demand, resulting in excess supply, would indicate which regions are susceptible to chronic excess supply because of high transportation charges. The upper Missouri River valley might be a likely candidate.

The fundamental assumption underlying this analysis is that user charges will be passed back to grain shippers in the form of higher transportation rates. This need not be the case. In particular, during periods of surplus transportation equipment and low export demand, it is conceivable that barge companies would absorb some of the user fee. Application of a percentage of the total user fee at specific origins would have two effects. First, the quantity of grain shipped by barge would in all likelihood increase. Second, given the increase in barge traffic the user fee sufficient to generate 100 percent of expenditures on OMRC would be smaller.

This study considered only inland waterway shallow-draft user charges. Deep water ports are not immune to user charge imposition. User fees on export shipments through deep-draft ports would impact domestic grain movements. The effect on grain movements might be dramatic especially if the user fee is constructed in a similar fashion to the river segment-specific ton-mile tax utilized in this study. If a port-specific ton-mile tax was incorporated within this model shipments through Great Lakes ports would in all probability be severely hampered.

Finally, the impact of increased user charges on the grain production and utilization decision of producers is an important area that needs attention. Increased transportation charges may affect the choice between cropping and livestock activities and the location of processing facilities. Farm to elevator transport cost would need to be included. A comparison of the returns to direct commodity marketing and indirect marketing of grain through the livestock enterprise could be quantified. A model of this design would further clarify the impact of inland waterway user charges.

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ACKNOWLEDGEMENTS

Each of the individuals mentioned on this page deserve much more than the simple words of recognition I have to offer.

My parents, John and Loretta Beaulieu, never lost sight of the goals I had set before myself. Their support and encouragement kept me on track.

Phillip Baumel offered me the opportunity to join his research effort. The experience was rewarding. His assistance during some difficult times will long be appreciated.

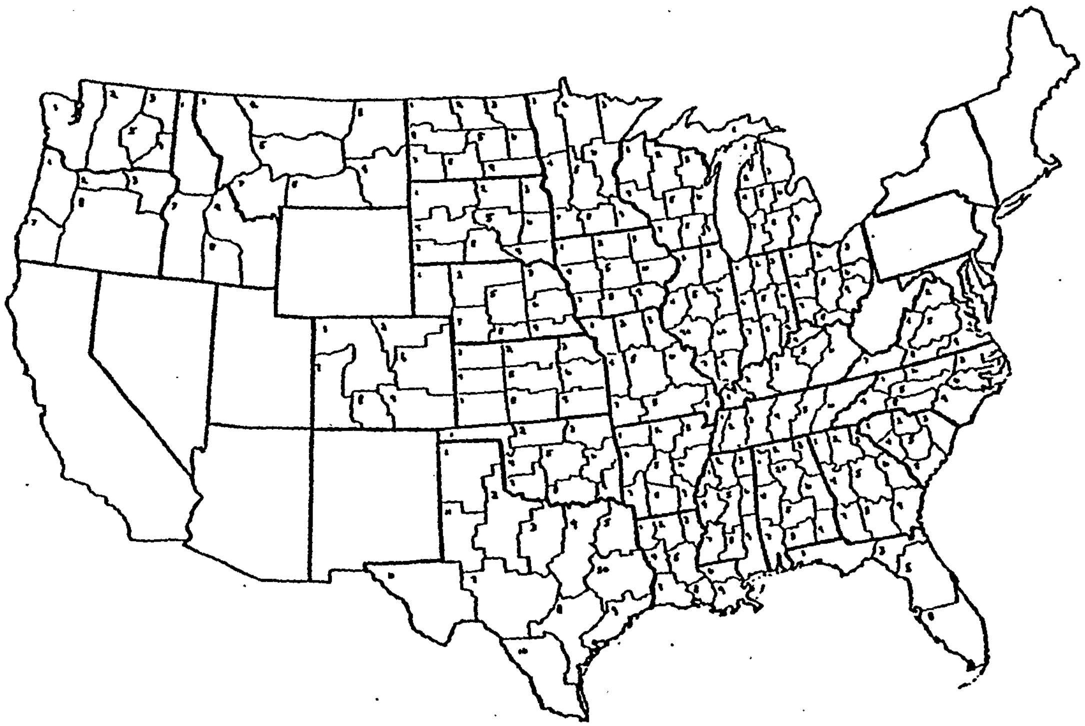
Barbara Klett typed this dissertation, in the greater part by long distance. I am sincerely grateful for her efforts.

Many other individuals offered their advice, judgement and encouragement at times when it was most needed. These people include: Neva Wagner, Benjamin Allen, Jim Christensen, Tom Drinka, John Dunn, Roger Ginder, Neil Harl, Bob Hauser, Roy Hickman, Curt Huyser, Mark Lange, David Lawrence, Jim McConnon, John Miller, Ken Stone, and John VanSickle.

SusAn Maguire, in recent months, has contributed more than she may realize to my well-being and growth. Simply stated, our relationship has become our motivation. This dissertation is only one sign of our growing dedication to our goals and to each other.

Finally, to my children, Matthew and Elizabeth, this work is dedicated.

APPENDIX A. CRD MAP AND SUPPLY/DEMAND PROJECTIONS BY CRD



Map A1. CRD regions by state.

TABLE A1. 1989/90 PROJECTIONS OF CORN PRODUCTION, SEED, FEED, AND PROCESSING BY REGION OR CITY IN 1000 BUSHELS

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
AL	1	1052	22	4877	46600
	2	5337	80	14882	0
	3	6235	139	15443	0
	4	397	14	3979	2260
	5	501	15	5283	0
	6	424	16	6746	0
	7	12119	108	3080	0
	8	5341	81	5929	0
	9	6555	148	10032	0
	20	578	23	25626	0
	TOTAL	38539	646	95877	48860
AZ	TOTAL	8068	93	25271	0
AR	1	185	2	33532	0
	2	207	4	7379	0
	3	1035	12	8850	0
	4	220	4	20479	0
	5	299	4	5978	0
	6	99	2	3105	0
	7	181	4	17690	0
	8	362	6	6224	0
	9	444	8	1727	0
	TOTAL	3032	46	104964	0
CA	TOTAL	49173	556	206914	31160
CO	1	35	2	2523	0
	2	38625	369	30912	0
	6	76020	636	20188	0
	7	793	10	3786	0
	8	71	4	1261	0
	9	2756	26	4416	0
	TOTAL	118300	1047	63086	0
DE	TOTAL	16015	149	22448	0
FL	1	6941	150	5758	0
	3	12271	265	13236	2540
	5	5431	117	31551	0
	8	2759	60	14332	0
	TOTAL	27402	592	64877	2540

TABLE A1. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
GA	1	915	7	15053	9050
	2	1488	15	34189	0
	3	176	6	15415	0
	4	1764	64	7781	0
	5	1003	171	13076	2260
	6	5555	216	10394	0
	7	57680	480	12314	2260
	8	31832	416	20547	0
	9	9810	827	15813	5070
	TOTAL	110223	2202	144582	18640
ID	TOTAL	2769	106	22843	0
IL	1	287694	2191	89773	0
	3	190553	1372	27592	7230
	4	129781	1193	55945	0
	5	248837	1932	26022	0
	6	230497	1901	18108	6790
	7	44607	339	24933	0
	9	59684	504	14944	0
	40	161954	1280	61908	0
	60	200655	1362	32105	0
	CHICAGO	.	.	.	109830
	DECATUR	.	.	.	95390
	PEORIA	.	.	.	37290
	TOTAL	554262	12074	351330	256530
IN	1	144271	1369	14658	0
	2	99841	960	35182	2260
	3	70249	692	21654	0
	4	106296	803	15232	25370
	5	186941	1431	35554	21280
	6	60358	539	16755	0
	7	91458	934	23480	4530
	8	45603	347	12445	0
	9	33448	257	10429	0
	TOTAL	838465	7332	185389	53440
IA	1	240787	1969	90405	0
	2	253577	2046	57848	0
	3	265173	1747	83609	0
	4	195426	2132	77592	0
	5	236694	2228	63212	5070
	6	226974	1652	79810	2260

TABLE A1. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	7	102829	1096	40600	0
	8	46213	705	31003	0
	9	137446	1229	56151	0
	CEDAR RAPIDS	.	.	.	112900
	CLINTON	.	.	.	46320
	KEOKUK	.	.	.	33760
	MUSCATINE	.	.	.	46650
	TOTAL	705119	14804	580230	246960
KS	1	23943	268	6696	0
	2	3799	38	16936	0
	3	4571	31	13755	0
	4	13256	150	11293	0
	5	4587	52	13158	0
	6	2128	39	13418	0
	7	81192	779	29423	0
	8	23848	210	13447	0
	9	331	8	15585	0
	TOTAL	157655	1575	133711	0
KY	1	30826	402	5439	0
	2	94313	780	14008	15180
	3	48767	485	19054	4530
	4	6137	56	3623	6790
	5	17431	157	11668	0
	6	6402	57	5929	0
	TOTAL	203876	1937	59721	26500
LA	TOTAL	0	0	28095	36780
MD	TOTAL	75525	776	43788	4530
MI	1	1439	20	2197	0
	2	3105	47	2562	0
	3	1767	23	2085	0
	4	3988	65	2672	0
	5	14817	283	8056	0
	6	47607	599	12096	0
	7	58259	548	19216	0
	8	78883	979	21941	0
	9	42584	525	13090	5070
	TOTAL	252449	3089	83915	5070

TABLE A1. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
MN	1	7744	0	23665	2030
	2	1004	25	8006	0
	3	0	0	4910	0
	4	69910	1082	59525	0
	5	126985	1659	97749	0
	6	29900	475	22564	0
	7	98017	1300	87231	0
	8	224644	2145	83638	0
	9	158821	1532	74467	0
	TOTAL	717025	8218	461755	2030
MS	1	77	2	542	0
	2	223	4	2987	0
	3	905	17	5292	0
	4	93	2	1239	2260
	5	552	14	13826	0
	6	373	13	5043	0
	7	303	11	4416	0
	8	642	25	14961	0
	9	1240	33	12134	0
	TOTAL	4408	121	60440	2260
MO	1	38845	546	28265	0
	2	22113	276	18768	0
	3	24733	294	23183	0
	4	16685	129	18145	0
	5	11971	166	34344	0
	6	18158	163	20938	0
	7	186	3	16605	0
	8	217	2	14293	2260
	9	22159	184	5837	0
	KANSAS CITY	.	.	.	37040
	TOTAL	155067	1763	180378	39300
MT	TOTAL	770	92	18385	0
NE	1	26174	253	14644	0
	2	104195	755	19149	0
	3	172790	1862	93662	0
	5	168578	1332	38124	0
	6	200869	1851	79101	2260
	7	120140	1044	14265	0
	8	126458	1095	19298	0
	9	83637	766	46689	2260

