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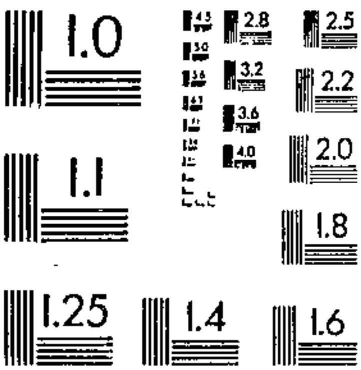

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A Waterway Tax on Grains

A Functional Market Analysis

Theresa Sun
Lester Myers

A WATERWAY TAX ON GRAINS: A FUNCTIONAL MARKET ANALYSIS, by Theresa Sun and Lester Myers, National Economics Division, Economic Research Service, U.S. Department of Agriculture, Technical Bulletin No. 1705.

ABSTRACT

A functional market model analyzing a theoretical inland waterway user charge of 5 cents per bushel for grains shows that U.S. farmers would bear 70 percent of the user charge. Foreign consumers would bear 20 percent, and grain exporters would bear 10 percent. If the charge had been in effect in the 1981/82 season, exports would have declined 2.7 million bushels for wheat, 10.0 million bushels for corn, and 0.7 million bushels for soybeans. Export prices would have increased 0.8 cent per bushel for wheat, 1.0 cent for corn, and 0.6 cent for soybeans. Prices for all three commodities would have declined 4 cents per bushel at the farm level. Total user charge receipts for grains would have been $108 million.

Keywords: Waterway user charge, grain exports, price elasticities, marketing margins

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SUMMARY

A functional market model analyzing a 5-cent-per-bushel waterway user charge for grains indicates that U.S. wheat farmers would bear 70 percent of the user charge. Corn and soybean farmers would bear 74 percent. The share of the tax absorbed by foreign consumers would be about 16 percent for wheat, 19 percent for corn, and 12 percent for soybeans. Exporters' share of the waterway tax would be an estimated 7 percent for corn and 14 percent for both wheat and soybeans.

If the 5-cent-per-bushel user charge had been in effect in the 1981/82 season, exports of wheat, corn, and soybeans would have been 2.7, 10.0, and 0.7 million bushels lower, respectively. Export prices for wheat, corn, and soybeans would have increased by 0.8, 1.0, and 0.6 cent per bushel, respectively. Wholesale prices would have declined by 7 cents for wheat and 1 cent for corn and soybeans. Farm-level prices for all three crops would have declined about 4 cents per bushel. Total user charge receipts for grains would have been an estimated $108 million.

Because most barged grain is destined for export, domestic marketing agents would pass most of their price increase on to the export market, where foreign buyers and exporters would share the costs. The extent of the tax burden of foreign buyers is about 12-19 percent and that of U.S. exporters is about 7-15 percent.

The amount of barged grains for domestic use is small, so total receipts of user taxes from this market are negligible. Domestic suppliers, however, would be negatively affected. A 5-cent-per-bushel user charge would have dropped 1981/82 domestic grain and soybean prices by 0.2-1.6 percent. Total revenues for domestic suppliers would have declined by $8-47 million. But, if these suppliers had also been processors, these price changes might have more than compensated for their losses.

Exporters would have lost $6-21 million in revenues, despite contributions of $6-19 million by foreign buyers to export revenues. Grain and soybean farmers would have lost the most--about $76-260 million, or 0.6-1.3 percent of the 1981/82 value of grain and soybean production.

The functional market model analyzes the effect of user charges in two stages. First, the model applies the marketing margin theory to estimate the user charge burden at the farm and the wholesale market for grains and soybeans. Second, the user charge burden and other price-quantity effects at the wholesale market are delineated into those for foreign consumers, domestic exporters, and domestic processors and suppliers.

The extent of the effect of waterway user fees on producers, consumers, and middlemen would depend on the characteristics of demand for and supply of grains at different levels of the marketing system. However, previous interregional analyses have been unable to estimate price and quantity effects directly at different levels, especially at the farm level. This functional market model considers the interrelationships of demand and supply for grains at farm, domestic wholesale, and export markets.

An implication of this analysis is that a Government policy of not subsidizing the U.S. inland waterways would penalize foreign grain and soybean buyers less than U.S. farmers. With a waterway user charge, foreign buyers would bear less than a fourth of the tax burden. U.S. grain and soybean farmers would be hurt most.

A Waterway Tax on Grains

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INTRODUCTION

This report uses a functional market model to analyze the effect of a waterway user charge of 5 cents per bushel on wheat, corn, and soybeans. In 1978 Congress levied a 4-cent-per-gallon fuel tax on commercial users of inland waterways, providing for regular increases until the tax reached a level of 10 cents per gallon in 1985. At 10 cents per gallon, the tax would recover 20-25 percent of the operation and maintenance expenses for the Nation's inland waterway system. Other forms of taxation Congress is considering might fully recover operation and maintenance expenditures and other costs associated with commercial navigation on the inland waterway system (22). 1/

The user charge may affect various economic groups in the grain industry--transportation agents such as barge, rail, and truck carriers, marketing firms such as grain elevators and exporters, and grain producers and consumers. The extent of this effect depends on the characteristics of demand for and supply of grains at different levels within the marketing system. It also depends on cost differentials among different shipping modes, the locational differences of demand and supply areas, the level of user charge administered, and the time allowed for these economic reactions to be transferred or dispersed among the markets. Thus, the economic effects of user charges would depend on time dimensions and spatial allocations, as well as on reactions by various economic entities in the marketing system.

Many studies have addressed user charges (1, 2, 5, 13, 15). Most of these studies use an interregional economics approach, which measures changes in transportation costs and commodity movements among surplus and deficit regions (1, 2, 13, 15). Some of the interregional analysis focuses on the domestic market (1, 13, 15). In such cases, estimates of cost changes per unit of commodity moved in the inland waterways are directly passed to the farmer-producer by reducing the farm price by the amount of the marketing cost change. One study focuses on the

*Theresa Sun is an economist with the Fruits, Vegetables, and Sweeteners Branch, National Economics Division; Lester Myers is branch chief of the Food Marketing and Consumption Economics Branch, National Economics Division.

1/ Underscored numbers in parentheses refer to items cited in the reference section at the end of this report.

international wheat market (2). It includes excess supply, excess demand, and transportation relationships for the exporting and importing countries. A waterway user charge would increase the transportation cost for U.S. wheat and would alter its world demand and price. The amount of user charge not covered by export price increases is the tax burden for U.S. farmers, as reflected in lower farm prices.

Although interregional analyses provide cross-sectional examination of the traffic diversions of a commodity under different user charges, they do not satisfactorily analyze the user charge effect at the farm level. In principle, one should not assume a direct cost pass-through from the domestic or export market without examining the demand and supply relationships among different marketing levels. To remedy this problem, we have formulated a functional market model to analyze the interrelationships among the domestic, export, and farm-level markets. In doing so, we may evaluate price, quantity, and revenue changes for producers, domestic processors, exporters, and foreign consumers. We may also compare price changes at the export and farm markets with those estimated using interregional analysis whenever possible.

BACKGROUND

To understand the following analysis, one needs to be familiar with the geographical nature of the waterway system, the different modes of grain transportation, and the available types of user charges.

Waterway System and Waterway Grain Transportation

The U.S. waterway system consists of over 25,000 miles of navigable channels of varying depths. It includes the Atlantic Coast-Intracoastal Waterway bordering the East, the Gulf Coast-Intracoastal Waterway in the South, the Pacific Coast Waterway in the West, and the Great Lakes-St. Lawrence Seaway in the North-Northeast. The Mississippi River and its tributaries are the most important internal waterway system. Running north to south from Minnesota, through the Midwest, and down to Louisiana, the Mississippi River system passes through the major grain and soybean-producing areas and accounts for over 35 percent of all inland waterways. The Columbia-Snake River system flows through Idaho, Oregon, and Washington in the Northwest and is also an important route for wheat shipments.

The inland waterway system is of great importance to U.S. grain transportation. A 1977 survey (the latest available) of grain movements revealed that barges moved 35 percent of the interstate shipment of corn, 24 percent of wheat, and 46 percent of soybeans (5). Because of its geographic advantage, the Mississippi River system leads other inland waterways in transporting grains and soybeans. About 60 percent of the soybeans and 40 percent of the corn and wheat begin barge movement on the Mississippi River.

Most of the grain that moves by barge is ultimately exported. About 90 percent of the barge shipments of corn and soybeans received in the Baton Rouge-New Orleans, LA, areas during 1977 were for export. Barge represents a significant mode of transportation for export grains and soybeans. In 1977, close to 61 percent of soybean exports, 50 percent of corn exports, and 29 percent of wheat exports were transported by barge. About 40 percent of the wheat exports moved by barge went through Oregon and Washington in the West (8).

Other Modes of Grain Transportation

Grain also moves by truck and rail. Grain may be shipped by rail directly from country elevators to ports for export or by truck to rail terminals or barge loading points for further transportation. Elevator operators decide where and how to ship grain based on the bids offered in the various markets and the transportation cost to those markets. Inland waterway carriers generally have a relative cost advantage over competing transportation modes. First, operating costs are lower and there is no fixed capital investment in the right-of-way (9). Second, barge rates are not regulated by the Interstate Commerce Commission (ICC) and may fluctuate according to market activities. However, rail terminals usually are nearer grain-producing or assembly areas, where grain-gathering costs are lower than at river terminals. Consequently, rail competes effectively with barge transportation beyond the river assembly point, and the rate changes in barge or rail transport may greatly influence the market share captured by either mode. Historically, both barge and rail rates have been insensitive to changes in truck rates for long distance hauls (15). The waterway industry claims user fees would increase barge rates, decrease barge traffic, and present shippers and producers with economic losses. If rates for other modes of transportation also increase proportionately, less traffic would be diverted, but total shipping costs would rise. However, the reactions of competing transportation modes may not be uniform. Thus, water-usage fees would affect some regions more than others.

Waterway User Charge Proposals

The user charge is intended to recover Federal Government expenditures on maintaining, repairing, and constructing (MRC) the Nation's waterway system. There are two basic types of user-charge structures. One is a uniform systemwide tax structure under which all waterway traffic pays a uniform toll charge. The system charge could be a uniform fuel tax, a uniform ton-mile tax, or a uniform license fee for tow-boats and barges. The alternative is a segment-based tax structure under which traffic is charged a fee reflecting the Government MRC cost on the river segment on which the traffic is moving. A segment charge could be a lockage fee that varies with lock chambers, a ton-mile tax that varies by waterway segment, or a variable license fee for tow-boats and barges on different waterway segments.

