EFFECTS OF INCREASING PANAMA CANAL TOLL RATES ON U.S. GRAIN EXPORTS

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Abstract

Some believe Panama Canal toll rates will increase dramatically as Panama's sovereignty over the Canal becomes complete at the end of this century. This paper focuses on the ability of Panama Canal management to extract additional toll revenues from United States grain traversing the Canal and the impact of increased toll rates on export grain flows. Analyses show toll rates established by a revenue-maximizing Canal management would exceed historical and current rates. A monopolizing Canal operator would have moderately increased Pacific port exports in the mid-1970's; whereas, in the 1979-82 period, Pacific port flows would have exceeded historical levels.

Key words: grain exports, Panama Canal, toll rates.

The purpose of this study is to evaluate the ability of Panama Canal management to extract additional toll revenues from United States grain transiting the Canal and to determine the effect of increasing toll rates on United States grain flows to port regions. Currently, the Canal is operated by the Panama Canal Commission, an agency of the United States government. However, a recently consummated treaty with the Panamanian government calls for graduated increases in that country's sovereignty over the Canal. By the year 2000, Panama is scheduled to be in complete control of Canal operations and defense. Some observers believe the Panamanian government will view the Canal as an instrument to increase revenues once American oversight and management is diminished (Brandes and Chun). Historically, toll rates have been designed to yield sufficient revenues to cover costs. In contrast, the Panamanian government may establish a toll rate structure which maximizes Canal revenues.

The Panama Canal is a critical transportation link for United States grain and soybean exports. Annually, 25 to 30 percent of United States grain exports pass through the Canal (Panama Canal Commission). Grain produced in the United States annually comprises from 91 to 94 percent of all grain moving through this transportation artery. Nearly all of the United States originated grain transiting the Canal embarks from Gulf ports with lesser quantities originating at Atlantic and Great Lake ports. Most of these exports are destined for Asia. Additional quantities move to the West Coasts of South and Central America, Table 1.

The objectives of this study are to (1) estimate the revenue-maximizing Panama Canal toll rate structure for United States corn, soybeans, sorghum, and wheat exports passing through the Canal and contrast this rate structure with historical rates to identify the potential rent which might accrue to this transportation artery and (2) identify the effect of a revenue-maximizing toll rate on the United States export-grain flow patterns and port area receipts.[1] A

TABLE 1. GRAIN AND SOYBEANS TRANSITING THE PANAMA CANAL BY MAJOR TRADE ROUTES, 1982[a]

	Destinations					
Origins	West Coast Central America	West Coast South America	Panama	Oceania	Asia	Total
	1,000 long tons					
East Coast United States[b]	793	3,231	92	27	28,896	33,039
East Coast Canada		7			145	152
East Coast South America	62					62
Europe	48	28				76

[a]Includes corn, barley, wheat, soybeans, rice, oats, sorghum, and unclassified grains.
[b]Includes U.S. Gulf, Atlantic, and Great Lakes ports.
Source: *Annual Report*, Panama Canal Commission, 1982.

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[1]The analysis proceeds upon the assumption that Canal management would set a toll rate for each type of United States grain traversing the Canal. It may also be possible for Canal management to further discriminate by country of destination; however, for the purposes of this analysis, it is assumed that this opportunity would be difficult to administer and therefore infeasible.

priori, toll increases would adversely affect the volume of Gulf and Atlantic ports grain exports to Asia and western South and Central America. This premise is based on the assumption that tolls would be incorporated into ship rates on those routes which involve canal passage and the rate increases would initially be borne by the United States grain producer via lower grain prices.[2] Thus, increases in Panama Canal toll rates would tend to redirect export grain to Pacific ports in order to bypass the Canal. This would expand the Pacific ports' supply region eastward while the Gulf and possibly the Atlantic supply regions would recede. Recently, Martin and Clement reported that changes in interport ship rate differentials (Gulf port rates versus Pacific port rates) influence internal grain flows to Gulf and Pacific ports. Thus, there is evidence that relative ship rates affect flows to these port areas.

MODEL, DATA, AND PROCEDURE

Model

A multicommodity, multiperiod, cost-minimizing spatial model is used to conduct the analysis. This methodology has proven useful for purposes of studying transportation of low-valued, bulky commodities such as grain. The model links United States surplus grain and soybean producing regions to domestic demand and foreign demand locations, Figure 1, and includes 165 domestic grain and soybean producing regions. Some regions have grain and/or soybean surpluses since estimated production exceeds estimated consumption, while other regions have estimated deficits. Domestic grain and soybean consumption estimates reflect livestock, poultry, human, and industrial demands. The model includes 85 domestic regions with estimated grain and soybean deficits. In addition, foreign demand for United States grain and soybean production is included for 25 world subregions. These estimated demands represent total world demand for United States produced grain and soybeans. Foreign demand and regional grain surplus and deficit estimates are predetermined quantities which are calculated exogenously of the spatial model.