TABLE A1. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	TOTAL	2841	8958	324932	4520
NV	TOTAL	0	0	3231	0
NJ	TOTAL	5085	87	8606	0
NM	TOTAL	19782	185	15155	0
NY	TOTAL	68493	1611	142566	21280
NC	1	2498	69	15222	36830
	2	4745	136	7224	0
	3	45531	566	13534	0
	4	2247	48	3960	0
	5	5130	123	19341	0
	6	39633	572	16658	17210
	8	8293	127	19381	0
	9	39766	477	28040	2260
	TOTAL	147843	2118	123360	56300
ND	1	90	1	1525	0
	2	537	0	2046	0
	3	344	8	1784	0
	4	83	1	2658	0
	5	1364	24	2614	0
	6	3425	60	2501	0
	7	142	9	2661	0
	8	809	21	3993	0
	9	19042	516	5735	0
	TOTAL	25836	640	25517	0
OH	1	74746	689	18259	0
	2	67554	551	11910	0
	3	46776	428	13516	0
	4	79487	670	28282	4530
	5	134788	969	21039	12720
	6	22695	198	7928	0
	7	64251	453	14576	46890
	8	26744	165	6433	16230
	9	15770	124	4379	0
	TOTAL	532811	4247	126322	80370
OK	1	7059	97	5343	0
	2	90	5	5147	2260

TABLE A1. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	3	63	3	4536	0
	4	277	6	3451	0
	5	239	4	6633	0
	6	18	1	3218	0
	7	394	6	3638	0
	8	224	3	2833	0
	9	24	1	2852	0
	TOTAL	8388	126	37651	2260
OR	TOTAL	1033	40	17590	0
PA	TOTAL	154883	1839	106277	57880
SC	1	1383	21	4051	4530
	2	363	6	1305	0
	3	22344	346	5274	0
	4	902	14	6241	0
	5	19004	294	9225	2260
	8	14603	226	6285	0
	TOTAL	58599	907	32381	6790
SD	1	1943	28	5796	0
	2	2391	108	20102	0
	3	9590	236	20493	0
	4	363	6	4152	0
	5	5662	169	20298	0
	6	43115	863	42622	0
	7	1440	17	5451	0
	8	3747	68	9651	0
	9	71551	1061	48588	0
	TOTAL	139802	2556	177153	0
TN	1	5673	65	4790	29900
	2	11432	154	11266	0
	3	12366	168	8531	4530
	4	13623	147	14114	0
	5	14439	188	8458	78520
	6	8279	118	12049	0
	MEMPHIS	.	.	.	40120
	TOTAL	65812	840	59208	153070
TX	1	226506	1815	78735	13970
	2	247	0	13039	0
	3	0	1	14983	0

TABLE A1. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	4	82	4	18815	6790
	5	82	4	32284	0
	6	165	0	7399	0
	7	2033	24	11267	0
	8	1841	51	28973	0
	9	8546	98	3177	0
	10	1099	71	10034	0
	11	33991	321	13028	0
	50	220	6	10043	0
	TOTAL	274812	2395	241777	20760
UT	TOTAL	1822	116	12024	0
VA	2	12603	177	13416	24890
	4	1202	9	4911	0
	5	8532	133	7475	0
	6	14086	274	3769	4530
	7	2325	14	7141	0
	8	4071	60	4901	0
	9	18206	303	10222	0
	TOTAL	61025	970	51835	29420
WA	TOTAL	11638	146	25436	0
WV	TOTAL	5817	104	12206	2260
WI	1	17173	322	14927	0
	2	13369	180	16907	0
	3	14673	194	8494	0
	4	52353	746	28089	0
	5	37209	465	12389	0
	6	60650	681	28431	0
	7	48042	557	36243	0
	8	87460	1110	36550	0
	9	31376	388	9693	2260
	TOTAL	362305	4643	191723	2260
WY	TOTAL	3095	89	7042	0

TABLE A2. 1989/90 PROJECTIONS OF SOYBEAN PRODUCTION, SEED, FEED, AND PROCESSING BY REGION OR CITY IN 1000 BUSHELS

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
AL	1	2914	157	0	34308
	2	10823	529	0	0
	3	6208	239	0	0
	4	5383	226	0	0
	5	7770	449	0	0
	6	3117	166	0	0
	7	4469	185	0	0
	8	8195	303	0	0
	9	10779	481	0	495
	20	3822	155	0	0
	TOTAL	63480	2890	0	34803
AZ	TOTAL	0	0	0	0
AR	1	52	1	0	6640
	2	79	2	0	0
	3	44132	1596	0	25454
	4	2004	86	0	0
	5	3380	141	0	0
	6	61265	2196	0	54397
	7	4860	259	0	0
	8	2017	87	0	0
	9	13217	607	0	0
	TOTAL	131006	4975	0	86491
CA	TOTAL	0	0	0	0
CO	TOTAL	0	0	0	0
DE	TOTAL	7631	267	0	0
FL	1	8602	351	0	0
	3	1757	72	0	0
	5	2465	101	0	0
	8	0	0	0	0
	TOTAL	12824	524	0	0
GA	1	7600	212	0	43161
	2	3432	144	0	0
	3	4225	186	0	0
	4	4930	231	0	0
	5	5346	370	0	5196
	6	8765	626	0	0

TABLE A2. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	7	14665	596	0	0
	8	11379	398	0	16600
	9	2626	148	0	0
	TOTAL	62968	2911	0	64957
ID	TOTAL	0	0	0	0
IL	1	26443	661	0	0
	3	37523	966	0	0
	4	30883	859	0	18108
	5	52532	1170	0	13207
	6	56854	1433	0	37396
	7	32729	1044	0	8348
	9	26718	1037	0	0
	40	58229	1505	0	33180
	60	70960	1688	0	15041
	CHICAGO	.	.	.	18255
	DECATUR	.	.	.	74138
	TOTAL	392871	10363	0	217673
IN	1	22642	644	0	0
	2	19375	578	0	19088
	3	20476	606	0	20258
	4	23743	629	0	11457
	5	47416	1103	0	35140
	6	17244	460	0	6356
	7	17943	465	0	1982
	8	1800	65	0	0
	9	4088	137	0	0
	TOTAL	174727	4687	0	94281
IA	1	81251	1668	0	18698
	2	69065	1772	0	8074
	3	30040	644	0	0
	4	67021	1344	0	1107
	5	51751	1439	0	0
	6	23870	676	0	0
	7	32007	942	0	0
	8	10720	448	0	0
	9	19937	691	0	8516
	CEDAR RAPIDS	.	.	.	24347
	DES MOINES	.	.	.	43161
	FORT DODGE	.	.	.	74528
	SIOUX CITY	.	.	.	31536

TABLE A2. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	TOTAL	385662	9624	0	209967
KS	1	72	0	0	0
	2	1296	44	0	0
	3	10416	431	0	0
	4	99	4	0	0
	5	759	29	0	0
	6	9732	578	0	0
	7	898	23	0	0
	8	3769	75	0	0
	9	12710	691	0	0
	TOTAL	39751	1875	0	45501
KY	1	15308	548	0	0
	2	40659	1247	0	9085
	3	14012	437	0	0
	4	891	30	0	0
	5	2224	64	0	0
	6	530	15	0	0
	LOUISVILLE	.	.	.	29881
	TOTAL	73624	2341	0	38966
LA	1	3757	165	0	1655
	2	814	44	0	0
	3	15203	722	0	0
	4	4036	148	0	0
	5	56847	1783	0	16600
	6	1035	33	0	0
	7	28103	1152	0	0
	8	6130	158	0	0
	9	395	7	0	0
	TOTAL	116320	4212	0	18255
MD	TOTAL	14371	467	0	35414
MI	1	0	0	0	0
	2	3	0	0	0
	3	22	0	0	0
	4	61	0	0	0
	5	5310	164	0	0
	6	9367	356	0	0
	7	1756	61	0	0
	8	7409	236	0	0
	9	8117	286	0	0

TABLE A2. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	TOTAL	32045	1103	0	0
MN	1	171	5	0	0
	2	0	5	0	0
	3	0	0	0	0
	4	18078	760	0	16600
	5	34917	888	0	11067
	6	1345	42	0	5533
	7	64307	1592	0	0
	8	82577	1763	0	49043
	9	12016	355	0	685
	TOTAL	213411	5410	0	82928
MS	1	18115	596	0	18993
	2	19200	660	0	548
	3	16476	741	0	0
	4	24105	923	0	12174
	5	9282	309	0	25728
	6	20535	771	0	0
	7	12112	407	0	0
	8	4483	139	0	0
	9	7907	235	0	0
	TOTAL	132215	4781	0	57443
MO	1	31392	1104	0	0
	2	31955	1072	0	0
	3	34092	1093	0	42761
	4	8955	361	0	0
	5	22417	513	0	0
	6	13229	427	0	0
	7	6158	308	0	0
	8	777	29	0	0
	9	45300	1434	0	43786
	KANSAS CITY	.	.	.	37069
	TOTAL	194275	6341	0	93616
MT	TOTAL	0	0	0	0
NE	1	0	0	0	1433
	2	661	1	0	0
	3	24415	751	0	1107
	5	1157	26	0	0
	6	27511	936	0	24653
	7	229	1	0	0

TABLE A2. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	8	407	11	0	0
	9	9179	283	0	0
	TOTAL	63559	2009	0	27193
NV	TOTAL	0	0	0	0
NJ	TOTAL	5938	184	0	0
NM	TOTAL	0	0	0	0
NY	TOTAL	858	33	0	0
NC	1	252	12	0	0
	2	2272	139	0	0
	3	26081	478	0	2213
	4	268	17	0	0
	5	2125	138	0	0
	6	6727	423	0	16485
	8	3971	375	0	0
	9	10903	699	0	17127
	TOTAL	52599	2281	0	35825
ND	1	0	0	0	0
	2	4	0	0	0
	3	160	7	0	0
	4	0	0	0	0
	5	0	0	0	0
	6	2678	76	0	0
	7	0	0	0	0
	8	0	0	0	0
	9	2293	65	0	0
	TOTAL	5135	148	0	0
OH	1	32757	952	0	17265
	2	25871	675	0	7821
	3	3227	103	0	0
	4	32361	761	0	25454
	5	52390	1171	0	6082
	6	216	7	0	0
	7	22157	560	0	0
	8	10492	321	0	0
	9	775	22	0	0
	TOTAL	180246	4572	0	56622