Economists (4) argue that two philosophies underlie a user-charge structure, one based on equity and the other on efficiency. Efficiency requires that prices both reflect costs and ration scarce resources. Equity suggests that a levy should be in proportion to the social benefits derived from a public investment. Because of different navigable conditions and volumes of traffic, the public expenditure per unit of traffic activity varies widely among river segments. With a uniform systemwide user charge, the traffic on low-cost river segments would pay higher tolls and subsidize expenditures on high-cost river segments. However, a segment user charge could entail a prohibitively high tax on a specific river, reducing its traffic and impairing regional development. Thus, some people would argue that a systemwide user charge is less of a distortion than are segment user charges (1).

INTERREGIONAL ANALYSIS OF A USER TAX

The studies reported here do not represent an exhaustive interregional analysis, but are chosen as representative of the various analytical methods used so far. Two approaches are generally used. The first is to model waterway networks in a computer program and simulate flows of waterborne commodities under alternative user-tax structures (15). The second is to use spatial equilibrium models to estimate minimum transportation costs and commodity flows to estimate maximum social welfare changes (1, 2, 13, 16).

The Data Resources, Inc. Waterway Model System

Data Resources, Inc. (DRI) has developed a system of waterway models composed of three parts: (1) macro-and-industry models, which provide the regional supply and demand quantities for the various waterborne commodities; (2) a waterway network model, which estimates the pattern of commodity flows and costs on the waterway system; and (3) a diversion model, which provides the rate of traffic diversion when transportation rates change. Because the macro-and-industry models were designed for purposes other than user-charge analysis, we will explain only the network and diversion models.

The Network Model

The DRI Network model segregates the waterway system into more than 200 links of Army Corps of Engineering Port Equivalents (P.E.). It provides a direct mapping of origin-destination commodity flows with operating conditions of these movements. The P.E. commodity flows are estimated from historical waterway shipments. The regional commodity supply levels and demand requirements were obtained from the DRI Macro-and-Industry model system. The mileage traversed and costs associated with the commodity flows are estimated by a mileage and a barge line-haul cost submodel. Barge line-haul costs vary by segment of operation and commodities for several reasons--notably barge loading costs, tow size, tow speed, and commodity characteristics. Based on the coordinated estimates of operating costs, mileage traversed, commodity shipped, and the amount of public expenditure to be recovered, the network model would then estimate the average unit cost per ton-mile and the barge toll. The latter is input into the diversion model to estimate traffic diversion.

The Diversion Model

The diversion model calculates the amount of traffic diversion relative to changes in the barge rate. By incorporating survey information about changes in commodity movements per unit change in barge cost and the level of traffic and user fees from the network model, the diversion model may simulate the traffic loss. Lower traffic levels due to user fees would boost per-unit user fees. Yet, higher user fees could lead to still greater traffic diversion. Consequently, the diversion and network models are alternatively linked in an iterative process. Between each stage of iteration, the rates of change in traffic and user fees decline. Thus, a stabilized commodity movement and toll level are obtainable after several model iterations.

Applying different user charge and transportation policy scenarios to the waterway system, DRI estimated economic conditions for the years 1990 and 2000. Assuming that rail and truck carriers did not change their rate policies, the 1990 grain traffic diversion with respect to either a fuel or a segment tax and the regional income effects would be as follows.

Segment Ton-Mile Tax. The effect of a segment ton-mile tax depends on the length of haul and the unit fees charged for transporting grains on river segments. Unit fees are highest on low-volume, high-maintenance cost rivers such as the Arkansas and Missouri Rivers, estimated by DRI to be $2 per ton on a ton-mile tax scheme in 1990. Thus, substantial traffic, about 40-50 percent for corn and wheat, would be lost on these rivers. The Ohio River is a low-cost river, with an estimated toll of less than $0.50 per ton-mile in 1990 and a resulting 9-percent traffic diversion for corn and soybeans. The distance traveled also effects the average cost and traffic diversion for grain transportation. Corn is generally shipped from the upper Mississippi and Illinois Rivers to the Gulf of Mexico, whereas soybeans are shipped from the lower Mississippi and Ohio Rivers. Consequently, corn has a higher average cost and diversion rate than soybeans have. The 1990 average ton-mile tax, in terms of 1979 dollars, would be $1.29 for corn and $0.90 for soybeans. In response to these fees, 15 percent of corn barge traffic and 13 percent of soybean traffic would be lost in 1990. As most wheat originates on the Columbia and Snake Rivers and the upper Mississippi, the average ton-mile tax and diversion rate for wheat would be between those for corn and soybeans, about $1.02 per ton-mile with a 14-percent loss of traffic in 1990.

Systemwide Fuel Tax. The effect of a systemwide fuel tax on grain movements would vary according to the origin of shipments. Grain moved on high-cost rivers would be less adversely affected than under a segment toll. However, grains moving on low-cost rivers, such as the Ohio and lower Mississippi, would pay substantially higher user costs under a systemwide fuel tax than under a segment toll. For corn and soybeans, the traffic loss under a systemwide fuel tax would be about 8 and 2 percent higher, respectively, on the Ohio River; for wheat, it would be 2 percent higher on the lower Mississippi. However, on the upper Mississippi, user costs would be lower, and traffic diversion would be less than under a segment toll. Other relatively high-cost rivers receiving relief under a fuel tax would include the Arkansas, Missouri, and Columbia and Snake Rivers. The average fuel tax for corn, wheat, and soybeans in 1990 was estimated to be $1.11, $0.63, and $0.79 (1979 dollars) per ton, respectively. The corresponding traffic loss was estimated by the DRI study to be 14 percent for corn, 7 percent for wheat, and 10 percent for soybeans.

Farm Income Loss. If tolls were transferred completely to farmers, Illinois, Iowa, and Minnesota farmers would bear the brunt of the burden whichever type of user charge was enforced. About 82 percent of the corn-related income loss and 72 percent of that of soybeans would be shared by these States. The impact of user fees on wheat farm income would fall mainly on Washington, Missouri, and Minnesota. Income loss for wheat farmers, unlike corn and soybean farmers, would differ substantially, depending on the tax-collection mechanism. A segment ton-mile tax would increase the farmers' tax burden 63 percent more than would a systemwide fuel toll.

Spatial Equilibrium Models

Economists often employ spatial equilibrium models to determine the equilibrium flows and prices of products under varying transportation and tariff structures. Under the Linear Programming (L.P.) framework, the problem is determining how the output from different regions should flow to consuming areas so that total transportation costs are minimized. Regional production and demand levels and unit transportation rates are held constant. Under a Nonlinear Programming (N.L.P.) framework, the objective is to maximize consumers' and producers' welfare based on some price-responsive demand and supply relationships for a product in different regions. Transportation rates can be a linear function of volume. If the demand and supply equations are of linear forms or are linear in logarithms, the problem is solvable with the Quadratic Programming (Q.P.) technique.

The Baumel L.P. Model for Corn, Wheat, and Soybeans

Baumel, Hauser, and Beaulier used an L.P. model to estimate market flows of corn, wheat, and soybeans for various transportation costs (1). To construct the model, the researchers assumed that grains originate from inland grain elevators and are shipped to domestic and foreign areas. Regional supply levels and demand requirements for these products were based on 1985 and 1990 projections obtained from the National Interregional Agricultural Projections System, U.S. Department of Agriculture (USDA). Transportation costs include rail, barge, and truck rates. The researchers also specified port and river capacities, grain-storage limitations, and seasonal aspects of the grain marketing system. The major grain-carrying river systems are the Mississippi, Illinois, Ohio, Missouri, Arkansas, and Columbia and Snake Rivers.

To determine the user charge effects, the researchers used 1979-80 transportation costs in the model to obtain a base solution. Subsequently, the model employed user-charge-inflated shipping costs. Changes in solutions from these model evaluations are the estimated user charge effects. The results indicate:

- Total grain shipments by barge would decline 14 percent in 1985 if a systemwide fuel tax is implemented. They would decline 18 percent with a segment ton-mile tax. The decline would be less if rail and truck companies decided to increase their rates.

- The tax per bushel of grain varies widely depending on the form of the taxes and the river travelled. Regions located near the low-cost Ohio and lower Mississippi rivers would be better off under a segment tax than a systemwide fuel tax. Illinois, Iowa, Minnesota, and Missouri would be hurt most by the user tax.

- If all the costs of taxes are transferred to grain farmers, with constant rail and truck rates, a grain farmer in 1985 might realize 2.7 cents per bushel less as a result of a fuel tax, or 3.3 cents per bushel less as a result of a segment ton-mile tax.

The Leath-Sheehan L.P. Model for Corn and Soybeans

Leath and Sheehan used an L.P. trade model to analyze user-charge effects on competitive relationships in the corn and soybean industries (13). Their model contains 59 domestic regions and 11 export areas. Economic assumptions included quarterly production levels, storage capacity, domestic and foreign demand levels, and the availability of truck, rail, and barge transportation. Model solutions of corn and soybean distribution for the 1977/78 marketing year represent the base solutions. Leath and Sheehan analyzed the effects of changes in barge rates in response to the imposition of a fuel tax, a uniform ton-mile tax, and a segment-specific ton-mile tax, assuming rail and truck rates remain fixed. Their results indicate:

- A segment-specific ton-mile fee would affect the volume of corn or soybeans shipped by barge more than would a uniform ton-mile fee.

- Soybean movements by barge would be more sensitive than corn movements, if the user charge recovered 50 percent or less of the waterway cost. Barge movements of corn would be affected more at full-cost than at partial-cost recovery.

- o User charges would alter locational advantages of producing and consuming regions of corn and soybeans. Great Lakes and Atlantic ports would handle more exports than they do now.

- o At the full cost-recovery level, total costs of marketing would increase \$53-\$74 million depending on the type of user charge.

<u>The Binkley-Sharples Q.P. Model for Wheat</u>

In evaluating the user charge effect on grain transportation, Binkley and Sharples showed that, because most barge shipment of grain is for the export market, one can simplify the problem by analyzing grain price and quantity changes in the world market (<u>2</u>).

Using an 18-region world trade model, Binkley and Sharples analyzed the user-charge effect on demand and price in the world wheat market. The model divides that market into 4 exporting countries (Canada, Argentina, Australia, and the United States) and 14 importing regions. For each exporting country, the model specified an excess supply function, which was derived from a constant domestic supply, and a constant elasticity demand function for ending stocks and domestic use. Of the 14 importing regions, 7 were assumed to have perfectly inelastic excess demand functions; that is, each region would import a specified quantity of wheat regardless of the price levels in the model. The other seven regions had constant demand elasticity estimates ranging from -0.2 to -0.8. The wheat trade model also contained a set of trade constraints. Most of these were bilateral trade agreements between importing and exporting countries.

The analysis compared two model solutions: (1) a base solution, which approximated the 1975/76-1977/78 average world trade pattern assuming no user charges, and (2) an impact solution where a fee of \$1.84 per metric ton (\$0.05 per bushel) is added to the cost of shipping wheat from the United States.