Surplus grain producing regions are linked to the grain-deficit domestic regions and to United States port areas by applicable transportation costs and/or rates. Domestic transportation may be by truck, rail, barge, or any combination of these modes. The two major river systems (Mississippi River and tributaries and the Columbia-Snake system) are included in the model by 43 barge loading locations, Figure 2. Truck and rail costs link United States surplus grain producing regions to the 43 barge loading locations. Barges may transport grain to other selected river locations or applicable ports for unloading. The model considers 16 port areas which include two Atlantic ports, five Gulf ports, four Great Lakes ports, and five Pacific ports, Figure 2. Each port is linked to the 25 world subregions by ocean shipping rates.

Since some Plains and most Corn Belt areas have access to unit trains, the rail parameters

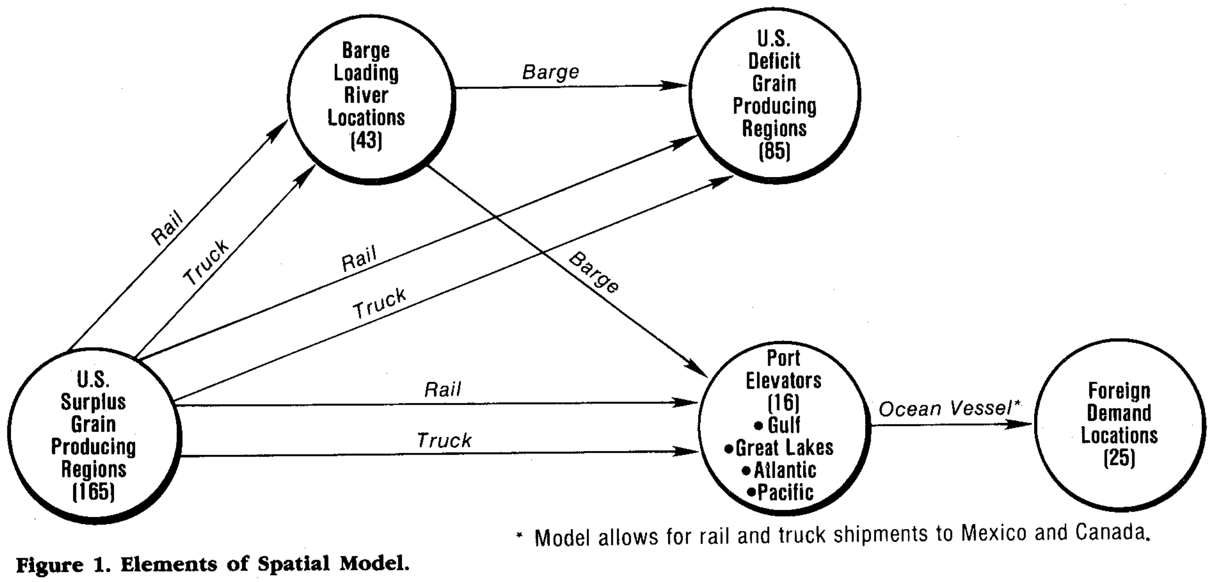

Figure 1. Elements of Spatial Model.

[2]Increases in ocean transportation rates would be primarily borne by the United States grain producers and foreign buyers. The proportion of transportation costs borne by the foreign buyers is a function of the price elasticity of foreign import demand for United States grain (D) and domestic supply elasticity (S), and is given by the following equation: $|D|/(|D| + S)$. Consequently, based on most estimates of elasticities, 80 to 95 percent of increased transportation costs would be borne by United States grain producers.

Figure 2. Barge Loading Facilities on Inland River System and Export Ports Included in Model.

linking these areas to Atlantic and Gulf ports reflect either 50, 75, or 100-car shipments. Similar movements to Pacific ports are represented by 50-car unit trains. In all other movements, single-car parameters are used.

Grain handling, storage, and transportation costs associated with marketing and distribution are included in the model. The multicommodity, least-cost network flow model includes corn, wheat (hard, soft, and durum), soybeans and sorghum. Four quarters or one crop year are represented. The least-cost model selects the grain distribution pattern that minimizes total costs (grain handling, storage, and transportation) and satisfies the predetermined domestic and foreign demands (Taylor). The solution was obtained with a revised out-of-kilter network code. This model was initially developed by Taylor and has been modified by Makus and then by Fuller et al. to investigate various grain transportation issues.