TABLE A2. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
OK	1	18	0	0	0
	2	159	12	0	0
	3	4107	212	0	0
	4	12	3	0	0
	5	1103	61	0	0
	6	1505	80	0	0
	7	104	0	0	0
	8	938	44	0	0
	9	399	37	0	0
	TOTAL	8345	449	0	0
OR	TOTAL	0	0	0	0
PA	TOTAL	3299	103	0	0
SC	1	3864	182	0	5312
	2	1772	84	0	0
	3	14801	698	0	4869
	4	3352	158	0	0
	5	9582	452	0	11067
	8	7560	356	0	0
	TOTAL	40931	1930	0	21248
SD	1	0	0	0	0
	2	15	3	0	0
	3	1101	38	0	0
	4	0	0	0	0
	5	496	5	0	0
	6	5628	155	0	0
	7	0	0	0	0
	8	321	2	0	0
	9	16749	420	0	0
	TOTAL	24310	623	0	0
TN	1	28852	998	0	1655
	2	23996	1228	0	0
	3	13699	592	0	2213
	4	10556	378	0	0
	5	4572	199	0	0
	6	1914	76	0	0
	MEMPHIS	.	.	.	56431
	TOTAL	83589	3471	0	60299

TABLE A2. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
TX	1	1132	40	0	6925
	2	0	0	0	0
	3	10	1	0	0
	4	667	69	0	0
	5	1989	139	0	0
	6	0	0	0	0
	7	0	0	0	0
	8	0	0	0	0
	9	26783	1104	0	11067
	10	0	0	0	0
	11	455	18	0	0
	50	2158	20	0	0
	TOTAL	33194	1391	0	17992
UT	TOTAL	0	0	0	0
VA	2	515	15	0	0
	4	9	0	0	0
	5	2310	76	0	0
	6	7594	218	0	0
	7	4	0	0	0
	8	1396	55	0	0
	9	5982	168	0	0
	TOTAL	17810	532	0	0
WA	TOTAL	0	0	0	0
WV	TOTAL	0	0	0	0
WI	1	99	5	0	0
	2	16	1	0	0
	3	5	1	0	0
	4	542	26	0	0
	5	181	9	0	0
	6	346	11	0	0
	7	993	23	0	0
	8	4213	94	0	0
	9	5161	139	0	0
	TOTAL	11556	309	0	0
WY	TOTAL	0	0	0	0

TABLE A3. 1989/90 PROJECTIONS OF WHEAT PRODUCTION, SEED, FEED, AND PROCESSING BY REGION OR CITY IN 1000 BUSHELS

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
AL	1	62	5	103	0
	2	388	19	592	0
	3	135	7	675	0
	4	553	30	100	0
	5	311	20	156	0
	6	133	9	305	0
	7	161	7	103	0
	8	173	8	187	0
	9	267	22	278	0
	20	142	7	1075	0
	TOTAL	2325	134	3574	0
AZ	TOTAL	14895	193	1372	630
AR	1	30	1	1728	0
	2	53	1	193	0
	3	17094	475	624	0
	4	377	14	946	0
	5	602	21	328	0
	6	10873	291	198	0
	7	2745	85	1035	0
	8	132	5	346	0
	9	1164	30	63	0
	TOTAL	33070	923	5461	0
CA	TOTAL	99131	1192	14785	28330
CO	1	1186	94	189	630
	2	10697	634	2314	10140
	6	39503	2001	1511	0
	7	1407	94	283	0
	8	2587	3	95	0
	9	9453	404	331	0
	TOTAL	64833	3230	4723	10770
DE	TOTAL	1048	34	626	0
FL	1	0	0	138	0
	3	0	0	357	0
	5	0	0	2013	0
	8	0	0	327	0
	TOTAL	0	0	2835	0

TABLE A3. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
GA	1	274	8	431	64670
	2	367	12	1514	0
	3	546	15	485	0
	4	467	22	266	0
	5	1267	57	460	0
	6	78	10	451	0
	7	362	9	365	0
	8	56	2	993	0
	9	15	2	899	0
	TOTAL	3432	137	5864	64670
ID	1	9611	191	330	0
	7	15285	304	330	0
	8	26753	533	330	0
	9	34706	691	330	0
	TOTAL	86355	1719	1320	0
IL	1	2213	48	2010	10680
	3	2188	47	944	0
	4	3266	78	941	0
	5	1985	48	479	0
	6	932	23	651	0
	7	12878	374	563	5570
	9	9543	238	235	0
	40	15358	365	1097	10260
	60	15047	381	617	3170
	TOTAL	63410	1602	7537	29680
IN	1	3820	95	502	0
	2	6441	170	1445	0
	3	8749	189	849	1960
	4	4427	122	350	0
	5	9923	233	963	4430
	6	6675	161	467	0
	7	7277	175	925	10920
	8	1507	45	457	0
	9	920	26	409	0
	TOTAL	49739	1216	6367	17310
IA	TOTAL	5013	163	4100	7030
KS	1	47305	1278	400	0
	2	56480	1684	503	0
	3	12597	456	311	0

TABLE A3. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	4	43469	1429	1056	0
	5	61632	2031	707	6460
	6	12221	444	401	0
	7	35573	1995	2994	0
	8	90135	2991	720	30900
	9	16658	637	590	16150
	TOTAL	376070	12945	7682	53510
KY	1	4125	121	90	510
	2	8664	310	324	0
	3	1708	72	362	2120
	4	107	3	74	0
	5	381	12	239	0
	6	237	8	211	0
	TOTAL	15222	526	1300	2630
LA	1	157	6	98	0
	2	36	1	107	0
	3	201	12	64	0
	4	7	0	36	0
	5	11	2	119	0
	6	57	0	442	0
	7	43	2	62	0
	8	0	1	37	6970
	9	1	1	22	0
	TOTAL	513	25	987	6970
MD	TOTAL	4421	131	1247	300
MI	1	170	0	56	0
	2	106	3	115	0
	3	240	7	58	0
	4	709	25	109	0
	5	4777	114	354	0
	6	9263	161	623	1580
	7	4864	120	839	7030
	8	15454	347	788	4750
	9	10479	254	588	2530
	TOTAL	46062	1031	3530	15890
MN	1	89656	2178	664	40
	2	2345	74	302	0
	3	38	0	291	0
	4	52112	1723	1047	2530

TABLE A3. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	5	15750	617	1677	0
	6	648	24	551	0
	7	12241	368	1595	0
	8	13328	0	1318	11390
	9	4557	111	1109	0
	MINNEAPOLIS	.	.	.	46060
	TOTAL	190675	5095	8554	60020
MS	1	1446	38	8	0
	2	785	31	64	0
	3	80	3	224	0
	4	398	14	35	0
	5	221	11	522	0
	6	273	9	107	0
	7	385	19	101	0
	8	99	5	956	0
	9	186	9	349	0
	TOTAL	3873	139	2366	0
MO	1	4919	282	662	0
	2	8086	141	430	0
	3	8781	164	470	0
	4	14494	404	466	0
	5	6547	245	1385	0
	6	7423	234	578	0
	7	5172	170	707	3990
	8	115	9	308	220
	9	26312	506	160	0
	KANSAS CITY	.	.	.	61740
	ST LOUIS	.	.	.	23870
	TOTAL	81849	2155	5166	89820
MT	1	1040	75	125	0
	2	85452	2479	125	0
	3	40689	2159	125	0
	5	25138	656	125	8550
	7	1768	122	125	0
	8	11165	393	125	0
	9	8113	381	125	0
	TOTAL	173365	6265	875	8550
NE	1	41229	1327	554	0
	2	765	22	389	0
	3	901	35	2691	0

TABLE A3. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	5	3646	88	1166	0
	6	6507	267	2805	17920
	7	23596	808	354	80
	8	8298	298	557	0
	9	19834	687	1108	350
	TOTAL	104776	3532	9624	18350
NV	TOTAL	1779	33	136	0
NJ	TOTAL	1005	37	404	0
NM	TOTAL	12207	725	939	410
NY	TOTAL	5763	159	5637	87330
NC	1	208	8	731	0
	2	1118	47	304	0
	3	1357	47	273	0
	4	56	1	168	0
	5	1070	40	695	0
	6	852	31	504	0
	8	591	22	1014	0
	9	343	14	1304	0
	TOTAL	5595	210	4993	0
ND	1	39526	1719	50	0
	2	27533	1130	61	0
	3	71722	2045	51	4430
	4	19932	927	78	0
	5	32837	1527	76	0
	6	57465	1522	61	0
	7	18817	1090	76	0
	8	18175	970	106	0
	9	51857	1976	141	0
	TOTAL	337864	12906	700	4430
OH	1	29666	624	1022	6970
	2	17133	348	454	3170
	3	3107	86	607	6970
	4	20409	439	1308	710
	5	16340	305	723	3230
	6	765	24	279	0
	7	3593	84	387	3230
	8	1521	32	222	0

TABLE A3. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	9	784	16	162	0
	TOTAL	93318	1958	5164	24280
OK	1	19496	1023	869	0
	2	105845	2809	662	12540
	3	3567	115	320	0
	4	57566	1489	365	1900
	5	42375	1114	358	5700
	6	1138	34	174	0
	7	68021	1980	557	0
	8	8856	233	109	0
	9	615	15	253	0
	TOTAL	307479	8812	3667	20140
OR	1	27196	650	263	8680
	2	17414	416	263	0
	3	18205	435	263	3170
	7	840	20	263	0
	8	6365	152	263	0
	TOTAL	70020	1673	1315	11850
PA	TOTAL	7952	255	4060	22110
SC	1	508	19	237	0
	2	260	10	237	0
	3	832	31	237	0
	4	475	18	237	0
	5	1034	39	237	0
	8	142	5	237	0
	TOTAL	3251	122	1422	0
SD	1	10712	499	92	0
	2	15949	1437	423	0
	3	20688	1320	427	0
	4	5875	361	64	0
	5	7476	509	431	0
	6	4706	237	697	0
	7	5197	196	139	0
	8	8203	406	131	0
	9	2901	136	815	0
	TOTAL	81707	5101	3219	0
TN	1	5094	144	158	0
	2	2729	102	236	0