Because of the user charge, the U.S. wheat export price increased by \$1.19 per metric ton. This solution implies that 65 percent of the user fee would be borne by importers and the remaining 35 percent would be passed on to the U.S. wheat producers in the form of reduced wheat prices.

In response to lower domestic wheat prices, U.S. producers would reduce wheat production by 0.1 percent. Domestic consumption would also increase by 0.1 percent. The increase in the U.S. export price would thereby reduce U.S. exports by 0.8 percent. Nevertheless, only half of the reduced U.S. exports would be lost to the importers because Canada and other exporters would capture the other half of the lost U.S. exports and would realize an average price increase of \$1.12 per ton.

Because of the explicit specifications of the excess supply and excess demand relations for the wheat-trading countries, the Q.P. model used was capable of estimating the export wheat quantity and price changes due to transportation cost (user charge) increases. However, the model did not trace a relationship between the export and farm-level prices. The change in farm prices was assumed to be the total user charge minus the portion absorbed by the export market. Such an analysis raises the question of how prices would change for grain elevators and processors within the marketing system. The objective of the L.P. and DRI models mentioned earlier was to obtain efficient distribution of grains from surplus to deficit regions with minimum transportation costs. Grain prices were not directly determined from these models. Price and income changes at the farm level were mostly determined by a straightforward reduction of the amount of marketing cost due to the user charge. Such an estimation was based on the assumption that producers would bear the full burden of waterway user charges. To address the issue of how the user charge would lower the output prices to grain farmers or would increase the purchase prices for grain elevators and exporters, as well as consumers, one must examine the behavioral supply and demand relationships for grain farmers, for intermediate marketing firms, and for exporters and foreign buyers. This is the functional market model to which we now turn.

A FUNCTIONAL MARKET MODEL FOR GRAIN

One can analyze the total impact of user charges through its cummulative effects at different market levels. This approach requires an understanding of supply and demand relationships at different levels within the grain marketing channel and how the market reacts to marketing cost changes. We begin by examining the characteristics of grain marketing channels and by specifying a theoretical framework for analyzing the effect of changes in user fees on marketing margins and prices. Next, we specify the intermarket reactions between domestic and export markets and the income redistribution effects of user charges. Finally, we empirically examine the effects of user charges.

Grain Marketing Channels and Trade

The U.S. grain marketing system, when examined through its functional market levels, may be divided into farm, wholesale, and retail markets. At the wholesale level, two markets exist: domestic and export. Three major marketing services are performed within and among these functional market levels which physically transform a product in time, space, and form. These include assembly, storage, processing, and distribution services. Grain may be assembled or reassembled several times, first to local elevators, then to terminal elevators. At the terminal point, grain may be moved to the wholesale market for domestic processing or to the export market for foreign consumption. At the domestic wholesale level, processing includes such functions as grading, packaging, and physical transformation. Processed products are subsequently dispersed in the distribution stage as finished goods for consumption. Grain products ultimately used for human consumption bear little resemblance to the harvested product. Soybeans are also highly transformed through processing prior to sales as human food and livestock feed products. However, most coarse grains, as well as some wheat, sold for livestock feed undergo little change in form. Feed processing is a significant business and accounts for the largest single purchased input within the livestock sector. Hence, domestic marketing of grain is an important function of the total grain wholesaling activity.

Although domestic feed and food markets are important, international markets also account for a significant proportion of total U.S. production of grains and soybeans. Over 50 percent of wheat, 20 percent of corn, and 28 percent of soybeans go to export markets. The U.S. share of world trade is about 40 percent for wheat and 40-60 percent for corn (14). These figures illutrate how important foreign demand is relative to domestic demand for feed grains and why international grain prices directly affect U.S. feed grain prices and, indirectly, affect the U.S. meat subsector.

The Farmer's Share of a Waterway User Tax on Grains

The effect of the waterway user charge in the grain marketing system is analyzed in two stages in this study. The first stage determines the market share of a user charge between the farm and wholesale markets. The second stage delineates the remaining user charge, as well as other price-quantity effects at the wholesale market into those proportions absorbed by foreign consumers, exporters, domestic processors, and first handlers. Theoretical considerations on marketing margins and supply of and demand for a product at different market levels provide the framework for our estimates of the grain farmer's share of the waterway user fees.

Theoretical Margin Analysis

Marketing costs are theoretically determined by the supply of and demand for marketing services. Because these supply and demand relationships are often difficult to measure empirically, marketing costs are often measured by calculating the marketing margin between prices paid by consumers and those obtained by producers. Following Tomek and Robinson (17), the consumers' demand for a final product is the primary demand, and producers' supply of material product is the primary supply. Then, by adding appropriate marketing margins to the primary supply, we obtain the derived supply at the consumer level. Similarly, by subtracting the appropriate margin from primary demand, we obtain the derived demand at the producer level.

If the costs of providing an existing set of marketing services change, the impact of changed marketing service costs is generally manifest by shifts in the derived demand, in the derived supply, or both. This, in turn, results in new equilibrium prices at both the consumer and producer levels. Assuming a competitive market structure, an increase in the margin means a downward shift in the derived demand and an upward shift in the derived supply; thus, retail prices will increase and farm prices will decrease, other factors being constant. A decrease in marketing margins would have the opposite effect. The magnitude of the price changes at the retail and farm levels depends on the absolute magnitudes of price elasticities of supply and demand.

For linear relations, equal elasticities would mean equal, but opposite, changes in retail and farm prices. If the absolute value of the demand elasticity is larger than that for the supply elasticity, the magnitude of the price change will be greater at the consumer level than at the producer level. If the supply elasticity is larger than the absolute value of the demand elasticity, the magnitude of the price change will be greater at the producer level. When supply is perfectly inelastic, farm price adjusts to the full extent of a margin change. For most agricultural products, however, the supply relation is thought to be more price inelastic than the demand relation, which implies that the impact of a given margin change is greater at the farm than at the retail level.

To quantify these theoretical concepts, Gardner (10) used a six-equation model to examine relationships among retail food, farm output, and marketing services in a competitive food industry. Specifically, his model consists of a retail demand, a processing-marketing industry's product supply, a farm product supply, a marketing service supply, and two marginal conditions for profit maximization. Effects of a change in the variables of the model are determined by factor cost shares and elasticities of the various demand and supply relationships. The effect of a change in marketing services on farmer's share is given by:

$$I_f = 1/\{1 + \{(E_s+\sigma)/(|E_r|+\sigma)\alpha\}\} \quad (1)$$

where:

I_f = the proportion of a change in marketing cost borne by the farmer,

E_s = the elasticity of farm output supply,

$|E_r|$ = the absolute value of elasticity of retail food demand,

σ = the elasticity of substitution between marketing input and farm output, and

α = the ratio of farm price, P_f, and retail price, P_r.

If the form of a product between different market levels is unchanged or is convertible with fixed conversion factors, then the elasticity of substitution is zero. In such a case, equation (1) becomes: 2/

$$I_f = 1/(1+E_s/|E_r|\alpha) \quad (1')$$

The Margin Analysis for Grains

We can apply equation (1') to analyze the user charge effect for grains between the wholesale and farm markets. At the wholesale market, grains are either converted to feed mixes with relatively fixed proportions or exported in commodity form. Thus, an assumption that the elasticity of substitution between marketing inputs and farm output (grains) is zero seems reasonable. Because grains moving through wholesale markets can be sold in both domestic and export markets, the demand elasticity at this level must reflect the price and quantity relationships for both markets. To derive this elasticity, we specify the average revenue and wholesale demand relationships. For example, if the quantity supplied to the domestic market is Q_d and that supplied to the export market is Q_e, the sum of these quantities, Q, is the total amount of grain supplied from the farm ($Q = Q_d + Q_e$), assuming net storage remains unchanged. Let prices at the domestic and export markets be denoted by P_d and P_e, respectively. The average grain revenue, P, from both domestic and export market sales is then:

$$P = P_d(Q_d/Q) + P_e(Q_e/Q) \quad (2)$$

Let $Q(P)$ be the equilibrium quantity demanded at the wholesale market, and let $Q_d(P_d)$ and $Q_e(P_e)$ be the equilibrium quantities demanded at the component domestic and export markets, respectively. The demand functions at the domestic and the export markets are:

$$Q_d = Q_d(P_d) \quad (3)$$

$$Q_e = Q_e(P_e) \quad (4)$$

The total demand curve at the wholesale level may be expressed as:

$$Q(P) = Q_d(P_d) + Q_e(P_e) \quad (5)$$

Differentiating this equation with respect to P and converting all derivatives

2/ Fisher (7) derives equation (1') from a different approach. See appendix.

into elasticities will yield E, the elasticity of demand at the wholesale market:

$$E = E_d \eta_{dp}(Q_d/Q) + \Sigma_d \eta_{ep}(Q_e/Q) \quad (6)$$

where E_d and Σ_d are the domestic and export demand elasticities, respectively. η_{dp} is the elasticity of price transmission between the domestic market price and the average wholesale market price. η_{ep} is the elasticity of price transmission between the export market price and the average wholesale market price. Q_d/Q and Q_e/Q are market share weights for the domestic and export markets, respectively.

If we substitute E for E_r and P for P_r in equation (1'), we obtain the distribution of the user charge burden between the farm and the composite wholesale (domestic plus export) markets. Specifically, let $\beta = P_f/P$; the farmer's share incident to a user charge then becomes:

$$I_f = 1/(1 + E_s/|E|\beta) \quad (7)$$

Note that in equation (7), if the elasticity of supply is zero, farmers would pay 100 percent of any increase in the user charge. In case $E_s = |E|\beta$, the increase in the user charge would be distributed equally between the farm and the wholesale market.

Interactions at Domestic and Export Markets

The part of the user charge not transmitted to farmers would induce changes in quantities and prices at both export and domestic wholesale markets. To establish a satisfactory scheme quantifying these changes, one has to specify the manner in which the two markets are linked. Given that most barged grains are moved to ports for export (table 1), a barge user tax would naturally affect the supply cost of exported grains the most. This situation implies that the export supply schedule of grain would shift upward and that the export price would increase. This price increase would reduce the quantity demanded for export. If grain storage is unchanged, the amount of grain available for the domestic market would increase by an amount equivalent to the export demand reduction. As a consequence, domestic price would be reduced.