Data

A substantial amount of data was required to construct and calibrate the spatial model. Initially, United States grain and soybean producing and consuming regions were identified to estimate each region's surplus or deficit. In addition, demand estimates for United States grain and soybeans by world subregion were required. Estimates of transportation costs which link surplus production areas to foreign and domestic demand locations and grain handling and storage costs were also necessary.

Examination of each state's geographical production pattern made possible the development of a regional demarcation scheme for each commodity. In those states with substantial production, crop reporting districts were the selected geographical unit, while in those regions with less intense production, crop reporting districts were aggregated. The USDA's National Interregional Agricultural Projection (NIRAP) model's output and a report by Lazarus et al. were the basis for developing estimates of each region's expected grain and animal production. Estimates of grain, livestock and poultry production were representative of the mid-1980's. Estimates of animal rations and grain consumption were derived from the USDA's *Livestock-Feed Relationships, National and State.* Projected domestic processing demands for wheat and corn were based on trends of historical consumption and population projections and were designed to represent the mid-1980's. Projected soybean crushings were based on historical relationships between soybean crushings and soybean exports. Projected crushings were allocated to regions based on current processing capacities (Hauser, 1982).

Information to estimate foreign demand by world subregion was obtained from data included in the USDA's *Grain Market News* and from personnel of the International Economics Division of the USDA's Economic Research Service. Demand projections for the mid-1980's were estimated for the 25 world subregions with the historical export data. The USDA's International Economics Division is involved in projecting United States export demand and provided input to adjust some estimates. The projected total world demands for United States produced corn, wheat, soybeans and sorghum were 2.47, 1.39, .77, and .26 billion bushels, respectively.[3]

The estimated truck and barge cost parameters are believed to be representative of rate levels in the longrun. Because these transportation industries exhibit competitive behavior, total costs are used as a proxy for rates (Sorenson). Costs were calculated to reflect sufficient returns to encourage reinvestment. Trucking cost estimates were obtained with a computer algorithm that employed budgeting and economic-engineering cost estimation techniques. A truck cost equation reflecting different taxing procedures, licensing fees and wage rates was developed for each state. The cost of a particular truck movement was based on the originating state and distance. All truck costs reflect 1981 operations of tractor semi-trailers. Barge and towboat costs were estimated using budgets developed by the United States Army Corps of Engineers. Information regarding towboat and barge operating characteristics on the various river segments was used to obtain unit costs of barge transportation between various river locations.

Because of the railroad industry's structural characteristics and the greater pricing freedom afforded by the Staggers Rail Act of 1980, it is difficult to predict railroad pricing behavior. However, for this analysis, railroads were assumed to charge the highest rate which intermodal competition would permit (Fuller et al.). The assumption was made that railroads would not attempt to capture traffic in the longrun if the maximum attainable rate yields a revenue-to-variable cost ratio less than 1.0. An earlier study by Fuller et al. outlined the procedure followed in identifying the maximum revenue-to-variable cost ratio allowed by intermodal competition in surplus grain producing regions. The identified ratio is multiplied by variable rail cost to convert to a rate parameter.

Variable rail cost estimates were based upon costs published in the Interstate Commerce Commission's (ICC) Statement No. 1C1-77, *Railroad Carload Cost Scales, 1977.* This document is based upon an application of Rail Form A, reflecting the operations of Class I line-haul railroads. *Rail Update Ratios* issued by the ICC were used to update these costs to 1981. A computerized algorithm estimated rail costs by reconstructing the formulae presented in the ICC's cost scale publication. The algorithm includes a multiple-car program which adjusts various parameters (e.g., way train mileage, train size, switching time, turn-around time, etc.) to obtain 25-, 50-, 75-, and 100-car unit train costs. The algorithm was obtained from the Department of Economics, Iowa State University (Hauser, 1980).

Substantial attention was focused on ship rates since relative ship rates (Gulf port versus Pacific port rates) would seem to affect the ability of Canal management to increase toll rates. Panama Canal tolls were assumed to be incorporated into ship costs and to be ultimately reflected in ship rates. Thus, upward toll adjustments would increase ship rates on those trade routes which involve Canal passage. This appeared to be a reasonable assumption in view of recent findings by Martin and Clement; Binkley; Harrar and Binkley; and Olson. They noted that the ocean grain transportation industry is virtually unregulated by governments and is characterized by unrestricted entry and free bargaining between shippers and ship owners. Harrar and Binkley, and Olson conclude that ocean transportation of grain is highly competitive. This is in contrast to liner transportation which is dominated by cartels.