TABLE A3. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	3	2029	74	210	0
	4	1490	59	316	0
	5	1517	63	214	0
	6	1068	41	303	0
	TOTAL	13927	483	1437	0
TX	1	40864	1983	6192	150
	2	35427	1875	787	0
	3	8414	437	488	16140
	4	44661	1487	901	0
	5	892	44	940	0
	6	1266	19	494	0
	7	2402	203	424	0
	8	2114	282	1400	5890
	9	86	8	70	0
	10	1151	61	515	0
	11	6473	432	835	0
	50	101	0	356	0
	TOTAL	143851	6831	13402	22180
UT	TOTAL	7708	324	1506	19980
VA	2	572	16	818	17400
	4	114	2	265	0
	5	1359	46	218	0
	6	3393	105	140	0
	7	21	1	212	0
	8	944	41	167	0
	9	1199	50	208	0
	TOTAL	7602	261	2028	17400
WA	1	2742	49	445	9660
	2	25457	535	445	0
	3	10672	251	445	7790
	5	68933	1894	445	0
	9	41240	1246	445	0
	TOTAL	149044	3975	4452	17450
WV	TOTAL	261	10	659	0
WI	1	84	2	515	0
	2	63	2	471	0
	3	141	2	180	0
	4	436	17	745	0

TABLE A3. (CONTINUED)

STATE	CRD,CITY OR TOTAL	PRODUCTION	SEED	FEED	PROCESSING
	5	84	3	293	0
	6	564	13	656	0
	7	50	2	857	0
	8	1577	33	955	0
	9	839	25	325	0
	TOTAL	3838	99	4997	0
WY	TOTAL	7697	381	321	0

APPENDIX B. GRAIN FLOWS BY ORIGINATING REGION AGGREGATED ACROSS TIME PERIODS BY CROP AND SOLUTION

The following anagrams are utilized in APPENDIX B to represent crop, destination and modal specifications.

CROP: B = soybeans, C = corn, W = wheat

Destination:

1) Export: GULF = Gulf of Mexico
ATLANTIC = East Coast Ports
LAKES = Great Lakes Ports
PACIFIC = Pacific Northwest Ports

2) Shipments to River for export:
RIVLM = Lower Mississippi River
RIVIL = Illinois River
RIVUM = Upper Mississippi River
RIVOH = Ohio River
RIVMD = Missouri River
RIVAR = Arkansas River
RIVCO = Columbia-Snake River

3) Domestic Shipments to Processing and Livestock Demands:
DOM (State Postal Code) = State Specific Processing[1]
SEAST = Southeastern United States
NEAST = Northeastern United States
SPLAINS = Southern Plains States
NPLAINS = Northern Plains States
WEST = Western United States
DOMKC = Kansas City[2]
DOMMPS = Memphis
DOMLOU = Louisville
DOMMIN = Minneapolis

Mode: T = Truck
TB = Truck-barge
R (number) = Rail and Size of Shipment
RB (number) = Rail-barge and Size of Shipment

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[1] DOMIA includes processing at Cedar Rapids, Clinton, Des Moines, Fort Dodge, Keokuk, Muscatine and Sioux City; DOMIL includes processing at Chicago, Decatur and Peoria.

[2] DOMKC includes processing at St. Louis.

TABLE B1. PROJECTED 1990 GRAIN FLOWS BY ORIGINATING STATE AND CRD, DESTINATION, TRANSPORT MODE, AND SOLUTION IN MILLIONS OF BUSHELS

					SOLUTION					
								SEGMENT TAX		
CROP	ORIGIN STATE	CRD	DESTINATION	MODE	BASE	FUEL	FUEL-SEGMENT	NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
B	AL	4	GULF	T	20.38	20.38	20.38	20.38	20.38	20.38
		7	GULF	T	4.28	4.28	4.28	4.28	4.28	4.28
		9	GULF	R1	4.65	4.65	4.65	4.65	4.65	4.65
		9	SEAST	T	8.10	8.10	8.10	8.10	8.10	8.10
B	AR	3	RIVLM	TB	17.10	17.10	17.10	17.10	17.10	17.10
		3	DOMMPS	T	15.85	15.85	15.85	15.85	15.85	15.85
B	FL	1	GULF	R1	8.25	8.25	8.25	8.25	8.25	8.25
		3	GULF	R1	1.69	1.69	1.69	1.69	1.69	1.69
B	GA	4	SEAST	R1	0.88	0.88	0.88	0.88	0.88	0.88
		4	SEAST	T	3.82	3.82	3.82	3.82	3.82	3.82
		5	ATLANTIC	T	6.44	6.44	6.44	6.44	6.44	6.44
		5	SEAST	T	1.47	1.47	1.47	1.47	1.47	1.47
		7	GULF	R1	14.07	14.07	14.07	14.07	14.07	14.07
		9	ATLANTIC	R1	2.48	2.48	2.48	2.48	2.48	2.48
B	IL	1	RIVIL	TB	25.80	25.80	25.80	20.51	25.80	25.80
		1	DOMIL	T	.	.	.	5.29	.	.
		3	RIVIL	TB	19.00	19.00	19.00	19.00	19.00	19.00
		3	LAKES	T	1.95	3.08	3.08	3.08	3.09	3.09
		3	DOMIL	T	15.59	14.46	14.46	14.46	14.45	14.45
		4	RIVIL	TB	6.61	6.61	6.61	6.61	6.61	6.61
		4	RIVUM	TB	7.32	7.32	7.32	7.32	7.32	7.32
		5	DOMIL	T	38.78	38.78	38.78	38.78	38.78	38.78
		6	GULF	R125	6.55	6.55	6.55	6.55	6.55	6.55
		6	LAKES	T	.	1.99	1.99	7.28	5.55	13.02
		6	DOMIL	T	13.02	11.04	11.04	5.75	7.47	.

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE	CRD	DESTINATION	MODE	SOLUTION: BASE	FUEL	FUEL-SEGMENT	SEGMENT TAX: NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		7	RIVLM	TB	22.95	22.95	22.95	22.95	22.95	22.95
		7	RIVOH	TB	25.24	25.24	25.24	25.24	25.24	25.24
		7	SEAST	R1	0.58	0.58	0.58	0.58	0.58	0.58
		40	RIVIL	TB	19.86	19.86	19.86	19.86	19.86	19.86
		40	DOMIL	T	4.37	4.37	4.37	4.37	4.37	4.37
		60	RIVLM	TB	28.85	28.85	28.85	28.85	28.85	28.85
		60	GULF	R125	19.40	23.85	23.85	23.85	23.85	23.85
		60	DOMIL	T	4.45	.	.	.	.	.
B	IN	1	ATLANTIC	R100	19.48	22.00	22.00	22.00	22.00	21.43
		1	LAKES	T	.	.	.	.	.	0.57
		1	DOMIL	R1	0.01	0.01	0.01	0.01	0.01	0.01
		1	DOMIL	T	2.52	.	.	.	.	.
		4	ATLANTIC	R100	10.44	10.44	10.44	10.44	10.44	10.44
		5	ATLANTIC	R100	4.29	4.29	4.29	4.29	4.29	4.29
		5	DOMLOU	T	6.64	6.64	6.64	6.64	6.64	6.64
		6	RIVOH[a]	TB	5.87	5.87	5.87	5.87	5.87	5.87
		6	ATLANTIC	R100	4.01	4.01	4.01	4.01	4.01	4.01
		6	SEAST	R1	0.17	0.17	0.17	0.17	0.17	0.17
		7	RIVOH	TB	9.51	7.34	9.51	9.51	9.51	9.51
		7	DOMLOU	T	7.15	9.32	7.15	7.15	7.15	7.15
		8	SEAST	R1	0.05	.	0.05	0.05	0.05	0.05
		8	DOMLOU	T	5.63	5.63	5.63	5.63	5.63	5.63
		8	DOMMPS	R1	.	0.05	.	.	.	.
B	IA	1	RIVUM	RB5	0.80	.	.	.	0.80	0.80
		1	GULF	R1	.	0.80	0.80	0.80	.	.
		1	GULF	R50	.	1.38	1.38	1.38	.	.

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE CRD	DESTINATION	MODE	BASE	FUEL	FUEL-SEGMENT	SOLUTION SEGMENT TAX NO RR RESPONSE	SEGMENT TAX 50% RR RESPONSE	SEGMENT TAX 100% RR RESPONSE
	1	GULF	R75	32.81	27.79	27.79	27.79	27.79	20.69
	1	DOMIA	T	26.58	26.54	26.54	26.54	26.58	26.58
	1	DOMIL	R25	.	0.04	0.04	0.04	.	.
	1	DOMIL	R50	.	3.65	3.65	3.65	5.03	12.13
	2	RIVUM	RB25	10.49	1.58	2.51	2.51	6.15	10.81
	2	RIVUM	RB5	0.20	0.20	0.20	0.20	0.20	0.20
	2	RIVUM	TB	4.18	4.18	3.84	3.84	2.12	2.12
	2	GULF	R50	5.19	5.19	5.19	5.19	5.19	5.19
	2	GULF	R75	.	0.38	0.38	0.38	0.38	.
	2	DOMIA	R50	.	7.17	6.58	6.58	4.66	.
	2	DOMIA	T	25.70	27.44	27.44	27.44	27.44	27.44
	2	DOMIL	R50	13.46	13.08	13.08	13.08	13.08	13.46
	3	RIVUM	RB25	3.87	3.87	3.87	3.87	3.87	3.87
	3	RIVUM	TB	25.54	25.54	25.54	25.54	25.54	25.54
	4	RIVMO	TB	2.41	.	.	.	.	.
	4	RIVUM	RB25	18.96	4.02	4.02	4.02	5.71	5.71
	4	GULF	R1	1.37	14.21	14.21	14.21	0.99	.
	4	GULF	R25	.	1.55	1.55	1.55	0.39	.
	4	GULF	R50	.	.	.	.	.	2.39
	4	PACIFIC	R75	8.24	8.46	8.46	8.46	14.37	14.45
	4	DOMIA	R25	.	.	.	.	.	1.29
	4	DOMIA	T	33.57	29.55	29.55	29.55	34.11	31.72
	4	DOMIL	R25	.	6.77	6.77	6.77	8.99	8.99
	5	RIVUM	RB25	6.82	4.02	4.02	4.02	4.02	6.82
	5	GULF	R75	4.75	7.87	7.55	7.55	10.06	1.51
	5	DOMIA	T	38.72	38.40	38.72	38.72	36.21	41.96