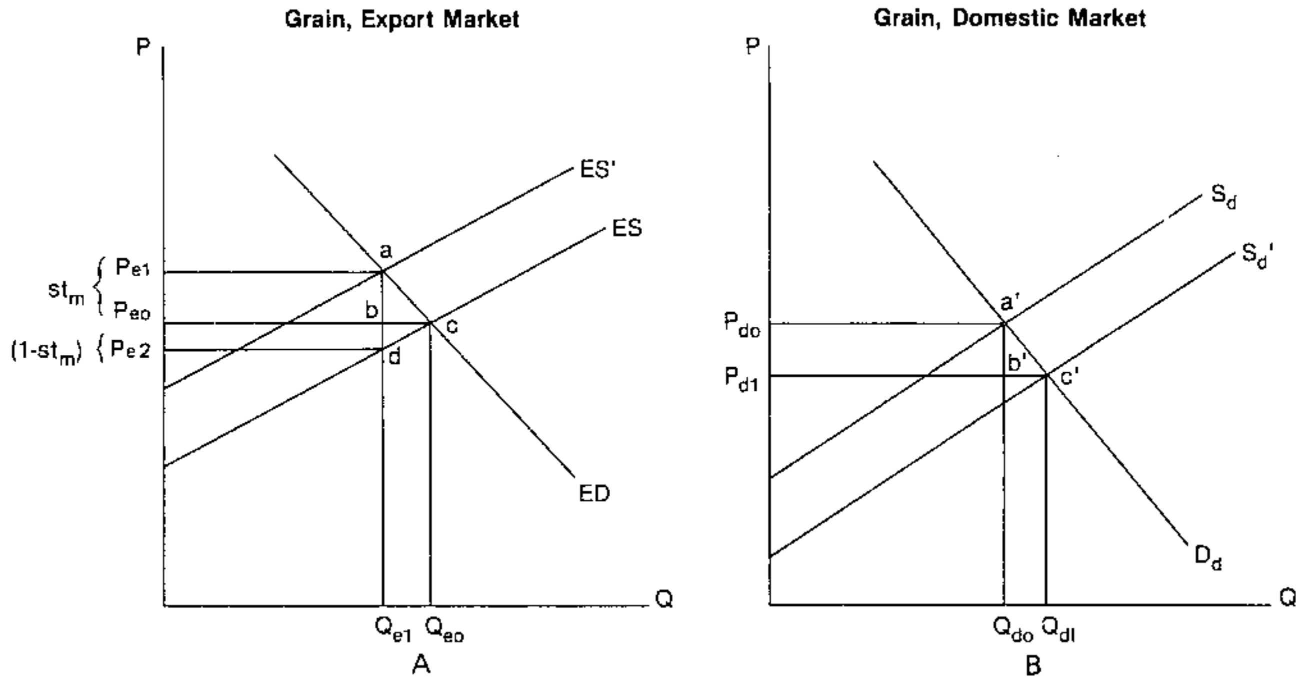
The situation may be more clearly depicted by graphs. Let ED and ES be the world import demand and the U.S. export supply schedules, respectively, at the export market (fig. A). Q_{eo} and P_{eo} are the equilibrium export quantity and price. For the domestic market (fig. B), let S_d and D_d be the domestic supply and demand schedules, respectively, and Q_{do} and P_{do} be the equilibrium quantity

Table 1--U.S. shipments of wheat, corn, and soybeans, by barge, 1977

Shipment	Wheat	Corn	Soybeans
	Million bushels		
Total	400	914	410
Export	313	878	386

Source: (2).

Price and Quantity Effects at Domestic and Export Markets



and price for domestic use. The total quantity of domestic and exported grains is the amount supplied by grain farmers net of storage, Q. When the user charge is imposed, the export supply schedule shifts upward by the share of per unit user tax, t_m (fig. A), which is equal to the total user tax, t, minus the farmer's share, t_f. With normal demand and supply relations (positive supply and negative demand slopes), export prices would increase by a fraction, s, of the tax, t_m. Thus, the price paid by foreign consumers would increase by only st_m. The terms of trade for the importers would improve by $(1-s)t_m$. The increase in the export price would discourage foreign consumers and would reduce grain trade by $\Delta Q_e = Q_{eo} - Q_{e1}$. If grain storage is at full capacity, the amount of grains not sold on the export market would flood the domestic market. This situation implies that the supply schedule at the wholesale market would shift horizontally by the amount $\Delta Q_d = Q_{d1} - Q_{do}$, or ΔQ_e. Depending on the nature of domestic demand, the price at this market would be reduced accordingly.

To quantify these relationships, let Σ_d be the demand elasticity and Σ_s be the supply elasticity at the export market. The change in export price from point c to point a, ΔP_e, equals st_m. This price change is about (1-s) fraction less than the total user charge, t_m, at the wholesale market. Then, by definition (12), the absolute value of demand elasticity at point a is:

$$|\Sigma_d| = (\Delta Q_e/Q_e) * (P_e/st_m) \tag{8}$$

or:

$$P_e(\Delta Q_e/Q_e) = |\Sigma_d| * st_m \tag{8'}$$

The elasticity of supply at point d is:

$$\Sigma_s = (\Delta Q_e/Q_e) * (P_e/(1-s)t_m) \tag{9}$$

or:

$$P_e(\Delta Q_e/Q_e) = \Sigma_s * (1-s)t_m \tag{9'}$$

Equating equations (8') and (9') and rearranging terms, we have:

$$s = \Sigma_s/(|\Sigma_d| + \Sigma_s) \tag{10}$$

The change in price paid by foreign consumers is, therefore:

$$st_m = \{\Sigma_s/(|\Sigma_d| + \Sigma_s)\} * t_m \tag{11}$$

and:

$$\Delta P_e = st_m \tag{11'}$$

From equation (8), the corresponding change of quantity at the export market is:

$$\Delta Q_e = |\Sigma_d| * (st_m/P_e) * Q_e \tag{12}$$

Assuming that surplus grain exports are diverted to the domestic market, then, $\Delta Q_e = \Delta Q_d$. If E_d and E_s are the elasticities of demand and supply, respectively, at the domestic wholesale market (fig. 1b), the change in the wholesale price is:

$$\Delta P_d = (1/E_d) * P_d * (\Delta Q_d/Q_d) \tag{13}$$

Of course, the relationship measures only the direct price-quantity response. It is assumed that, in the short run, the cross effects of substitutes are held constant.

Distribution Effects of a User Tax

The various adjustments in the different grain markets would change income and expenditures for the various economic groups. The usual tool for these economic analyses is the theory of consumer surplus and producer profit. These measurements are used here in a "positive" economics sense to measure what is, not in a "normative" economics sense to measure what ought to be. In other words, the analysis is not an intergroup comparison of utility gain or loss. It explains only what the situation is in terms of revenue and expenditure changes in the different economic sectors. Such analysis provides useful information to policymakers on the cost and income redistribution effects of policy changes regarding user fees.

Assuming the supply and demand curves represent, respectively, the producers' (sellers') profit maximization schedule and consumers' (buyers') money measure of well-being, then foreign buyers' loss (C_e) at the export market due to the grain price increase is:

$$C_e = (st_m * Q_{e1}) + 1/2(st_m * \Delta Q_e) \tag{14}$$

The first part of the equation shows the change in the export revenue due to the export price increase. If all grain exports were transported by barge, this amount (st_m*Q_{e1}) would be the proportion of the user tax revenue paid by foreign consumers. However, only part of the exports represent barged grain. Let f_e be the proportion of export grains using barge transportation. Then, the actual tax revenue (G_{e1}) from foreign consumers is the amount ($st_m * Q_{e1}$) discounted by the proportion, f_e:

$$G_{e1} = f_e * (st_m * Q_{e1}) \tag{15}$$

G_{e1} is only part of the cost absorbed by the export market. A remaining part of the user charge, $(1-s)t_m$, not passed to foreign consumers because of their improved terms of trade, is left for the export grain elevators. However, only f_e proportion of the export grain comes by barge. The actual amount of tax revenue from grain exporters is then:

$$G_{e2} = f_e * \{(1-s)t_m * Q_{e1}\} \tag{16}$$

If one combines equations (15) and (16), the total tax cost for the export market is then:

$$G_e = f_e * (t_m * Q_{e1}) \tag{17}$$

The net change in the export revenue, $\Delta\pi_e$, is the difference between the gain from the price increase, the loss from the decrease in trade, and the user charge burden:

$$\Delta\pi_e = (st_m * Q_{e1}) - (P_{eo} * \Delta Q_e) - G_e \tag{18}$$

Most of the user tax at the domestic market is passed to the export market through the export-destined barged grains. There is still a residual of barged grains in the domestic market. These residual barged grains should also bear the user tax. If f is the fraction of the total U.S. grains (Q) being barged and $f_e * Q_e$ is the amount of barged grains at the export market, then the residual of barged grains at the domestic market, Q_{dt}, is:

$$Q_{dt} = (f * Q) - (f_e * Q_e) \tag{19}$$

The tax burden at the domestic market, G_d, is:

$$G_d = Q_{dt} * t_m \tag{20}$$

If there is no flexibility in grain storage, the supply of grains would be inelastic at the domestic market. Domestic elevators and marketing agents would absorb the user charge. The major effect of the user charge at the domestic market, however, is indirectly induced by the reduction of grains supplied to the export market. When less grain is sold in export markets, domestic supply increases by a like amount assuming no change in storage. Such an increase in quantity would change the domestic supply and demand relationships and would depress the domestic price (equation (13)). The domestic buyers' (processors') gain, C_d, from the price decrease, is:

$$C_d = (\Delta P_d * Q_{do}) + 1/2(\Delta P_d * \Delta Q_d) \tag{21}$$

The revenue change for the suppliers or marketing agents at the domestic market is the combination of the gain from the increased sales at the new price, the loss from the decreased price at the old volume, and the user tax burden, G_d:

$$\Delta\pi_d = (P_{d1} * \Delta Q_d) - (\Delta P_d * Q_{do}) - G_d \tag{22}$$

At the farm level, the farmers' share of the user charge, t_f, is the increase in the marketing cost to farmers. Let total supply of grain, Q, be constant in the short run; the decrease in farm-level income, $\Delta\pi_f$, is:

$$\Delta\pi_f = t_f * Q \qquad (23)$$

The tax collected from grain farmers, G_f, however, is the total amount of grains barged to both domestic and export markets, $f*Q$, multiplied by the farmers' tax share, t_f:

$$G_f = f * Q * t_f \qquad (24)$$

The Government tax revenue, G, of the user charge is the total amount of grain moved by barge to both domestic and export markets, $f*Q$, multiplied by the full amount of the unit user tax, $t = t_f + t_m$:

$$G = f * Q * t \qquad (25)$$

Equation (25) is equivalent to the sum of tax revenues from farm, domestic, and export markets:

$$G = G_f + G_e + G_d \qquad (25')$$

Empirical Application

We use the above theory to empirically measure the possible economic effects at wholesale, export, and farm markets when a 5-cent-per-bushel user charge is imposed for grain and soybean barge transportation. The analysis is based on 1981/82 grain and soybean marketings and prices (app. table 1). The basic supply and demand elasticities used were obtained from the Economic Research Service, International Economics Division (app. table 2). The elasticities of price transmission between the weighted-average wholesale price and its components, the domestic and export prices, are estimated by use of a log-linear price function (see appendix). Substituting these elasticities and the 1981/82 grain marketing shares in equation (6), we obtain the weighted elasticities of demand for grains and soybeans at the wholesale market. These elasticities are -0.55 for wheat, -0.63 for corn, and -0.61 for soybeans. With these estimates, one can obtain the farmers' share of a 5-cent user charge and subsequent estimates of export and domestic market changes. 3/

Distribution of a User Tax Between the Farm and the Wholesale Markets

The burden of user charges for grains and soybeans is higher at the farm level than at the wholesale market. About 70-74 percent of the tax increase is borne by farmers. Only 26-30 percent is shared by marketing agents and/or consumers (table 2). In a study on the nature of marketing cost and farm price, Fisher (7) indicated that the more elastic the demand of a product relative to its supply, the higher the share of the marketing cost at the farm level. Such is the case for grains and soybeans. For a 5-cent-per-bushel user tax, the estimated wheat price at the farm level would decline by 3.5 cents per bushel. The prices of corn and soybeans would each decline by an estimated 3.7 cents per bushel. This decline is about 0.9 percent of the average 1981/82 wheat price, 1.5 percent of the average corn price, and 0.6 percent of the average soybean price (table 3).