A priori, the ability of Panama Canal management to profitably adjust tolls would be dependent on the ship rate relationship between Gulf and Pacific ports. For example, if ocean transportation rates linking Gulf ports to Asia are less or on par with rates from Pacific ports, there may be substantial opportunity for upward toll adjustments. Conversely, if rates from Gulf ports are relatively high, the opportunity for upward toll adjustments may be limited. A recent review of historical ship rate relationships by Harris shows rate differences between Gulf and Pacific ports to Japan to be substantial at times. Thus, to conduct a meaningful analysis, it is necessary to determine the Canal's revenue-maximizing toll rates for differing historical ship rate structures.

Due to extreme variability in ocean shipping

[3]Estimating future demand for United States produced grain and soybeans is very difficult. Since 1978, U.S. corn exports have ranged from 1.9 to 2.5 billion bushels while wheat outflow has varied between 1.2 and 1.6 billion bushels. Annual soybean exports ranged up to .9 billion bushels in 1982, while lowest export volumes occurred in 1978-79 with outflow of .7 billion bushels. Sorghum exports have ranged between .2 and .3 billion bushels since 1978.

rates, particularly in recent years, it is difficult to construct ship rate structures that are representative of an extended time period. International Wheat Council data show monthly interport rate differentials (Gulf port versus Pacific port rates) to have been relatively constant in the mid-1970's; however, by 1978, interport rate variability dramatically increased. In 1978, Pacific ports' monthly rate advantage to Japan varied between 2 and 22 cents per bushel and, in 1979, 1980, and 1981, the Pacific ports' monthly rate advantage ranged from 10 to 36 cents per bushel. Thus, constructing ship rate structures representative of particular years is difficult. In view of this, a series of ship rate models reflecting varying interport ship rate differentials was constructed.

Six ship rate models were constructed based on research and data from Harrar and Binkley, International Wheat Council, and Maritime Research, Inc. The Harrar and Binkley study focused on mid-1970 ship rates and was the basis for the initial model. The five remaining models were constructed by simply increasing the initial model's rates on these trade routes linking Gulf ports to Asia and the west coasts of Central and South America. Rates were increased by 6, 12, 18, 24, and 30 cents, while rates from Pacific ports were left at initial levels. Based on Maritime Research, Inc. and International Wheat Council data, this would yield a range of ship rate structures that was applicable to the 1978-1982 period. The 6-, 12-, and 18-cent models appeared representative of periods between 1978 and 1982, while the 18- and 24-cent models appeared generally representative of periods between 1979-1981.[4]

Grain handling and storage costs were based upon United States Department of Agriculture estimates for country elevators, inland terminals, and port terminals. These estimates were based upon a 1971-72 survey of the commercial storage industry updated to 1980 using producer price indices and current volume estimates, as well as data collected from an abbreviated survey of grain handlers (Leath). The cost parameters relate per bushel storage costs and per unit costs of receiving and loading grain by truck, rail, and barge for each type of grain handling facility.

Procedure

The spatial model is used to determine the ability of a revenue-maximizing Canal management to increase toll revenues for five of the historic ship rate structures. To accomplish this, a developed ship rate structure is entered into the model, the model solved, and flows via the Canal recorded. Then, ocean shipping costs linking Gulf, Atlantic, and Great Lake ports to the seven world subregions which may receive their United States grain imports via the Panama Canal (Japan, China, Korea, Taiwan, Southeast Asia, and the west coasts of Central and South America) are adjusted upward in 6-cent increments to facilitate an analysis of increasing toll rates. As noted, it seems reasonable to assume that Panama Canal tolls are reflected in shipping rates on trade routes traversing the Canal. The model is solved for each upward adjustment in toll rate and the volume flowing via the Canal is recorded. The volume flowing via the Canal is multiplied by the appropriate toll rate in order to estimate associated revenues. This procedure is followed for five of the historic ship rate structures to identify the associated revenue-maximizing toll rate. The revenue-maximizing toll rate is compared with historic and current tolls for purposes of determining the ability of management to adjust tolls upward.[5] Port grain flows associated with revenue-maximizing toll rates are recorded for purposes of identifying the impact on grain flow patterns.