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE	CRD	DESTINATION	MODE	SOLUTION: BASE	FUEL	FUEL-SEGMENT	SEGMENT TAX: NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		6	RIVUM	TB	14.15	14.15	14.15	14.15	14.15	14.15
		6	DOMIA	T	9.05	9.05	9.05	9.05	9.05	9.05
		7	RIVMO	TB	2.32	.	.	.	2.32	2.32
		7	GULF	R1	0.01	0.01	0.01	0.01	.	.
		7	GULF	R25	6.68	6.68	6.68	6.68	6.68	6.68
		7	GULF	R50	3.63	3.63	3.63	3.63	3.63	3.63
		7	PACIFIC	R75	9.00	11.32	11.32	11.32	9.00	9.00
		7	DOMIA	T	9.41	9.41	9.41	9.41	9.41	9.41
		7	DOMIL	R1	.	.	.	.	0.01	0.01
		8	RIVUM	TB	1.84	1.84	1.57	1.57	1.84	1.84
		8	GULF	R25	0.10	1.26	1.26	1.26	0.10	0.10
		8	GULF	R50	1.33	2.53	2.53	2.53	3.57	3.57
		8	DOMIA	T	6.88	4.52	4.79	4.79	4.63	4.63
		8	DOMIL	R1	0.11	0.11	0.11	0.11	0.11	0.11
		9	RIVUM	TB	10.72	10.72	10.72	10.72	10.72	10.72
B	KY	1	RIVLM	TB	14.76	14.76	14.76	14.76	14.76	14.76
		2	RIVOH	TB	11.23	.	11.22	11.22	11.22	11.22
		2	SEAST	R1	17.94	17.99	17.94	17.94	17.94	17.94
		2	DOMMPS	R1	.	11.17	.	.	.	.
		3	DOMMFS	R1	.	1.03	.	.	.	.
		3	DOMLOU	T	10.44	7.26	10.44	10.44	10.44	10.44
B	LA	3	RIVLM	TB	14.48	14.48	14.48	14.48	14.48	14.48
		5	GULF	T	76.67	76.67	76.67	76.67	76.67	76.67
B	MI	6	ATLANTIC	R100	27.71	27.71	27.71	27.71	27.71	27.71
		8	ATLANTIC	R100	3.16	3.16	3.16	3.16	3.16	3.16
B	MN	5	RIVUM	TB	21.95	.	.	.	.	.

TABLE B1. (CONTINUED)

					SOLUTION					
								SEGMENT TAX		
CROP	ORIGIN STATE	CRD	DESTINATION	MODE	BASE	FUEL	FUEL-SEGMENT	NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		5	LAKES	R1	.	21.95	21.95	21.95	21.95	21.95
		5	LAKES	T	1.02	1.02	1.02	1.02	1.02	1.02
		7	GULF	R25	11.84	12.27	12.27	12.27	12.27	.
		7	GULF	R50	6.73	6.73	6.73	6.73	6.73	6.73
		7	GULF	R75	26.27	25.84	25.84	23.14	23.15	23.02
		7	LAKES	T	17.88	17.88	17.88	20.57	20.57	32.98
		8	RIVUM	TB	31.81	.	.	.	.	.
		8	GULF	R25	.	.	.	.	24.20	24.20
		8	GULF	R50	.	.	.	.	7.62	.
		8	LAKES	R1	.	31.81	31.81	31.81	.	7.62
		9	RIVUM	TB	10.97	10.97	10.97	10.97	10.97	10.97
B	MS	2	DOMMPS	T	17.99	17.99	17.99	17.99	17.99	17.99
		3	GULF	T	15.73	15.73	15.73	15.73	15.73	15.73
		4	RIVLM	TB	11.02	11.02	11.02	11.02	11.02	11.02
		5	GULF	R1	26.76	26.76	26.76	26.76	26.76	26.76
B	MO	1	RIVUM	TB	1.83	1.83	1.83	1.83	1.83	1.83
		1	DOMKC	T	28.46	28.46	28.46	28.46	28.46	28.46
		2	RIVUM	TB	30.89	30.89	30.89	30.89	30.89	30.89
		3	RIVLM	TB	1.08	1.08	1.08	1.08	1.08	1.08
		4	GULF	R1	0.01	0.01	0.01	0.01	0.01	0.01
		4	DOMKC	T	8.58	8.58	8.58	8.58	8.58	8.58
		5	RIVLM	TB	21.90	21.90	21.90	21.90	21.90	21.90
		9	RIVLM	TB	30.35	30.35	30.35	30.35	30.35	30.35
B	NE	3	GULF	R1	2.87	5.05	5.05	5.05	5.05	5.05
		3	GULF	R50	2.63	2.63	2.63	2.63	2.63	2.63
		3	PACIFIC	R25	1.89	1.89	1.89	1.89	1.89	1.89

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE	CRD	DESTINATION	MODE	SOLUTION: BASE	FUEL	FUEL-SEGMENT	SEGMENT TAX: NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		3	PACIFIC	R75	6.84	6.84	6.84	6.84	6.84	6.84
		3	DOMIA	T	8.34	6.16	6.16	6.16	6.16	6.16
		6	PACIFIC	R75	1.15	1.15	1.15	1.15	1.15	1.15
		9	RIVMO	TB	5.69	.	.	.	.	5.69
		9	GULF	R1	0.64	1.67	1.67	1.67	7.02	0.64
		9	PACIFIC	R25	2.56	1.87	1.87	1.87	1.87	2.56
		9	PACIFIC	R75	.	5.35	5.35	5.35	.	.
B	NC	1	ATLANTIC	R1	3.93	3.93	3.93	3.93	3.93	3.93
		1	SEAST	R1	4.29	4.29	4.29	4.29	4.29	4.29
		3	ATLANTIC	T	16.24	16.24	16.24	16.24	16.24	16.24
		3	SEAST	T	7.16	7.16	7.16	7.16	7.16	7.16
B	OH	1	ATLANTIC	R100	6.40	6.40	6.40	6.40	6.40	6.40
		1	ATLANTIC	R65	6.96	6.96	6.96	6.96	6.96	6.96
		2	ATLANTIC	R100	6.90	6.90	6.90	6.90	6.91	6.18
		2	ATLANTIC	R65	10.24	10.24	10.24	10.24	10.24	10.97
		2	LAKES	R1	0.25	0.25	0.25	0.25	0.25	0.25
		3	SEAST	R1	3.13	3.13	3.13	3.13	3.13	3.13
		4	ATLANTIC	R100	4.31	.	3.57	3.57	.	.
		4	ATLANTIC	R65	1.87	6.18	2.61	2.61	6.18	6.18
		5	ATLANTIC	R100	45.14	45.14	45.14	45.14	45.14	45.14
		5	LAKES	R1	.	0.01	0.01	0.01	0.01	0.01
		5	SEAST	R1	0.01	.	.	.	.	.
		7	RIVOH	TB	21.60	21.60	21.60	21.60	21.60	21.60
		8	RIVOH	TB	10.17	10.17	10.17	10.17	10.17	10.17
B	SC	1	SEAST	R1	3.26	3.26	3.26	3.26	3.26	3.26
		3	ATLANTIC	R1	3.87	3.87	3.87	3.87	3.87	3.87

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE	ORIGIN CRD	DESTINATION	MODE	SOLUTION: BASE	FUEL	FUEL-SEGMENT	SEGMENT TAX: NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		3	SEAST	T	5.37	5.37	5.37	5.37	5.37	5.37
		5	ATLANTIC	T	5.27	5.27	5.27	5.27	5.27	5.27
B	SD	9	GULF	R1	.	1.14	.	.	.	.
		9	DOMIA	T	15.19	15.19	15.19	15.19	15.19	15.19
B	TN	1	GULF	R1	26.40	38.66	26.40	26.40	26.40	26.40
		1	DOMMPS	T	22.56	10.30	22.56	22.56	22.56	22.56
		3	GULF	R1	21.07	21.07	21.07	21.07	21.07	21.07
B	TX	9	GULF	T	14.62	14.62	14.62	14.62	14.62	14.62
B	WI	8	LAKES	T	4.12	4.12	4.12	4.12	4.12	4.12
		9	LAKES	T	5.02	5.02	5.02	5.02	5.02	5.02
C	AL	7	GULF	T	8.93	8.93	8.93	8.93	8.93	8.93
C	CO	2	WEST	R1	60.86	60.86	60.86	60.86	60.86	60.86
C	FL	1	GULF	R1	1.03	1.03	1.03	1.03	1.03	1.03
C	GA	7	GULF	R1	2.07	2.07	2.07	2.07	2.07	2.07
		7	SEAST	R1	33.13	35.03	35.03	35.03	35.03	35.03
		7	SEAST	T	7.43	5.53	5.53	5.53	5.53	5.53
		8	SEAST	R1	2.84	2.84	2.84	2.84	2.84	2.84
		8	SEAST	T	8.03	8.03	8.03	8.03	8.03	8.03
C	IL	1	RIVIL	TB	145.85	145.85	145.85	145.85	145.85	145.85
		1	DOMIA	T	46.65	40.39	40.39	40.39	40.39	40.39
		1	DOMIL	T	3.17	9.43	9.43	9.43	9.43	9.43
		3	RIVIL	TB	80.75	80.75	80.75	80.75	80.75	80.75
		3	LAKES	T	.	.	.	.	7.30	16.41
		3	DOMIL	T	73.54	73.53	73.53	73.53	66.24	57.12
		4	RIVIL	TB	27.60	27.60	27.60	27.60	27.59	27.59
		4	RIVUM	TB	44.30	39.37	39.37	39.37	39.37	42.14