3/ Appendix gives the estimating procedures.

Table 2--User tax at wholesale and farm-level markets 1/

Commodity	Wholesale		Farm	
	Percent	Cents/bushel	Percent	Cents/bushel
Wheat	30.2	1.51	69.8	3.49
Corn	26.2	1.32	73.8	3.69
Soybeans	26.2	1.31	73.8	3.69

1/ Total user tax = 5 cents per bushel.

Table 3--Farm prices and changes caused by a 5-cent-per-bushel user tax 1/

Commodity	Farm price		
	Reported average	Estimated change	
	Dollars/bushel	Percent	Dollars/bushel
Wheat	3.71	-0.90	-0.035
Corn	2.46	-1.50	-.037
Soybeans	6.04	-.60	-.037

1/ 1981/82 = base period.

The balance of the user tax, about 1.5 cents for wheat, 1.3 cents for corn, and 1.3 cents for soybeans, would fall on economic groups beyond the farm level.

Export Tax Distribution and Price Changes

Because most barged grains are moved to ports for export, the waterway user tax will affect grain exports more than domestic wholesale markets. Export supply schedules for grains and soybeans will shift upward by the amount of the tax share at the wholesale market (t_m in equation (8)). The amount of change in the grain export price, however, may not equal the supply shift. Only when the elasticity of export demand is zero would grain export price increase by the full amount of the supply shift. In such a case, the quantity exported will not change. If export demand is perfectly elastic, however, export price will not change, but quantity demanded will be reduced to the extent that exporters bear the full amount of the user tax. Between these extreme situations, both export quantity and price would change. The export price would change less than the supply shift. Thus, foreign consumers would assume part of the user tax allocated to the export market, and grain exporters would bear the rest.

For corn and wheat, foreign consumers would bear over half, 56-73 percent, of the export tax burden. At least 44 percent of the soybean export tax would also be shifted to foreign consumers (table 4). U.S. exporters, on the other hand, would bear the remaining export tax, about 27-44 percent for corn and wheat and 56 percent for soybeans. In terms of the total user charge, foreign consumers' share is 12-19 percent, and grain exporters' share is 7-15 percent. If these results are applied to the 1981/82 grain and soybean export prices (table 5), corn price would increase 0.3 percent or 1 cent per bushel, wheat price would increase 0.2 percent or 0.8 cent per bushel, and soybean price would increase 0.1 percent or 0.6 cent per bushel. The corresponding volume reduction is about 0.5 percent or 10 million bushels for corn, 0.2 percent or 3 million bushels for wheat, and 0.1 percent or 0.7 million bushels for soybeans.

Domestic Market Quantity and Price Changes

The domestic market is affected in two ways: a direct user charge burden and an indirect supply price effect. Because of the small amount of barged grains sold at the domestic market, the domestic user charge burden is small, about $1.3 million in 1981/82 (table 6). The main effect is the indirect price effect. Because we assume that the storage of domestic grain would not change, reduced sales at the export market would increase domestic supply, thus reducing domestic price. The amount of price decline depends on both the elasticity of the demand and the relative change in supply. Wheat has a larger percentage

Table 4--Grain user tax burden for foreign consumers and exporters

Commodity	Foreign consumer: Market tax share: Export	Foreign consumer: Market tax share: Total 1/	Foreign consumer: User tax share 2/	Exporter: Market tax share: Export	Exporter: Market tax share: Total 1/	Exporter: User tax share 2/
	Percent		Cents/bushel	Percent		Cents/bushel
Wheat	55.8	16.85	0.843	44.2	13.35	0.667
Corn	73.0	19.20	.960	27.0	7.10	.355
Soybeans	44.3	11.61	.580	55.7	14.59	.730

1/ Total of farm and wholesale markets.
2/ User tax = 5 cents per bushel.

Table 5--Value and change in export volumes and prices for wheat, corn, and soybeans 1/

Commodity	Export volume: Actual volume	Export volume: Estimated change		Export price: Actual price	Export price: Estimated change	
	Million bushels		Percent	Dollars/bushel		Percent
Wheat	1,771	-2.657	-0.2	4.65	0.008	0.2
Corn	1,967	-10.032	-.5	2.83	.010	.3
Soybeans	929	-.743	-.1	7.40	.006	.1

1/ 1981/82 = base period.

increase in supply (about 0.3 percent) than corn (0.2 percent) or soybeans (less than 0.1 percent) (table 7). Domestic demand for wheat is less elastic than that for other products (app. table 2). Thus, the percentage change in price is larger for wheat. Wheat prices would decrease by an estimated 1.6 percent, corn prices by 0.5 percent, and soybean prices by 0.2 percent. The absolute price decrease is 7 cents per bushel for wheat and 1 cent per bushel for both corn and soybeans.

Distribution of Gain and Loss

We can measure economic gains or losses to grain buyers at the domestic and export markets using the concept of consumer surplus. Changes in gross revenue represent the change in the economic well-being of sellers. The estimated economic loss to foreign grain buyers due to the export price increase is about $19 million for corn, $14 million for wheat, and $6 million for soybeans (table 8). According to a 1977 survey (8), the proportion of barged exports is about 29 percent for wheat, 51 percent for corn, and 61 percent for soybeans. Consequently, part of the foreign consumers' payment, $3–$10 million (table 6), should be considered as tax duty. Exporters should also pay their share of the

Table 6—Distribution of waterway user tax burden

Commodity	Export market subtotal			Domestic market	Farm	Total
	Foreign buyer	Exporter	Sum			
	Million dollars					
Wheat	4.10	3.59	7.69	0.19	18.39	26.27
Corn	9.78	2.94	12.72	1.04	39.15	52.91
Soybeans	3.40	3.96	7.36	.11	21.23	28.70
Total	17.28	10.49	27.77	1.34	78.77	107.88

Table 7--Value and changes in domestic market volumes and prices for wheat, corn, and soybeans 1/

Commodity	Domestic wholesale volume			Domestic wholesale price		
	Actual volume	Estimated change		Actual price	Estimated change	
	Million bushels		Percent	Dollars/bushel		Percent
Wheat	856	2.657	0.3	4.26	-0.068	-1.6
Corn	5,087	10.032	.2	2.58	-.013	-.5
Soybeans	1,121	.743	.1	6.26	-.011	-.2

1/ 1981/82 = base period.

tax duty of $3-$4 million. The tax duty for the barged grains at the export market is about $12 million for corn, $7 million for wheat, and $7 million for soybeans. The net revenue loss is about $21 million for corn, $6 million for wheat, and $7 million for soybeans (table 8).

Because supplies of grains and soybeans are quite inelastic, domestic suppliers experience net losses. Lost revenue from wheat sales is about $47 million. For corn and soybeans, these losses are $41 million and $8 million, respectively. The waterway tax burden of this market is comparatively small, less than $0.2 million for wheat and soybeans and about $1 million for corn. Gains for domestic processors from these price reductions are substantial. The processors' surplus due to a price reduction would have been an estimated $58 million for wheat, $65 million for corn, and $12 million for soybeans, if the waterway user fee had been in effect during 1981/82. If processors are also suppliers in this market, their economic gains would more than compensate for their losses.

Farmers would lose most if waterway user fees were implemented. Net farm loss due to farm price reductions would have been an estimated be $92 million for wheat, $260 million for corn, and $75 million for soybeans for 1981/82. About 20 percent of wheat, 15 percent of corn, and 28 percent of soybean supplies are transported by barge. Hence, the Government tax revenue for these barged grains, at 5 cents per bushel, is about $26 million for wheat, $53 million for corn, and $29 million for soybeans (table 8). These payments are assumed to offset $108 million in public expenditures for waterway maintenance. Of the total expenditure transfer, foreign buyers would have paid an estimated $17 million, U.S. exporters would have paid over $10 million, and grain and oilseed producers would have paid about $79 million.

COMPARISON OF THE QUADRATIC PROGRAMMING AND FUNCTIONAL MARKET MODELS

Because the assumption of a 5-cent-per-bushel user charge is the same for both the Quadratic Programming (Q.P.) and the Functional Market (F.M.) models, one can compare the price and quantity changes for wheat.

Table 8--Welfare effects at export, domestic, and farm-level markets 1/

Economic sector	Wheat	Corn	Soybeans	Total
		Million dollars		
Export:				
Consumers' loss	-14.16	-19.62	-5.57	-39.36
Exporters' loss:	-5.90	-21.54	-7.29	-34.73
Domestic:				
Processors' gain	58.47	65.68	12.67	136.82
Suppliers' loss:	-47.43	-40.91	-8.14	-96.48
Farm:				
Farmers' loss	-91.95	-260.29	-75.65	-427.89

1/ Includes tax payment of table 6.

There are striking differences between the export and farm price effects obtained from the Q.P. wheat model and our user charge study. In the Q.P. model, 65 percent of the user fee would be borne by foreign consumers and 35 percent by U.S. farmers. Our study indicates that about 70 percent of the user charge would be borne by U.S. farmers, 17 percent by foreign buyers, and 13 percent by exporters, with some residual effect for inland elevators.