COMPARISON OF HISTORICAL AND MODEL-PROJECTED FLOWS

To gain insight into the model's ability to accurately represent grain flows, the alternative ship rate structures were entered in the model and flow patterns of the various solutions compared with actual flows. Meaningful comparisons between model-projected and actual flows are difficult to make. The model includes grain production, consumption and foreign demand

[4]Harrar and Binkley found international grain transportation rates to be highly volatile. Absolute rate levels tend to fluctuate widely as do relative rates on differing trade routes. For example, the average Gulf-Japan rate increased from about 18 cents per bushel in the 1971-72 crop year to 37 cents per bushel in 1972-73 and to 82 cents per bushel in the 1973-74 period. The 1975-77 period was relatively stable with Gulf-Japan rates averaging near 40 cents per bushel. Increasing bunker fuel prices and expanding transportation demands in the latter 1970's provided impetus for dramatic rate increases that culminated in 1980-81 with rates exceeding $1.00 per bushel. In 1982, the Gulf-Japan rate decreased reaching 1978 levels, at which time rates varied between 48 and 60 cents per bushel.

[5]Canal tolls are levied "per net vessel ton of 100 cubic feet of actual earning capacity." The Panama Canal's measurement of vessel net tonnage is prescribed by specific rules of measurement; however, the Canal's net tonnage value is very similar to that listed in Lloyd's *Registry of Shipping*. To gain insight on the per bushel cost of transiting the Canal and how recent toll adjustments have impacted per bushel costs, information on a sample of grain-carrying ships known to transit the Panama Canal was collected. Information included ship name and quantity of grain carried. This information, in combination with toll schedules and net tonnage estimates from the Lloyd's *Registry of Shipping*, was used to estimate per bushel costs.

estimates that are representative of the mid-1980's rather than historical values. Further, the model is constructed such that the production, consumption, and foreign demand estimates have a pre-determined geographical location; whereas, the actual location of these activities exhibits year-to-year variation. Additional divergence in actual and model-projected flows is due to difficulty estimating a ship rate structure that is representative of a particular period. The developed ship rate structures are deterministic, while actual interport rate differences exhibit wide monthly variations. Accordingly, it is difficult to develop a ship rate structure that accurately reflects a time period for which flows are recorded. In spite of these reservations, the model relates the effect of the widening interport ship rate differential, and generated flows that approximate historical proportions.

Ship rate data show that rates from Pacific ports to Japan, Taiwan, and Korea were often equal to rates from Gulf ports in 1975-77. In the latter 1970's, the Pacific ports developed a rate advantage to Japan and this advantage widened to reach a maximum annual average differential of 21 cents per bushel in 1980. Since then, the Pacific ports' rate advantage has declined and in 1983 the Pacific ports' advantage averaged about 6 cents per bushel relative to Gulf ports (USDA, *Grain Market News;* Leath et al. (a) (b) (c)).

In the mid-1970's (1975-77 when Gulf and Pacific port rates were often equal), Gulf ports handled an average 66 percent of total United States corn outflow while the Pacific ports' share was less than 1 percent. The model projects Gulf ports would export 68 percent of total United States corn outflow and Pacific ports would handle no corn when a ship rate structure representative of the mid-1970's is included. Thus, projected and actual proportions were similar for this time period.

Historic annual port flow information for corn, soybeans, and sorghum shows that Pacific and Gulf port flows are affected by the rate advantage of Pacific ports to Asia. Corn flows to Pacific ports increased as this port area's rate advantage to Asia increased in 1979, 1980, and 1981 (USDA, *Grain Market News).* In 1979, 1980, and 1981, corn exports from Pacific ports increased to 11, 18, and 13 percent of total corn outflow while Gulf ports' respective shares declined to 58, 59, and 63 percent. The Pacific ports' annual average rate advantage in 1979, 1980, and 1981 was 13, 21, and 14 cents, respectively, while monthly variability ranged from 10 to 36 cents per bushel (International Wheat Council).

Several developed ship rate structures were included in the model for purposes of approximating these flows. One model included a Pacific port rate advantage to Japan of 18 cents per bushel while another included a 24- cent advantage. The model including the 24-cent Pacific port advantage projected the Pacific ports' share at 17 percent and the Gulf ports' share at 52 percent while the model including the 18-cent differential yielded Pacific and Gulf flows equal to 5 and 64 percent of total outflow, respectively. The model clearly reflects the effect of increasing interport ship rate differentials on Gulf and Pacific port flows and yields port shares that are similar to historic values.

In contrast to corn, a large volume of soybean exports is not redirected to Pacific ports as the rate advantage widens. Historically, the Gulf, Atlantic, and Great Lake ports have handled nearly all United States soybean exports while Pacific ports' share has been very small or zero (Leath et al. (b); USDA, *Grain Market News*). With few exceptions, Gulf ports have handled over 70 percent of the soybean exports. The model projected no soybean flows to Pacific ports until these ports' rate advantage approximated 12 cents per bushel. Model projected flows to Pacific ports at differentials of 18 and 24 cents were 2 and 8 percent of total outflow, respectively.