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE	CRD	DESTINATION	MODE	SOLUTION BASE	FUEL	FUEL-SEGMENT	SEGMENT TAX NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		4	DOMIA	T	.	4.93	4.93	4.93	4.93	2.16
		4	DOMIL	R1	0.71	0.71	0.71	0.71	0.71	0.71
		5	RIVIL	TB	105.09	89.30	89.29	89.29	105.83	105.82
		5	GULF	R125	22.04	44.08	44.08	44.08	27.55	27.55
		5	DOMIL	T	93.76	87.50	87.50	87.50	87.50	87.50
		6	RIVIL	TB	3.82	.	.	.	.	.
		6	ATLANTIC	R100	11.05	8.84	8.84	8.84	8.84	8.84
		6	GULF	R125	90.06	90.06	90.06	90.06	90.06	90.06
		6	LAKES	T	46.77	58.33	58.70	58.70	63.16	63.16
		6	SEAST	R1	2.10	.	.	.	.	.
		6	DOMIL	R1	.	2.10	2.10	2.10	2.10	2.10
		6	DOMIL	T	49.93	44.40	44.03	44.03	39.57	39.57
		7	RIVLM	TB	31.20	31.20	31.20	31.20	31.20	31.20
		7	RIVOH	TB	32.47	32.47	32.47	32.47	32.47	32.47
		40	RIVIL	TB	98;82	98.82	98.82	98.82	98.82	98.82
		60	RIVLM	TB	20.06	.	.	.	20.05	20.06
		60	GULF	R125	11.02	18.54	18.54	18.54	18.54	11.02
		60	SEAST	R1	59.17	97.95	73.03	73.03	52.98	59.17
		60	DOMMPS	R1	76.88	50.65	75.56	75.56	75.56	76.88
C	IN	1	ATLANTIC	R100	99.69	78.88	78.88	78.88	78.88	79.49
		1	ATLANTIC	R65	12.77	30.88	30.88	30.88	30.88	30.88
		1	DOMIL	T	15.74	18.45	18.45	18.45	18.45	17.84
		2	ATLANTIC	R100	45.63	45.63	45.63	45.63	45.63	45.63
		2	NEAST	R1	10.13	10.13	10.13	10.13	5.51	3.01
		2	DOMIL	T	5.66	5.66	5.66	5.66	10.28	12.78
		3	ATLANTIC	R100	32.66	32.66	32.66	32.66	32.66	32.66

TABLE B1. (CONTINUED)

					SOLUTION					
								SEGMENT TAX		
CROP	ORIGIN STATE	CRD	DESTINATION	MODE	BASE	FUEL	FUEL-SEGMENT	NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		3	NEAST	R1	12.96	12.96	12.96	12.96	12.96	12.96
		4	ATLANTIC	R100	.	22.77	.	.	.	2.50
		4	SEAST	R1	64.86	42.09	63.54	63.54	63.54	62.36
		4	DOMMPS	R1	.	.	1.32	1.32	1.32	.
		5	ATLANTIC	R100	121.09	121.09	121.09	121.09	121.09	121.09
		5	ATLANTIC	R65	7.55	7.55	7.55	7.55	7.55	7.55
		6	ATLANTIC	R100	8.57	17.54	17.54	17.54	17.54	17.54
		6	SEAST	R1	34.46	25.49	25.49	25.49	25.49	25.49
		7	RIVOH	TB	62.51	62.51	62.51	62.51	62.51	62.51
		8	RIVOH	TB	55.58	30.57	55.58	55.58	55.58	55.58
		8	DOMMPS	R1	.	25.01	.	.	.	.
C	IA	1	RIVUM	RB25	20.73	.	.	.	.	.
		1	RIVUM	RB5	44.53	.	.	.	.	.
		1	GULF	R1	.	44.53	44.53	44.53	.	.
		1	GULF	R50	.	3.73	3.73	3.73	3.73	.
		1	GULF	R75	40.92	46.31	46.31	46.31	46.31	50.04
		1	PACIFIC	R25	2.01	.	.	.	.	0.33
		1	PACIFIC	R50	4.70	7.20	7.20	7.20	7.20	6.78
		1	PACIFIC	R75	.	.	.	.	.	0.65
		1	SEAST	R1	.	.	.	.	44.53	43.88
		1	DOMIA	R50	22.11	17.47	17.10	17.10	9.97	2.75
		1	DOMIL	R50	.	0.73	1.10	1.10	8.23	15.45
		1	DOMKC	R25	.	27.64	27.64	27.64	27.64	26.49
		1	DOMKC	R50	13.38	0.77	0.77	0.77	0.77	1.99
		2	RIVUM	RB25	55.10	51.67	50.68	50.68	55.10	52.90
		2	RIVUM	RB5	20.66	20.66	20.66	20.66	20.66	20.66

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE CRD	DESTINATION	MODE	SOLUTION: BASE	FUEL	FUEL-SEGMENT	SEGMENT TAX: NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
	2	RIVUM	TB	6.26	.	.	.	.	.
	2	GULF	R25	1.60	1.60	1.60	1.60	1.60	1.60
	2	GULF	R50	11.56	24.00	24.00	24.00	14.75	11.56
	2	GULF	R75	63.86	63.46	63.46	63.46	63.46	63.86
	2	DOMIA	R25	4.71	6.55	6.91	6.91	6.91	6.91
	2	DOMIA	R50	11.05	0.61	1.24	1.24	6.07	11.05
	2	DOMIA	T	18.92	25.18	25.18	25.18	25.18	25.18
	3	RIVUM	TB	179.88	179.88	179.88	179.88	179.88	179.88
	4	RIVMO	TB	1.07	1.07	1.07	1.07	1.07	1.07
	4	RIVUM	RB25	23.90	4.40	4.40	4.40	7.74	28.63
	4	GULF	R1	.	13.34	11.21	11.21	.	.
	4	GULF	R25	2.59	8.37	8.37	8.37	7.36	0.61
	4	GULF	R50	3.84	3.84	3.84	3.84	3.84	1.28
	4	GULF	R75	18.13	18.13	18.13	18.13	18.13	18.13
	4	PACIFIC	R25	.	0.83	0.83	0.83	0.83	0.83
	4	PACIFIC	R50	3.84	3.84	3.84	3.84	3.84	3.84
	4	PACIFIC	R75	11.47	3.02	3.02	3.02	4.90	4.81
	4	SEAST	R1	44.24	50.19	52.33	52.33	59.31	47.90
	4	DOMKC	R25	6.57	8.63	8.63	8.63	8.63	8.56
	5	RIVUM	RB25	54.88	39.14	38.80	38.80	41.49	54.88
	5	GULF	R50	1.91	8.59	9.22	9.22	6.91	1.91
	5	GULF	R75	29.95	45.69	46.03	46.03	43.34	29.95
	5	DOMIA	R25	1.34	4.15	4.15	4.15	3.39	3.39
	5	DOMIA	R50	9.94	17.54	16.91	16.91	19.97	24.97
	5	DOMIA	T	51.12	51.12	51.12	51.12	51.12	51.12
	5	DOMKC	R50	17.09	.	.	.	.	.

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE	CRD	DESTINATION	MODE	SOLUTION			SEGMENT TAX		
					BASE	FUEL	FUEL-SEGMENT	NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		6	RIVUM	TB	100.44	100.44	100.44	100.44	100.44	100.44
		6	DOMIA	T	45.12	45.12	45.12	45.12	45.12	45.12
		7	RIVMO	TB	1.07	1.07	1.07	1.07	1.07	1.07
		7	SEAST	R1	58.42	58.42	58.42	58.42	22.31	29.35
		7	SPLAINS	R1	.	.	.	.	36.11	29.07
		8	RIVUM	TB	3.76	3.76	3.76	3.76	3.76	3.76
		8	GULF	R25	0.82	1.96	1.96	1.96	.	.
		8	GULF	R50	2.41	1.13	1.13	1.13	.	.
		8	SEAST	R1	0.27	.	.	.	.	.
		8	SPLAINS	R1	3.50	6.01	6.01	6.01	9.10	9.10
		8	DOMIA	T	3.68	1.59	1.59	1.59	1.59	1.59
		9	RIVUM	TB	52.89	52.89	52.89	52.89	52.89	52.89
		9	DOMIA	T	27.24	27.24	27.24	27.24	27.24	27.24
C	KS	1	SPLAINS	R1	13.72	13.72	13.72	13.72	13.72	13.72
		1	SPLAINS	T	5.07	5.07	5.07	5.07	5.07	5.07
		7	GULF	R1	28.12	28.12	28.12	28.12	28.12	28.12
		7	SPLAINS	R1	1.89	1.89	1.89	1.89	1.89	1.89
		7	SPLAINS	T	20.97	20.97	20.97	20.97	20.97	20.97
		8	SPLAINS	T	10.19	10.19	10.19	10.19	10.19	10.19
C	KY	1	SEAST	T	24.99	24.99	24.99	24.99	24.99	24.99
		2	SEAST	R1	62.84	62.84	62.84	62.84	62.85	62.84
		2	SEAST	T	1.50	1.50	1.50	1.50	1.50	1.50
		3	SEAST	R1	24.70	24.70	24.69	24.69	24.70	24.70
		3	DOMMPS	R1	3.36	4.58	3.36	3.36	3.36	3.36
		4	SEAST	R1	1.27	1.27	1.27	1.27	1.27	1.27
C	MI	6	ATLANTIC	R100	42.00	42.00	42.00	42.00	42.00	42.00

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE	CRD	DESTINATION	MODE	SOLUTION BASE	FUEL	FUEL-SEGMENT	SEGMENT TAX NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		7	ATLANTIC	R1	0.01	0.01	0.01	0.01	0.01	0.01
		7	LAKES	T	38.48	38.48	38.48	38.48	38.48	38.48
		8	ATLANTIC	R100	11.90	11.90	11.90	11.90	11.90	11.90
		8	LAKES	T	44.07	44.07	44.07	44.07	44.07	44.07
		9	LAKES	T	23.88	23.88	23.88	23.88	23.88	23.88
		9	NEAST	R1	0.01	0.01	0.01	0.01	0.01	0.01
C	MN	5	RIVUM	TB	13.91	13.91	.	.	.	.
		5	LAKES	R1	0.01	0.01	13.92	13.92	13.92	13.92
		5	PACIFIC	R54	1.80	1.80	1.80	1.80	1.80	1.80
		5	NPLAINS	T	11.86	11.86	11.86	11.86	11.86	11.86
		6	RIVUM	TB	6.89	.	.	.	.	.
		6	LAKES	T	.	6.89	6.89	6.89	6.89	6.89
		7	GULF	R75	0.77	0.77	0.77	0.77	0.77	0.77
		7	NPLAINS	T	8.75	8.75	8.75	8.75	8.75	8.75
		8	RIVUM	TB	46.75	.	.	.	.	.
		8	GULF	R50	11.08	11.08	11.08	11.08	2.92	.
		8	GULF	R75	34.64	34.60	34.60	34.60	8.68	8.68
		8	LAKES	R1	46.36	93.15	93.15	93.15	127.23	130.15
		9	RIVUM	TB	82.80	82.80	82.80	82.80	82.80	82.80
		3	RIVUM	TB	1.26	1.26	1.26	1.26	1.26	1.26
C	NE	1	NPLAINS	T	2.82	2.82	2.82	2.82	2.82	2.82
		1	WEST	R1	8.45	8.45	8.45	8.45	8.45	8.45
		2	PACIFIC	R25	2.84	2.84	2.84	2.84	2.84	2.84
		2	PACIFIC	R50	3.34	3.34	3.34	3.34	3.34	3.34
		2	NPLAINS	T	37.10	37.10	37.10	37.10	37.10	37.10
		2	WEST	R1	41.01	41.01	41.01	41.01	41.01	41.01