When comparing the results, one needs to consider both the method and underlying assumptions. The Q.P. model focused only on international trade for wheat. Thus, the ultimate effect of a user's charge depends on the elasticities of demand and supply in the world market. Assuming that foreign demands were price inelastic and that foreign buyers had limited alternative sources of supply, the demand for U.S. grain exports appears to be inelastic (see (3)). When the export price increases because of a user's charge, a significant portion of the price increase is passed on to foreign demanders. An important policy implication of this analysis is that if the Government wants to subsidize U.S. waterways, it will subsidize not only U.S. grain producers but also foreign grain consumers. This leads Binkley and Sharples (2) to conclude: "If one purpose of subsidized waterway is to enhance farm income, it may be an inefficient method, because part of the subsidy may be providing benefits to foreign consumers."

In contrast to the Q.P. model, the F.M. analysis takes into consideration the supply and demand interrelationships among domestic, export, and farm-level markets. Applying the marketing margin theory, the F.M. model first analyzes the user charge effects between the farm and the wholesale levels (including both domestic and export markets). The elasticity of farm supply relative to that of demand at the wholesale market determines the user charge at the farm level. At the wholesale level, because of the preponderance of grain barged for export, the effect of the user's fee is to increase the cost of inputs for exporters. However, because of the interrelationship between export supply and demand, wheat export price would increase by only a fraction of the wholesale tax share. That is, foreign buyers would pay 56 percent of the 30 percent of the user tax, and exporters would pay the balance. We assume that rail and truck transportation rates would also increase by the amount of the wholesale user charge. This same assumption, stated differently in the Q.P. model, is that all wheat exports are barged. However, rail and truck may not increase their rates. In such a situation, the barge industry may have to either absorb part of the cost increase, or divert part of their shipments to other modes of transportation. In a study of the demand for barge service and mode utilization, Hauser (11) observed that the demand for waterway shipments is elastic. The elasticity of barge shipment with respect to barge rate change is -1.62 to -3.52, depending on the structure of the barge rate changes. Substitution among transportation modes for the export-bound grain traffic varies. Barges may lose 6-7 percent of the total export-bound grain traffic to rail and truck carriers, depending on the fuel or segment taxes imposed. When other carriers increase their export shipments, their operating costs may also increase. Nevertheless, total export costs may increase less than user charges at the wholesale market. If so, the tax burden of foreign consumers would be even less than our study indicated.

At the domestic market, although there are some residual user charges, the major effect is the price change following a supply increase. Domestic supplies increase because we assume that grain storage does not change in the short run. Thus, the unsold wheat from the export market would overflow into the domestic market. If storage capacity is not limited, inland elevators might store part of the increased supply, and the domestic price would be less severely depressed.

CONCLUSION

The effects of waterway user charges have generally been analyzed with spatial equilibrium or waterway network programming models. The purpose of these models has been to measure regional changes in grain costs and movements from producing to consuming areas. Our study abstracts from the economics of regional differences within the United States and focuses on the aggregate economic effects at different levels within the grain marketing system.

Our analysis is based on the theory of the farmer's share with respect to marketing cost changes in a competitive industry. The underlying assumptions are: (1) that carriers other than barges would increase their transportation rates sufficiently to respond to the user fee increases so that the competitive relationship would be unchanged, and (2) storage would not change at any level of the market. Thus, export supply curves would shift by the middleman's share of the user tax. Such a shift would, in turn, increase export prices, decrease exports of grains and soybeans, and depress domestic prices.

Results show that farmers would bear a larger burden, 70 percent of the user tax. Foreign buyers would bear 20 percent, and exporters would absorb the remainder. The interaction among markets would alter the economic well-being of other economic groups. Domestic wholesale processors would benefit by the reduction in exports, but suppliers would lose revenues because of an inelastic demand structure. However, the major income loss would be at the farm level. In addition to the tax share ($79 million), farmers would have to pay an additional $349 million because of lower overall prices following marketing cost increases. Because farm prices will change most, farmers have a strong economic interest in promoting efficiency in marketing services.

The analysis is short run. It is also partial in that it does not consider the cross-demand relationships among different grain products and the effect of intermodal shipping substitution. The interaction between the feed and the animal product sectors is also held constant. The issue of waterway user charges is extremely complex. What we suggest here is a simple model to provide limited results. However, by relaxing certain assumptions, one could develop a more general model allowing for a wide-ranging series of empirical examinations. For any model of this type, the results would be sensitive to the export and domestic market supply-demand price elasticities used. Nevertheless, this model would provide a useful framework for simulating effects under alternative elasticity estimates.

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APPENDIX

Appendix table 1--Disappearances and prices for wheat, corn, and soybeans, 1981/82

Commodity	Disappearances			Price		
	Domestic	Export	Total	Domestic	Export	Farm
	----- Million bushels -----			--- Dollars per bushel ---		
Wheat	856	1,771	2,627	4.26	4.65	3.71
Corn	5,087	1,967	7,054	2.58	2.83	2.50
Soybeans	1,121	929	2,050	6.26	7.40	6.04

Source: (20).

Appendix table 2--Domestic and export supply and demand elasticities for wheat, corn, and soybeans

Commodity	Domestic		Export	
	Demand	Supply	Demand	Supply
	Elasticity			
Wheat	-0.20	0.20	-0.838	1.06
Corn 1/	-.40	.20	-1.510	4.08
Soybeans 2/	-.40	.20	-.969	.77

1/ Includes other coarse grains.
2/ Includes soybean meal.

Source: (6).

Price Transmission Equations

A log-linear function is used to estimate elasticities of price transmission between (1) the domestic and the weighted-average grain wholesale prices and (2) the export and the weighted-average grain wholesale prices. The equations are listed below. LnP_{di} (i = 1, 2, 3 for wheat, corn, and soybeans, respectively) denotes the logarithmic grain domestic price. LnP_{ei} denotes the grain export price, and LnP_i denotes the weighted-average of wholesale and export price. Because the equations are log-linear, the coefficients of LnP_i are the elasticities of price transmission. Figures in parentheses are t statistics for the coefficients. Data used are listed in appendix tables 3, 4, and 5.

Wheat equations:

$$LnP_{dw} = \underset{(1.37)}{0.022} + \underset{(59.1)}{0.966}\ LnP_w \qquad R^2 = 0.992 \tag{1}$$

$$LnP_{ew} = \underset{(-1.23)}{-0.017} + \underset{(75.3)}{1.021}\ LnP_w \qquad R^2 = 0.995 \tag{2}$$

Corn equations:

$$LnP_{dc} = \underset{(-3.31)}{-0.009} + \underset{(250.2)}{0.989}\ LnP_c \qquad R^2 = 0.999 \tag{3}$$

$$LnP_{ec} = \underset{(12.96)}{0.078} + \underset{(116.2)}{0.974}\ LnP_c \qquad R^2 = 0.998 \tag{4}$$

Soybean equations:

$$LnP_{ds} = \underset{(-0.08)}{-0.005} + \underset{(24.8)}{0.995}\ LnP_s \qquad R^2 = 0.976 \tag{5}$$

$$LnP_{es} = \underset{(0.35)}{0.041} + \underset{(13.77)}{0.983}\ LnP_s \qquad R^2 = 0.926 \tag{6}$$

Appendix table 3--Wheat prices and disappearances at different markets

Year	Price				Disappearance		
	Domestic 1/	Export 2/	Farm	Weighted average wholesale 3/	Domestic	Export	Total 4/
	----- Dollars/bushel -----				----- Million bushels -----		
1954	2.62	2.49	2.08	2.58	612	274	886
1955	2.42	2.37	1.97	2.40	604	346	950
1956	2.35	2.43	2.01	2.39	588	549	1,137
1957	2.34	2.35	1.92	2.34	593	402	995
1958	2.18	2.19	1.72	2.18	608	443	1,051
1959	2.21	2.23	1.77	2.22	597	510	1,107
1960	2.15	2.18	1.75	2.17	603	662	1,265
1961	2.33	2.25	1.86	2.29	608	719	1,327
1962	2.39	2.40	2.01	2.39	580	644	1,224
1963	2.30	2.31	1.90	2.31	589	856	1,445
1964	1.79	1.76	1.36	1.77	644	725	1,369
1965	1.76	1.78	1.37	1.77	732	867	1,599
1966	1.96	2.02	1.61	1.99	674	744	1,418
1967	1.75	1.76	1.40	1.76	633	761	1,394
1968	1.60	1.54	1.25	1.57	735	544	1,279
1969	1.69	1.54	1.26	1.62	772	606	1,378
1970	1.82	1.68	1.38	1.75	769	738	1,507
1971	1.60	1.74	1.34	1.66	856	632	1,488
1972	2.13	2.44	1.90	2.32	786	1,186	1,972
1973	4.48	4.74	4.20	4.64	754	1,217	1,971
1974	4.76	4.46	4.12	4.58	672	1,018	1,690
1975	4.17	4.05	3.58	4.10	721	1,173	1,894
1976	3.23	3.14	2.66	3.18	748	950	1,698
1977	2.83	3.00	2.42	2.93	849	1,124	1,973
1978	3.33	3.69	2.97	3.54	857	1,194	2,051
1979	4.21	4.65	3.78	4.49	783	1,375	2,158
1980	4.57	4.85	4.05	4.76	776	1,514	2,290
1981	4.26	4.65	3.71	4.52	856	1,771	2,627
Average	2.69	2.74	2.26	2.72	700	841	1,541

1/ Minneapolis wholesale price.
2/ Gulf port hard red winter wheat price.
3/ Quantity weighted average of wholesale and export prices.
4/ Sum of wholesale and export disappearances.

Source: (21).

Appendix table 4--Corn prices and disappearances at different markets

Year	Price				Disappearance		
	Domestic 1/	Export 2/	Farm	Weighted average wholesale 3/	Domestic	Export	Total 4/
	------ Dollars/bushel ------				----- Million bushels -----		
1961	1.12	1.23	1.10	1.13	3,527.7	435.4	3,963.1
1962	1.23	1.34	1.12	1.24	3,478.8	415.9	3,894.7
1963	1.25	1.39	1.11	1.27	3,348.4	500.4	3,848.8
1964	1.31	1.42	1.17	1.33	3,305.2	569.5	3,874.7
1965	1.32	1.43	1.16	1.34	3,721.8	687.3	4,409.1
1966	1.36	1.45	1.24	1.37	3,696.8	487.1	4,183.9
1967	1.14	1.22	1.03	1.15	3,885.6	633.3	4,518.9
1968	1.22	1.30	1.08	1.23	3,965.6	535.6	4,501.2
1969	1.31	1.42	1.16	1.32	4,189.9	611.5	4,801.5
1970	1.47	1.56	1.33	1.48	3,977.7	517.0	4,494.7
1971	1.23	1.34	1.08	1.25	4,391.5	795.9	5,187.4
1972	1.91	2.17	1.57	1.96	4,742.1	1,257.8	5,999.9
1973	2.95	3.11	2.55	2.98	4,652.7	1,243.2	5,895.9
1974	3.12	3.26	3.02	3.15	3,677.1	1,148.6	4,825.7
1975	2.75	2.91	2.54	2.80	4,093.0	1,711.4	5,804.4
1976	2.30	2.50	2.15	2.36	4,121.3	1,684.1	5,805.4
1977	2.26	2.50	2.02	2.33	4,334.3	1,947.8	6,282.1
1978	2.54	2.81	2.25	2.62	4,943.5	2,133.1	7,076.6
1979	2.81	3.02	2.52	2.88	5,193.7	2,432.6	7,626.3
1980	3.38	3.54	3.11	3.43	4,874.3	2,355.2	7,229.5
1981	2.58	2.83	2.50	2.65	5,087.5	1,966.9	7,054.4
Average:	1.93	2.08	1.75	1.97	4,152.8	1,146.2	5,299.0

1/ No. 2 yellow Chicago wholesale price.
2/ Gulf port No. 2 yellow price.
3/ Quantity weighted average of wholesale and export prices.
4/ Sum of wholesale and export disappearances.