The model includes greater surpluses of soybeans in western Minnesota and eastern North Dakota than have historically occurred. Consequently, with the 24-cent rate differential this production moved to Pacific Northwest ports, and these ports' projected share exceeded historical levels. Although, the actual Pacific ports' export level is somewhat below that projected with the model when including a 24-cent rate differential, the estimated and historical flows are generally unresponsive to widening interport rate differentials.

Historical sorghum flow data show Gulf ports responsible for up to 99 percent of total exports during much of the 1970's (USDA, *Grain Market News*). Until the latter 1970's, Pacific ports handled no more than 3 to 4 percent of annual exports in any given year. However, as the interport rate differential widened in 1979-81, substantial shifts occurred. In 1979, 1980, and 1981, Gulf ports respective export shares were 86, 62, and 66 percent while Pacific ports' shares increased to 14, 24, and 22 percent, respectively. Clearly, the widening rate advantage of Pacific ports increased flows to this port area. The model projected no flows to Pacific ports until the interport rate differential widened to 18 cents per bushel, at which time substantial quantities (27 percent) were redirected to Pacific ports; whereas, with a 24-cent per bushel rate advantage, Pacific ports were projected to handle up to 40 percent of annual exports. In general, the model-projected sorghum flows show the same responsiveness to changing interport rate differentials as that exhibited by the historical flow data.

Wheat flows show little sensitivity to changing interport rate differentials. Historically, Pacific ports have handled about one-third of the U.S. outflow while Gulf ports' share has varied between 50 and 60 percent. Analysis with the hard, soft, and durum wheat models also showed little sensitivity of flows to changing ship rate structures.[6] Thus, historical evidence and model-projected flows imply a revenue-maximizing Canal operator would not substantially alter wheat flows (Leath et al. (c); USDA, *Grain Market News*). For this reason, wheat was not included in the analysis.

Interport rate differentials apparently affect corn, sorghum and, to a lesser extent, soybean flows to Gulf and Pacific port areas. When ship rate structures approximating historical levels are included in the model analysis, flows approximate historical patterns. Exact replication of flows is impossible since numerous variables are simultaneously affecting flows and the model analysis only centers on changing interport rate differentials. In spite of this, the historical portions exiting the various port areas are similar to model-generated flows. Thus, the model appears capable of accomplishing study objectives.

RESULTS

Results are presented in two sections. The first section identifies toll rates which maximize Canal revenues for the various ship rate structures. The revenue-maximizing toll rates are compared with historic tolls to determine the feasibility of upward toll rate adjustments. The second section focuses on the impact of increasing toll rates on United States port grain flows.

Revenue-Maximizing Toll Rates

Table 2 shows the Canal's estimated revenue-maximizing toll rate for transiting United States grains when ship rate structures associated with the 0-, 6-, 12-, 18- and 24-cent models are analyzed. The revenue-maximizing tolls would range from 6 cents per bushel for sorghum and corn to 24 cents per bushel for soybeans. Information in Table 2 indicates that revenue-maximizing toll rates would substantially exceed actual tolls which increased from 1.0 cent per bushel in the early 1970's to the current level of 2.5 cents per bushel. In general, the analysis shows a relatively inelastic relationship between changes in toll rates and quantity of United States grain traversing the Canal. Thus, Canal management would have substantial opportunity to increase toll rates and revenues should it adopt a revenue-maximizing philosophy.[7]

As expected, revenue-maximizing toll rates tend to decrease as ship rates from Gulf ports to Asia increase relative to rates from Pacific ports; i.e., there is greater opportunity for upward toll adjustments when the ship rate structure is characterized by the 0-cent model as compared to the 24-cent per bushel rate model, Table 2. Similarly, total toll revenues decrease

TABLE 2. PANAMA CANAL'S ESTIMATED REVENUE-MAXIMIZING TOLL RATES FOR SELECTED GRAINS AT VARIOUS SHIP RATE STRUCTURES, U.S., 1975-1981

Historic ship rate structures[a]	Estimated revenue-maximizing toll rates for selected grains		
	Corn	Soybeans	Sorghum
	----------- cents/bushel -----------		
0-cent[b]	18	24	12
6-cent[c]	12	18	6
12-cent[c]	12	18	6
18-cent[c,d]	6	18	6
24-cent[d]	6	12	6