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE	CRD	DESTINATION	MODE	SOLUTION					
								SEGMENT TAX		
					BASE	FUEL	FUEL-SEGMENT	NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		3	GULF	R1	46.00	44.78	46.00	46.00	46.00	46.65
		3	GULF	R50	0.94	0.94	0.94	0.94	0.94	0.94
		3	PACIFIC	R25	0.67	0.67	0.67	0.67	0.67	0.67
		3	PACIFIC	R75	20.29	20.29	20.29	20.29	20.29	19.64
		5	GULF	R1	4.00	4.00	4.00	4.00	4.00	4.00
		5	PACIFIC	R25	11.14	11.14	11.14	11.14	11.14	11.14
		5	PACIFIC	R50	13.12	13.12	13.12	13.12	13.12	13.12
		5	PACIFIC	R75	15.14	15.14	15.14	15.14	15.14	15.14
		5	SPLAINS	T	5.84	5.84	5.84	5.84	5.84	5.84
		5	WEST	R1	79.89	79.89	79.89	79.89	79.89	79.89
		6	PACIFIC	R25	19.08	19.08	19.08	19.08	19.08	4.77
		6	PACIFIC	R50	37.81	37.81	37.81	37.81	37.81	37.81
		6	PACIFIC	R75	20.08	20.08	20.08	20.08	20.08	20.08
		6	SPLAINS	R1	40.48	40.48	40.48	40.48	40.48	53.39
		6	SPLAINS	T	0.18	0.18	0.18	0.18	0.18	1.57
		7	WEST	R1	104.79	104.79	104.79	104.79	104.79	104.79
		8	GULF	R1	.	2.51	2.51	2.51	41.71	48.98
		8	PACIFIC	R25	1.41	1.41	1.41	1.41	1.41	1.41
		8	PACIFIC	R50	27.09	27.09	27.09	27.09	27.09	27.09
		8	PACIFIC	R75	7.73	7.73	7.73	7.73	7.73	7.73
		8	SPLAINS	R1	47.58	45.07	45.07	45.07	5.87	.
		8	SPLAINS	T	22.25	22.25	22.25	22.25	22.25	20.85
		9	SPLAINS	R1	22.73	22.73	22.73	22.73	22.73	22.73
		9	SPLAINS	T	9.03	9.03	9.03	9.03	9.03	9.04
C	NC	3	ATLANTIC	T	3.16	3.16	3.16	3.16	3.16	3.16
		3	SEAST	T	28.27	28.27	28.27	28.27	28.27	28.27

TABLE B1. (CONTINUED)

					SOLUTION					
								SEGMENT TAX		
CROP	ORIGIN STATE	CRD	DESTINATION	MODE	BASE	FUEL	FUEL-SEGMENT	NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		6	ATLANTIC	T	3.67	3.67	3.67	3.67	3.67	3.67
		6	SEAST	R1	1.52	1.52	1.52	1.52	1.52	1.52
		9	SEAST	R1	8.99	8.99	8.99	8.99	8.99	8.99
C	OH	1	ATLANTIC	R100	45.76	43.27	43.27	43.27	43.27	43.27
		1	ATLANTIC	R65	.	2.49	2.49	2.49	2.49	2.49
		1	LAKES	T	0.96	0.96	0.96	0.96	0.96	0.96
		1	NEAST	R1	9.08	9.08	9.08	9.08	9.08	9.08
		2	ATLANTIC	R100	7.14	5.09	5.09	5.09	2.52	1.27
		2	ATLANTIC	R65	1.25	3.30	3.30	3.30	1.25	.
		2	NEAST	R1	46.68	46.68	46.68	46.68	51.31	53.81
		3	NEAST	R1	32.81	32.81	32.81	32.81	32.81	32.81
		4	ATLANTIC	R100	13.93	21.22	16.07	16.07	16.07	16.07
		4	ATLANTIC	R65	.	3.32	7.15	7.15	2.49	2.49
		4	SEAST	R1	32.05	21.45	22.78	22.78	27.43	27.43
		5	ATLANTIC	R100	48.89	48.89	48.89	48.89	48.89	48.89
		5	SEAST	R1	51.16	51.16	51.16	51.16	51.16	51.16
		6	ATLANTIC	R100	15.29	15.29	15.29	15.29	15.29	15.29
		6	SEAST	R1	1.82	1.82	1.82	1.82	1.82	1.82
		6	SEAST	T	8.75	8.75	8.75	8.75	8.75	8.75
		7	SEAST	R1	2.32	2.32	2.32	2.32	2.32	2.32
		8	SEAST	R1	3.91	3.91	3.91	3.91	3.91	3.91
C	SC	3	SEAST	R1	16.04	16.04	16.04	16.04	16.04	16.04
		5	ATLANTIC	T	4.69	4.69	4.69	4.69	4.69	4.69
		5	SEAST	R1	9.63	9.64	9.64	9.64	9.64	9.64
C	SD	9	NPLAINS	T	21.90	21.90	21.90	21.90	21.90	21.90
C	TX	1	GULF	R1	14.42	14.42	14.42	14.42	14.42	14.42

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE	CRD	DESTINATION	MODE	SOLUTION: BASE	SOLUTION: FUEL	SOLUTION: FUEL-SEGMENT	SEGMENT TAX: NO RR RESPONSE	SEGMENT TAX: 50% RR RESPONSE	SEGMENT TAX: 100% RR RESPONSE
		1	SPLAINS	T	117.56	117.56	117.56	117.56	117.56	117.56
		11	SPLAINS	T	13.42	13.42	13.42	13.42	13.42	13.42
C	VA	6	ATLANTIC	T	3.29	3.29	3.29	3.29	3.29	3.29
		6	SEAST	T	34.39	34.39	34.39	34.39	34.39	34.39
C	WI	4	RIVUM	TB	23.50	23.50	23.50	23.50	23.50	23.50
		5	LAKES	T	28.54	28.54	28.54	28.54	28.54	28.54
		7	LAKES	T	11.25	11.25	11.25	11.25	11.25	11.25
		8	LAKES	T	49.80	49.80	49.80	49.80	49.80	49.80
		9	LAKES	T	50.60	50.60	50.60	50.60	50.60	50.60
W	AR	3	RIVLM	TB	16.00	16.00	16.00	16.00	16.00	16.00
		6	RIVLM	TB	10.38	10.38	10.38	10.38	10.38	10.38
W	CA	0	PACIFIC	T	54.82	54.82	54.82	54.82	54.82	54.82
W	CO	2	PACIFIC	R1	42.32	42.32	42.32	42.32	42.32	42.32
W	ID	1	RIVCO	TB	9.09	9.09	9.09	9.09	9.09	9.09
		7	PACIFIC	R1	2.45	2.45	2.45	2.45	2.45	2.45
		7	PACIFIC	R26	12.20	12.20	12.20	12.20	12.20	12.20
		8	PACIFIC	R1	14.82	14.82	14.82	14.82	14.82	14.82
		8	PACIFIC	R26	11.08	11.08	11.08	11.08	11.08	11.08
		9	RIVCO	TB	2.78	2.78	2.78	2.78	2.78	2.78
		9	PACIFIC		16.81	16.81	16.81	16.81	16.81	16.81
W	IL	7	RIVLM	TB	13.46	13.46	13.46	13.46	13.46	13.46
		7	RIVOH	TB	0.79	0.79	0.79	0.79	0.79	0.79
		7	GULF	R1	1.58	1.58	1.58	1.58	1.58	1.58
		40	RIVIL	TB	0.93	0.93	0.93	0.93	0.93	0.93
		40	RIVLM	TB	1.81	1.81	1.81	1.81	1.81	1.81
		60	RIVIL	TB	2.63	2.63	2.63	2.63	2.63	2.63

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE	CRD	DESTINATION	MODE	SOLUTION: BASE	FUEL	FUEL-SEGMENT	SEGMENT TAX: NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		60	RIVLM	TB	5.49	5.49	5.49	5.49	5.49	5.49
		60	LAKES	R1	0.09	0.09	0.09	0.09	0.09	0.09
W	IN	1	ATLANTIC	R100	1.22	1.21	1.21	1.21	1.21	1.21
		1	ATLANTIC	R65	1.21	1.22	1.22	1.22	1.22	1.22
		2	ATLANTIC	R100	3.64	3.64	3.64	3.64	3.64	3.64
		3	ATLANTIC	R100	4.34	4.34	4.34	4.34	4.34	4.34
		4	ATLANTIC	R100	2.98	2.98	2.98	2.98	2.98	2.98
		5	ATLANTIC	R100	3.24	3.24	3.24	3.24	3.24	3.24
		6	ATLANTIC	R1	1.82	1.82	1.82	1.82	1.82	1.82
		6	ATLANTIC	R100	2.74	2.74	2.74	2.74	2.74	2.74
		7	ATLANTIC	R65	0.47	0.47	0.47	0.47	0.47	0.47
W	KS	1	RIVMO	TB	33.61	7.62	7.62	7.62	7.62	33.61
		1	GULF	R1	.	25.99	25.99	25.99	25.99	.
		1	DOMKC	T	7.65	7.65	7.65	7.65	7.65	7.65
		2	GULF	R1	17.17	17.17	17.17	17.17	17.17	17.17
		2	DOMKC	T	31.89	31.89	31.89	31.89	31.89	31.89
		3	DOMKC	T	10.68	10.68	10.68	10.68	10.68	10.68
		4	GULF	R1	37.03	37.03	37.03	37.03	37.03	37.03
		5	GULF	R1	33.46	33.46	33.46	33.46	33.46	33.46
		5	PACIFIC	R75	13.93	13.93	13.93	13.93	13.93	13.93
		6	DOMKC	T	10.27	10.27	10.27	10.27	10.27	10.27
		7	GULF	R1	27.63	27.63	27.63	27.63	27.63	27.63
		8	GULF	R1	45.67	45.67	45.67	45.67	45.67	45.67
		8	PACIFIC	R75	4.51	4.51	4.51	4.51	4.51	4.51
W	MI	6	ATLANTIC	R100	5.20	5.20	5.20	5.20	5.20	5.20
		9	ATLANTIC	R1	1.61	1.61	1.61	1.61	1.61	1.61