Source: (18).

Appendix table 5--Soybean prices and disappearances at different markets

Year	Price: Domestic 1/	Price: Export 2/	Price: Farm	Price: Weighted average wholesale 3/	Disappearance: Domestic	Disappearance: Export	Disappearance: Total 4/
	Dollars/bushel				Million bushels		
1966	2.86	3.20	2.75	2.96	612	262	874
1967	2.61	2.89	2.49	2.69	633	267	900
1968	2.55	2.75	2.43	2.61	659	287	946
1969	2.53	2.69	2.35	2.59	795	433	1,228
1970	3.00	2.90	2.85	2.97	824	434	1,258
1971	3.24	3.25	3.03	3.24	786	417	1,203
1972	6.22	3.65	4.37	5.21	734	479	1,213
1973	6.12	7.43	5.68	6.61	898	539	1,437
1974	6.33	6.97	6.64	6.55	778	421	1,199
1975	5.26	5.72	4.92	5.43	936	555	1,491
1976	7.33	6.08	6.81	6.84	867	564	1,431
1977	6.14	7.37	5.88	6.64	1,009	700	1,709
1978	7.11	7.04	6.66	7.08	1,117	739	1,856
1979	6.51	7.56	6.28	6.95	1,208	875	2,083
1980	7.67	7.39	7.57	7.56	1,109	724	1,833
1981	6.26	7.40	6.04	6.78	1,121	929	2,050
Average	5.11	5.26	4.80	5.17	863	522	1,385

1/ No. 1 yellow Illinois processor price.
2/ Gulf port No. 2 soybean price.
3/ Quantity weighted average of wholesale and export prices.
4/ Sum of wholesale and export disappearances.

Source: (19).

Estimating Procedures

The following wheat example explains procedures for estimating the effects of various user charges. Variable notations are categorized in the following table:

Appendix table 6--Variable notations for the waterway user charge equations 1/

Variable name	Farm level	Wholesale level: Domestic: First handler	Wholesale level: Domestic: Processor	Wholesale level: Domestic: Sub-total	Wholesale level: Export: Foreign buyer	Wholesale level: Export: Exporter	Wholesale level: Export: Sub-total	Total
Quantity	Q			Q_d			Q_e	Q
Price	P_f			P_d			P_e	P
Elasticity of:								
Demand				E_d			Σ_d	E
Supply				E_s			Σ_s	
Price transmission				η_{dp}			η_{ep}	
User fee	t_f			t_m	$s*t_m$	$(1-s)*t_m$	t_m	
Revenue change		$\Delta\pi_d$	C_d		C_e	$\Delta\pi_e$		
Government receipt	G_f			G_d	G_{e1}	G_{e2}	G_e	G
Proportion of grains barged	f						f_e	

1/ Blanks indicate not applicable.

Marketing Cost Share at the Wholesale and Farm Markets for Wheat

(1) The weighted-average demand elasticity for wheat at the wholesale market is estimated as follows:

From text equation (6), $E = E_d \eta_{dp} * (Q_d/Q) + \Sigma_e \eta_{ep} * (Q_e/Q)$. From appendix tables 1 and 2, $E_d = -0.2$, $\Sigma_d = -0.838$. From price transmission equations, $\eta_{dp} = 0.966$, and $\eta_{ep} = 1.021$. From appendix tables 3 and 4, the average (1954-81) domestic and export wheat quantities are: $Q_d = 699.96$ million bushels and $Q_e = 840.86$ million bushels. The total average of wholesale wheat is 1,540.82 million bushels. Substitute these figures into the above equation; the weighted average wholesale demand elasticity for wheat is:

$$E = 0.2 * 0.966 * 0.454 + (-0.838) * 1.021 * 0.546 = -0.555$$

(2) Wheat farmers' share of the marketing cost change is estimated as follows:

From text equation (7), $I_f = 1/\{1+(E_s/|E|\beta)\}$, where $\beta = P/P_f$. From appendix tables 1 and 3, $E_s = 0.2$; the average (1954-81) wheat wholesale and farm prices are: $P = \$2.722$ per bushel and $P_f = \$2.263$ per bushel. Substituting these figures into equation (7), the percentage of marketing cost change for wheat farmers is:

$$I_f = 1/\{1 + (0.2/0.555) * (2.722/2.263)\}$$
$$= 0.698$$

The wholesale market's percentage share of the marketing cost change is:

$$I_m = 1 - I_f$$
$$= 1 - 0.698$$
$$= 0.302$$

If t is the 5-cent-per-bushel user tax for wheat, then the user charge burden for wheat farmers is:

$$t_f = 5 * 0.698$$
$$= 3.49¢/\text{bu.}$$

The user tax at the middleman's market is:

$$t_m = 5 - 3.49$$
$$= 1.51¢/\text{bu.}$$

Tax Share at the Wheat Export Market

(1) The fraction, s, of the export market cost share, I_m, borne by the foreign wheat buyers is estimated from text equation (10); $s = \Sigma_s/(|\Sigma_d|+\Sigma_s)$. From appendix table 1, export supply and demand elasticities for wheat are: $\Sigma_s = 1.06$, $\Sigma_d = -0.838$. Substitute these figures into equation (10):

$$s = 1.06/(0.838 + 1.06)$$
$$= 0.558$$

In terms of the total wheat marketing system, the foreign wheat buyers' percentage cost share is:

$$s * I_m = 0.558 * 0.302$$
$$= 0.1685 \text{ or } 16.85\%$$

From the previous section, the actual amount of tax burden at the export market for wheat, $t_m = 1.51¢$ per bushel. The tax duty of foreign wheat buyers is then:

$$s * t_m = 0.558 * 1.51$$
$$= 0.843¢/\text{bu.}$$

(2) The wheat exporters' percentage share of the export tax is:

$(1-s) = 1 - 0.558$
$= 0.442$ or 44.2%

In terms of the total marketing system, the percentage share is:

$(1-s) * I_m = 0.442 * 0.302$
$= 0.1335$ or 13.35%

The actual exporter's tax burden, when $t_m = 1.51$ ¢/bu., is:

$1.51 - 0.843 = 0.667$¢/bu.

Wholesale Quantity and Price Changes

(1) Volume change at the export market is estimated from text equation (12), $\Delta Q_e = st_m/P_e * |\Sigma_d| * Q_e$. From appendix table 2, the 1981/82 wheat export price and volume were: P_e = \$4.65 per bushel and Q_e = 1,771 million bushels. Substitute these figures and estimates of st_m, Σ_d from the above section into equation (12); wheat export volume reduction for the data period is:

$\Delta Q_e = (0.843/465) * (0.838*1,771) = -2.657$ million bushels.

The estimated total amount of wheat export, after user tax, is;

$Q_{e1} = 1,771 - 2.657$
$= 1,768.343$ million bushels

(2) Domestic processors' price change is estimated from text equation (13), $\Delta P_d = (1/E_d) * P_d * (\Delta Q_d/Q_d)$. Let the supply of wheat at the domestic market increase by the amount of wheat export reduction; then, $\Delta Q_d = 2.657$ million bushels. From appendix tables 1 and 2, $E_d = -0.2$, Q_d = 856 million bushels, P_d = \$4.26 per bushel. Substitute these figures into equation (13); the domestic market wheat price change is:

$\Delta P_d = (1/-0.2) * (2.657/856) * 426$
$= 6.816$¢/bu.

The estimated domestic wheat price is:

$P_{d1} = 4.26 - 0.0682$
$= 4.192$\$/bu.

Welfare Effects

(1) Foreign buyers' loss is estimated from text equation (14); $C_e = (st_m * Q_{e1}) + 1/2(st_m * \Delta Q_e)$. From above, $st_m = 0.843$¢ per bushel, Q_{e1} = 1,786.343 million bushels, ΔQ_e = 2.657 million bushels. Substitute these figures into equation (14); foreign wheat buyers loss is:

$C_e = (0.843*1786.343) + 1/2(0.843*2.657)$
= \$14.16 million

(2) The foreign wheat buyers' tax burden, G_{e1}, is the first part of the above equation discounted by the proportion of barged export wheat $G_{e1} = (st_m*Q_{e1}) * f_e$. Substitute st_m=0.843, Q_{e1}=1786.343 million bushels

and $f_e = 0.29$ into this equation:

$$G_{e1} = 0.843 * 1{,}786.343 * 0.29$$
$$= \$4.10 \text{ million}$$

(3) The tax burden to wheat exporters, G_{e2}, is estimated as:

$$G_{e2} = (1-s) * (t_m * Q_{e1}) * f_e$$
$$= 0.667 * 1{,}786.343 * 0.29$$
$$= \$3.59 \text{ million}$$

(4) The total revenue change for wheat exporters' is estimated by equation (18); $\Delta\pi_e = (st_m * Q_{e1}) - (P_{eo} * \Delta Q_e) - G_e$. From above, $P_{eo} = \$4.65$ per bushel, $Q_{e1} = 1{,}768.34$ million bushels, $\Delta Q_e = 2.675$ million bushels, $st_m = 0.843$, and $G_e = G_{e1} + G_{e2}$, or \$7.69 million. Substitute these figures into equation (18):

$$\Delta\pi_e = (0.843 * 1{,}786.343) - (4.65 * 2.657) - 7.69$$
$$= -\$5.90 \text{ million}$$