[a]In the 0 cent model, the ship rates for grain moving from Gulf ports to Japan, Taiwan, and Korea are par with rates from Pacific ports. These three countries receive about 75 percent of the grain destined to the seven world subregions whose imports of United States grain may traverse the Panama Canal. In the 0-cent model, rates from Gulf and Pacific ports to the west coast of Mexico are set at similar levels, while rates from Pacific ports to the west coast of South America are approximately 20 percent higher than rates from Gulf ports. Rates from Gulf ports to Southeast Asia are about 18 percent higher than rates from Pacific ports while rates from Gulf ports to China are about 7 percent higher than rates from Pacific ports. The remaining models were constructed by simply increasing rates which linked Atlantic and Gulf ports to the seven world subregions receiving grain via the Panama Canal by 6, 12, 18, and 24 cents while leaving rates from Pacific ports at initial levels.

[b]This ship rate structure was applicable for periods in the mid-1970's.

[c]This ship rate structure was applicable for periods in 1978.

[d]This ship rate structure was applicable for periods in 1979-81.

[6]Analysis with the hard, soft, and durum wheat models indicated flow patterns would not be significantly altered by upward adjustments in Panama Canal tolls. The aggregation of soft red and white wheats, and hard red winter and hard red spring wheats into two models may have generated overlysimplified flow patterns, thus reducing quantities which traverse the Canal.

[7]Several alternatives are available for routing United States grain to Asian nations other than movements via the Panama Canal or Pacific ports. Grain loading at Gulf or Atlantic ports may move to Asian markets via the Straits of Magellan (southern tip of South America), Cape of Good Hope (southern tip of Africa), or the Suez Canal. It is difficult to make reliable estimates of rates or costs on these routes since no United States grain moves to Asian markets over these courses. It is estimated that per bushel ship costs would increase 20 to 32 cents above costs associated with the traditional trade routes if grain was redirected to an alternative route. Accordingly, some of the estimated revenue-maximization toll rates may marginally overstate the Canal's maximum toll level.

TABLE 3. ESTIMATED GRAIN FLOWS EXITING THE GULF AND PACIFIC PORTS FOR VARIOUS SHIP RATE STRUCTURES, U.S. 1975-81

Historic ship rate structures[a]	Corn		Soybeans		Sorghum	
	Gulf ports	Pacific ports	Gulf ports	Pacific ports	Gulf ports	Pacific ports
	(1,000,000 bushels)					
0-cent[b]	1,692.0	8.0	553.0	0.0	261.0	0.0
6-cent[c]	1,692.0	8.0	553.0	0.0	261.0	0.0
12-cent[c]	1,692.0	8.0	553.0	8.0	261.0	0.0
18-cent[c,d]	1,583.0	117.0	552.0	19.0	189.0	72.0
24-cent[d]	1,284.0	416.0	514.0	58.0	157.0	104.0

[a]See Table 2, footnote a.
[b]This ship rate structure was applicable for periods in the mid-1970's.
[c]This ship rate structure was applicable for periods in 1978.
[d]This ship rate structure was applicable for periods in 1979-81.

as a change in ship rate structure places Gulf ports at an increasing disadvantage. For example, when the rate structure approximates the 0 cent model, the Canal's estimated annual toll revenues from transiting corn, soybeans, and sorghum is $166 million. Revenue decreases to an estimated $29 million when rates are characterized by the 24-cent per bushel model.

The analysis shows Canal management would have unequal ability to extract rent from passage of various grains transiting the Panama Canal. For example, the revenue-maximizing toll on sorghum ranges from 6 to 12 cents per bushel while the revenue-maximizing toll rate for soybeans range from 12 to 24 cents per bushel, Table 2. Much of the nation's soybean production is located near the Mississippi River system which facilitates inexpensive transportation to Gulf ports. To transport soybean production to Pacific ports would involve comparatively large domestic transportation costs. Thus, Canal management has substantial ability to increase toll rates. In contrast, large quantities of sorghum are produced in the plains of Kansas and Nebraska, an area for which the transportation cost advantage to Gulf ports is comparatively small relative to movements destined for Pacific ports. As a result, relatively small upward toll adjustments redirect sorghum to Pacific ports and thus diminish the ability of Canal management to increase toll rates.