TABLE B1. (CONTINUED)

					SOLUTION					
								SEGMENT TAX		
CROP	ORIGIN STATE	CRD	DESTINATION	MODE	BASE	FUEL	FUEL-SEGMENT	NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		9	LAKES	T	3.75	3.75	3.75	3.75	3.75	3.75
W	MN	1	LAKES	R1	27.55	.	.	.	.	.
		1	LAKES	R26	15.98	13.98	13.98	13.98	13.98	13.98
		1	LAKES	T	24.56	54.10	54.10	54.10	54.10	54.10
		4	RIVUM	RB52	12.54	2.69	.	.	.	.
		4	LAKES	T	23.54	23.54	23.54	23.54	23.54	23.54
		4	DOMMIN	T	0.71	10.56	13.24	13.24	13.24	13.25
		5	LAKES	R52	8.68	8.68	8.68	8.68	8.68	8.68
		5	LAKES	T	.	1.06	1.06	1.06	1.06	1.06
		5	DOMMIN	R1	0.86	0.86	0.86	0.86	0.86	0.86
		5	DOMMIN	T	1.06	.	.	.	.	.
		7	GULF	R75	.	0.43	0.43	3.12	3.12	3.26
		7	LAKES	T	.	.	2.69	.	.	.
		7	DOMMIN	R1	8.10	7.67	4.98	4.98	4.98	4.85
		8	RIVUM	TB	0.04	.	.	.	.	.
		8	GULF	R75	0.08	0.12	0.12	0.12	0.12	0.12
		8	LAKES	R26	0.07	0.07	0.07	0.07	0.07	0.07
W	MO	1	RIVUM	TB	2.33	2.33	2.33	2.33	2.33	2.33
		1	DOMKC	T	1.26	1.26	1.26	1.26	1.26	1.26
		2	RIVUM	TB	6.80	6.80	6.80	6.80	6.80	6.80
		3	RIVLM	TB	7.36	7.36	7.36	7.36	7.36	7.36
		4	RIVMO	TB	12.31	12.31	12.31	12.31	12.31	12.31
		5	RIVLM	TB	4.44	4.44	4.44	4.44	4.44	4.44
		6	RIVLM	TB	5.97	5.97	5.97	5.97	5.97	5.97
		9	RIVLM	TB	23.17	23.17	23.17	23.17	23.17	23.17
W	MT	2	RIVCO	TB	27.80	27.38	27.38	27.38	27.80	27.80

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE	CRD	DESTINATION	MODE	SOLUTION: BASE	SOLUTION: FUEL	SOLUTION: FUEL-SEGMENT	SEGMENT TAX: NO RR RESPONSE	SEGMENT TAX: 50% RR RESPONSE	SEGMENT TAX: 100% RR RESPONSE
		2	PACIFIC	R1	.	0.42	0.42	0.42	.	.
		2	PACIFIC	R26	55.04	55.04	55.04	55.04	55.04	55.04
		3	PACIFIC	R1	32.01	32.01	32.01	32.01	32.01	32.01
		3	PACIFIC	R26	6.40	6.40	6.40	6.40	6.40	6.40
		5	RIVCO	TB	21.49	21.49	21.49	21.49	21.49	21.49
		5	PACIFIC	R26	4.95	4.95	4.95	4.95	4.95	4.95
		9	PACIFIC	R1	4.47	4.47	4.47	4.47	4.47	4.47
		9	PACIFIC	R26	3.15	3.15	3.15	3.15	3.15	3.15
W	NE	1	PACIFIC	R1	20.38	20.38	20.38	20.38	20.38	20.38
		1	PACIFIC	R50	9.80	9.80	9.80	9.80	9.80	9.80
		7	GULF	R50	3.56	3.56	3.56	3.56	3.56	3.56
		7	PACIFIC	R1	13.60	13.60	13.60	13.60	13.60	13.60
		8	GULF	R50	2.97	2.97	2.97	2.97	2.97	2.97
		8	GULF	R75	2.74	2.74	2.74	2.74	2.74	2.74
		9	RIVMO	TB	6.17	5.30	5.30	5.30	5.30	6.17
		9	GULF	R25	.	0.87	0.87	0.87	0.87	.
		9	GULF	R50	7.41	7.41	7.41	7.41	7.41	7.41
W	ND	1	LAKES	T	20.26	20.26	20.26	20.26	20.26	20.26
		1	PACIFIC	R26	5.68	5.68	5.68	5.68	5.68	5.68
		1	PACIFIC	R54	3.68	3.68	3.68	3.68	3.68	3.68
		2	LAKES	R1	12.13	.	.	.	.	.
		2	LAKES	T	.	12.13	12.13	12.13	12.13	12.13
		2	PACIFIC	R26	8.52	8.52	8.52	8.52	8.52	8.52
		3	LAKES	R1	26.11	.	.	.	.	.
		3	LAKES	R26	20.77	20.77	20.77	20.77	20.77	20.77
		3	LAKES	T	.	26.11	26.11	26.11	26.11	26.11

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE	ORIGIN CRD	DESTINATION	MODE	SOLUTION: BASE	FUEL	FUEL-SEGMENT	SEGMENT TAX: NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		3	PACIFIC	R26	4.25	4.25	4.25	4.25	4.25	4.25
		4	LAKES	R1	26.56	27.66	27.66	27.66	27.66	27.66
		4	LAKES	R26	3.22	.	.	.	.	.
		4	PACIFIC	R26	0.71	2.84	2.84	2.84	2.84	2.84
		5	LAKES	R1	23.07	10.86	.	.	.	.
		5	LAKES	T	.	12.22	23.07	23.07	23.07	23.07
		5	PACIFIC	R26	1.41	1.41	1.41	1.41	1.41	1.41
		6	LAKES	R1	29.56	28.14	26.02	10.00	10.00	.
		6	LAKES	R26	7.15	7.15	7.15	7.15	7.15	7.15
		6	LAKES	T	.	.	2.12	18.14	18.14	28.14
		6	PACIFIC	R26	7.09	8.51	8.51	8.51	8.51	8.51
		9	LAKES	R26	5.37	5.37	5.37	5.37	5.37	5.37
		9	LAKES	T	32.38	32.38	32.38	32.38	32.38	32.38
		9	PACIFIC	R26	0.35	0.35	0.35	0.35	0.35	0.35
		9	PACIFIC	R52	0.88	0.88	0.88	0.88	0.88	0.88
		9	DOMMIN	T	6.60	6.60	6.60	6.60	6.60	6.60
W	OH	1	ATLANTIC	R100	13.55	15.87	15.87	15.87	15.87	15.87
		1	ATLANTIC	R65	2.32	.	.	.	.	.
		2	ATLANTIC	R1	0.10	0.10	0.10	0.10	0.10	0.10
		2	ATLANTIC	R100	4.03	5.95	5.95	5.95	4.03	4.03
		2	ATLANTIC	R65	5.80	3.88	3.88	3.88	5.80	5.80
		4	ATLANTIC	R100	11.21	13.53	13.53	13.53	13.53	13.53
		4	ATLANTIC	R65	2.32	.	.	.	.	.
		5	ATLANTIC	R100	9.11	9.11	9.11	9.11	9.11	9.11
		7	RIVOH	TB	0.87	0.87	0.87	0.87	0.87	0.87
W	OK	1	GULF	R1	17.59	17.59	17.59	17.59	17.59	17.59

TABLE B1. (CONTINUED)

					SOLUTION					
								SEGMENT TAX		
CROP	ORIGIN STATE	CRD	DESTINATION	MODE	BASE	FUEL	FUEL-SEGMENT	NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
		2	GULF	R1	89.85	89.85	89.85	89.85	89.85	89.85
		3	RIVAR	TB	4.42	4.42	4.42	4.42	4.42	4.42
		4	GULF	R1	53.81	53.81	53.81	53.81	53.81	53.81
		5	RIVAR	TB	21.48	.	.	.	.	21.48
		5	GULF	R1	13.73	35.21	35.21	35.21	35.21	13.73
		7	GULF	R1	65.49	65.49	65.49	65.49	65.49	65.49
		8	GULF	R1	8.52	8.52	8.52	8.52	8.52	8.52
W	OR	1	PACIFIC	T	17.60	17.60	17.60	17.60	17.60	17.60
		2	PACIFIC	R1	16.73	16.73	16.73	16.73	16.73	16.73
		3	RIVCO	TB	14.33	14.33	14.33	14.33	14.33	14.33
W	SD	1	IVUM	B1	16.02	16.02	16.02	.	.	.
		1	LAKES	R1	.	.	.	16.02	16.02	16.02
		2	DOMMIN	T	11.05	11.05	11.05	11.05	11.05	11.05
		3	RIVUM	RB26	1.38	.	.	.	.	.
		3	LAKES	R26	.	3.25	3.25	3.25	3.25	2.91
		3	PACIFIC	R26	.	.	.	.	.	0.22
		3	DOMMIN	T	13.47	11.60	11.60	11.60	11.60	11.73
		5	LAKES	T	.	6.49	6.49	6.49	6.49	6.49
		5	PACIFIC	R26	1.36	1.36	1.36	1.36	1.36	1.36
		5	DOMMIN	R1	6.49	.	.	.	.	.
		6	PACIFIC	R52	3.29	3.29	3.29	3.29	3.29	3.29
W	TX	1	GULF	R1	70.50	70.50	70.50	70.50	70.50	70.50
		3	GULF	R1	33.62	33.62	33.62	33.62	33.62	33.62
W	WA	2	RIVCO	TB	14.69	6.37	6.37	6.37	6.37	6.37
		2	PACIFIC	R1	1.71	10.04	10.04	10.04	10.04	10.04
		2	PACIFIC	T	8.08	8.08	8.08	8.08	8.08	8.08

TABLE B1. (CONTINUED)

CROP	ORIGIN STATE CRD	DESTINATION	MODE	SOLUTION					
							SEGMENT TAX		
				BASE	FUEL	FUEL-SEGMENT	NO RR RESPONSE	50% RR RESPONSE	100% RR RESPONSE
	3	RIVCO	TB	2.18	.	.	.	.	2.18
	3	PACIFIC	R1	.	2.18	2.18	2.18	2.18	.
	5	RIVCO	TB	48.61	48.62	48.62	48.62	48.62	48.62
	5	PACIFIC	T	17.98	17.98	17.98	17.98	17.98	17.98
	9	RIVCO	TB	39.54	39.54	39.54	39.54	39.54	39.54