(5) The domestic processors' gain is estimated from text equation (21); $C_d = (\Delta P_d * Q_{do}) + 1/2(\Delta P_d * \Delta Q_d)$. Since P_d = 6.816¢ per bushel, Q_{do} = 856 million bushels, and ΔQ_d = 2.65. million bushels, substitute these figures into equation (21):

$$C_d = (0.0682 * 856) + 1/2(0.0682 * 2.657)$$
$$= \$58.47 \text{ million}$$

The tax burden for the domestic market is estimated from text equation (20), $G_d = Q_{dt} * t_m$. Because $Q_{dt} = (f * Q) - (f_e * Q_e)$ and $f * Q = 525.4$ million bushels, $f_e * Q_e = 513.59$ million bushels, $t_m = 0.015$, then:

$$G_d = 12.5814 * 0.15$$
$$= \$0.189 \text{ million}$$

The domestic suppliers' revenue change is estimated from text equation (22); $\Delta\pi_d = (P_{d1} * \Delta Q_d)) - (\Delta P_d * Q_{do}) - G_d$. Using above figures, we have:

$$\Delta\pi_d = (4.192 * 2.657) - (0.6682 * 856) - 0.189$$
$$= \$47.43 \text{ million}$$

(6) From text equation (23), farmers' revenue loss is: $\Delta\pi_f = t_f * Q$. For wheat farmers, $t_f = \$0.035$ per bushel, $Q = 2{,}627$ million bushels, thus:

$$\Delta\pi_f = 0.035 * 2{,}627$$
$$= \$91.95 \text{ million}$$

Wheat farmers' tax burden is f, or 0.2 percent of the revenue loss:

$$G_f = f * \Delta\pi_f$$
$$= 0.2 * \$91.95$$
$$= \$18.39 \text{ million}$$

(7) Government tax revenue is the total amount of taxes from farm, domestic and export markets; $G = G_f + G_d + G_e$. Or:

$$G = 18.39 + 0.19 + 7.69$$
$$= \$26.27 \text{ million}$$

We may also estimate this Government tax revenue from text equation (25); $G = (f * Q) * t$. Thus:

$$G = 0.2 * 2{,}627 * 0.05$$
$$= \$26.27 \text{ million}$$

Mathematical Derivation of Marketing Cost Effect on Farm Price

There are two ways to derive the mathematical expression of a marketing margin effect on farm price (equation (1) in the text). The first is by way of Gardner's model (10). The second is to use Fisher's market margin analysis (7).

The Competitive Market Model Approach

Consider Gardner's model of a competitive food industry using two input factors, the raw agricultural commodities, a, and a marketing input factor, b, to produce food x. Let the production of x be linearly homogeneous, and let the quantity demanded for x be influenced by the size of population, N, in addition to the price, P_x. Then, the demand and supply functions for x are:

$$x = f(a,b) \quad (1)$$
$$x = D(P_x,N) \quad (2)$$

If P_a and P_b a: prices of input factors a and b, respectively, then, to maximize profit, firms should demand inputs by the amount that the value of marginal product equals factor prices:

$$P_a = P_x f_a \quad (3)$$
$$P_b = P_x f_b \quad (4)$$

The model is completed by equations representing supply relations of a and b. Let W denote the influence of weather on the production of agricultural products and T represent the influence of tax on the cost of marketing services. Then:

$$P_a = h(a,W) \quad (5)$$
$$P_b = g(b,T) \quad (6)$$

Note that the six equations can be reduced to three by equating (1) and (2) to eliminate x, (3) and (5) to eliminate P_a, and (4) and (6) to eliminate P_b.

$$D(P_x,N) = f(a,b) \quad (7)$$
$$h(a,W) = P_x f_a \quad (8)$$
$$g(b,T) = P_x f_b \quad (9)$$

One can analyze the general effect of an increase in tax on the market equilibrium by differentiating the above equations with respect to T, while holding N and W as constants:

$$D_{px}(dP_x/dT) = f_a(da/dT)+f_b(db/dT) \quad (10)$$
$$h_a(da/dT) = P_x f_{aa}(da/dT)+P_x f_{ab}(db/dT)+f_a(dP_x/dT) \quad (11)$$
$$g_b(db/dT)+g_t = P_x f_{ba}(da/dT)+P_x f_{bb}(db/dT)+f_b(dP_x/dT) \quad (12)$$

From equations (2) to (6), $f_a = P_a/P_x$, $f_b = P_b/P_x$, $D_{px} = dx/dP_x$, $h_a = dP_a/da$, and $g_b = dP_b/db$. Also, for a linearly homogeneous production function, the elasticity of substitution between factors a and b is: $\sigma = f_a f_b/x f_{ab}$. This relation can also be expressed as $f_{ab} = f_a f_b/\sigma x$, or $f_{aa} = -(b/a)(f_a f_b/\sigma x)$. If we substitute these relations into equations (10), (11), (12) and rearrange terms, we have:

$$(dx/dP_x)(dP_x/dT) = (P_a/P_x)(da/dT) + (P_b/P_x)(db/dT) \quad (13)$$

$$(dP_a/da)(da/dT) = - P_x(b/a)(P_aP_b/P_xP_x\sigma x)(da/dT) + P_x(P_aP_b/P_xP_x\sigma x)(db/dT) + (P_a/P_x)(dP_x/dT) \quad (14)$$

$$(dP_b/db)(db/dT) + (dP_b/dT) = P_x(P_aP_b/P_xP_x\sigma x)(da/dT) - P_x(a/b)(P_aP_b/P_xP_x\sigma x)(db/dT) + (P_b/P_x)(dP_x/dT) \quad (15)$$

It would be useful to express these equations in terms of demand and supply elasticities and of market shares of inputs. Let $S_a = aP_a/xP_x$, $S_b = bP_b/xP_x$ be the relative market shares of a and b, η be the price elasticity of demand for the product x, and e_a, e_b be the price elasticities of supplies of input factors a and b. Also, let e_t be the elasticity of input supply b with respect to tax, and let E_{at}, E_{bt}, E_{pxt} be the total elasticities which tell how the first subscripted variable responds to changes in the second subscripted variable. Now, multiply $(P_x x/xP_x)$, (TP_x/P_xT), (Ta/aT), and (Tb/bT) into equation (13):

$$(dx/dP_x)(P_x x/xP_x)(dP_x/dT)(TP_x/P_xT) = (P_a/P_x)(da/dT)(Ta/aT)(xP_x/xP_x) + (P_a/P_x)(db/dT)(Tb/bT)(xP_x/xP_x) \quad (16)$$

If we substitute the appropriate symbols of elasticities and market shares into (16) and rearrange terms, we have:

$$0 = S_aE_{at} + S_bE_{bt} - \eta E_{pxt} \quad (17)$$

Similarly, from equations (14) and (15), we have:

$$0 = -[(S_b/\sigma) + (1/e_a)]E_{at} + (S_b/\sigma)E_{bt} + E_{pxt} \quad (18)$$

$$e_t = (S_a/\sigma)E_{at} - [(S_a/\sigma) + (1/e_b)]E_{bt} + E_{pxt} \quad (19)$$

In matrix notation, the system of equations (17), (18), and (19) is:

$$d = AX \quad (20)$$

$$\text{where: } d = \begin{vmatrix} 0 \\ 0 \\ e_t \end{vmatrix} \quad A = \begin{vmatrix} S_a & S_b & -\eta \\ -[(S_b/\sigma) + (1/e_a)] & S_b/\sigma & 1 \\ S_a/\sigma & -[(S_a/\sigma) + (1/e_t)] & 1 \end{vmatrix} \quad x = \begin{vmatrix} E_{at} \\ E_{bt} \\ E_{pxt} \end{vmatrix}$$

Let the effect of a change in the marketing cost (T in this model) on the change in farm price of a be I_f. Then, the farmer's share of an increase in the marketing charge is expression (7):

$$I_f = (\partial P_a/\partial T)/[(\partial P_a/\partial T) + (\partial P_x/\partial T)] \quad (21)$$

Equation (21) can also be written as:

$$I_f = [E_{pat}(P_a/T)]/\{[E_{pat}(P_a/T)]\} + \{[E_{pxt}(P_x/T)]\} \quad (22)$$

To obtain the values of E_{pat} and E_{pxt} in the above equation, we need to solve equation-system (20). Applying Cramer's rule, we have:

$$E_{pxt} = \{e_t S_b[((S_a+S_b)/\sigma) + (1/e_a)]\}/|A| \quad (23)$$

where $|A|$ is the determinant of matrix A in (20). Since $(S_a+S_b) = 1$, equation (23) can be written as:

$$E_{pxt} = \{e_t S_b[(1/\sigma) + (1/e_a)]\}/|A| \quad (24)$$

To obtain E_{pat}, we need to estimate E_{at} because the ratio (E_{at}/e_a) is equal to E_{pat}. From equation-system (20), we derive:

$$E_{at} = \{e_t S_b[(\eta/\sigma) + 1]\}/|A| \quad (25)$$

Thus:

$$E_{pat} = \{e_t S_b[(\eta/\sigma) + 1]\}/(e_a|A|) \quad (26)$$

If we substitute equations (24) and (26) and $(P_a/P_x) = \alpha$ into equation (22) and rearrange terms, we have:

$$I_f = 1/\{1 + [(e_a+\sigma)/(\eta+\sigma)\alpha]\} \quad (27)$$

when $\sigma = 0$, the relation becomes:

$$I_f = 1/[1 + (e_a/\eta\alpha)] \quad (28)$$

which is equation (1') in the text.

<u>The Marketing Margin Approach</u>

Fisher (7) uses the relationship between the marketing margin and elasticities of a product at two levels of the market to derive the effect of margin on farm price. Consider that the change in the margin, ΔM, of a product x can be decomposed into its effect on farm and retail prices; that is:

$$\Delta M = \Delta P_x + \Delta P_a \quad (1)$$

where P_x and P_a denote retail and farm prices for x. The proportion of the marketing cost change borne by the farmer, I_f, is given by:

$$I_f = (\Delta P_a)/(\Delta P_a + \Delta P_x) \quad (2)$$

If the demand and supply curves for the product are linear over the range of our analysis, then the change in the margin between P_x and P_a is related to the product's demand and supply elasticities at retail and farm markets. Specifically, let η be the demand and e_a be the supply elasticities for x at the retail and the farm market, respectively; then:

$$\eta = (\Delta x/\Delta P_x)(P_x/x) \quad (3)$$
$$e_a = (\Delta x/\Delta P_a)(P_a/x) \quad (4)$$

Interchangeably, equations (3) and (4) can be expressed as:

$$\Delta P_x = (\Delta x/\eta)(P_x/x) \quad (5)$$
$$\Delta P_a = (\Delta x/e_a)(P_a/x) \quad (6)$$

Substitute these two expressions into equation (2):

$$I_f = [(\Delta x/e_a)(P_a/x)]/[(\Delta x/\eta)(P_x/x)] + (\Delta x/e_a)(P_a/x)] \quad (7)$$

or:

$$I_f = 1/\{1 + (\Delta x P_x/\eta x)(e_a x/\Delta x P_a)\} \quad (8)$$

Let $(P_a/P_x) = \alpha$ and substitute it into equation (8):

$$I_f = 1/[1 + (e_a/\alpha\eta)] \quad (9)$$

This is the result obtained by equation (30) in the previous approach.

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