Effect of Revenue-Maximizing Tolls on U.S. Grain Flows

As noted, a monopolizing Canal operator would have the ability to increase tolls on United States grain trade routes passing the Canal. Consequently, ship rates linking Gulf ports to Asia and the west coast of South and Central America would increase. Thus, the revenue-maximizing operator would inadvertently redirect grain to United States Pacific ports. The effect of a revenue-maximizing Canal toll rate on port grain flows is accomplished by contrasting the model-projected flows associated with the historic ship rate structures, Table 3, with flows that would have existed had Canal management maximized toll revenues, Table 4. The projected Gulf and Pacific ports' export shares are contrasted with historical proportions.

In the absence of revenue-maximizing Canal management, Gulf ports are projected to handle about 68 percent and Pacific ports less than 1 percent of United States corn exports when Pacific port ship rate advantages to Asia range up to 12 cents per bushel, Table 3. In contrast, with a revenue-maximizing operator, up to 5 percent of United States corn exports would have been directed to Pacific ports with a Pacific port ship rate advantage of 6 cents or less, and up to 17 percent with a Pacific port advantage of 18 cents per bushel, Table 4. The 5 percent

TABLE 4. ESTIMATED GRAIN FLOWS EXITING THE GULF AND PACIFIC PORTS FOR ALTERNATIVE SHIP RATE STRUCTURES WITH CANAL MANAGEMENT IMPOSED REVENUE-MAXIMIZING TOLL RATES, 1975-81

Historic ship rate structures[a]	Corn		Soybeans		Sorghum	
	Gulf ports	Pacific ports	Gulf ports	Pacific ports	Gulf ports	Pacific ports
	(1,000,000 bushels)					
0-cent[b]	1,583.0	117.0	514.0	58.0	261.0	0.0
6-cent[c]	1,583.0	117.0	514.0	58.0	261.0	0.0
12-cent[c]	1,284.0	416.0	459.0	113.0	189.0	72.0
18-cent[c,d]	1,284.0	416.0	401.0	163.0	158.0	104.0
24-cent[d]	960.0	740.0	401.0	163.0	128.0	133.0

[a]See Table 2, footnote a.
[b]This ship rate structure was applicable for periods in the mid-1970's.
[c]This ship rate structure was applicable for periods in 1978.
[d]This ship rate structure was applicable for periods in 1979-81.

proportion is similar to actual shares in 1978 and 1982 while the 17 percent proportion approximates the Pacific port share in 1980. If Canal management introduced revenue-maximizing toll rates when ship rates approximate the 24-cent interport rate differential, up to 30 percent of United States corn exports are projected to exit Pacific ports. This substantially exceeds the largest actual proportion (18 percent) which exited this area in 1980. This analysis shows Pacific ports' outflow of corn would increase with a revenue-maximizing Canal management. However, many of the predicted flow patterns closely parallel those existing during 1980-82.

Based on model-projected flows, soybean flow patterns would be substantially altered by a revenue-maximizing Canal operator and flows to Pacific ports would exceed historical levels. Without a monopolizing Canal operator, there would be very small soybean flows to Pacific ports until the interport differential exceeds 12 cents per bushel, Table 2. An estimated, 8 percent of annual soybean exports would exit Pacific ports when this port area's rate advantage approximates 24 cents per bushel, Table 3. If Canal management imposed revenue-maximizing tolls, approximately 8 percent of soybean outflow would exit Pacific ports when this port area's ship rate advantage was 6 cents or less, Table 4. Up to 21 percent of the soybeans would be projected to exit Pacific ports at the 18- and 24-cent ship rate advantages. The projected port shares substantially exceed the historical maximum (3 percent) ever exiting Pacific ports. As noted earlier, the model includes soybean surpluses in North Dakota and western Minnesota in excess of historical levels. Consequently, the flow of soybeans from these areas to Pacific Northwest ports generates relatively large Pacific port share estimates. The model is calibrated to include mid-1980 regional surpluses. Thus, flows to Pacific ports will be over-estimated to the extent that soybean production falls short of expectations in these regions.

When Pacific port ship rate advantages are 6 cents per bushel or less, a revenue-maximizing Canal operator would have no effect on sorghum flows to Gulf and Pacific ports, tables 3 and 4. However, at higher ship rate differentials, the monopolizing operator would substantially alter flows. During those time periods when the ship rate structure is reflected by the 12 cent per bushel ship rate model, a revenue-maximizing operator would establish sorghum tolls which would direct about 27 percent of sorghum exports to Pacific ports. This approximates the historical maximum (24 percent) which exited this port region in 1980. At higher interport ship rate differentials, sorghum volumes in excess of historical levels are projected to exit Pacific port areas, Table 4. The analysis indicates sorghum flow patterns to be substantially altered if a revenue-maximizing Canal operator existed in the early 1980's.

SUMMARY AND CONCLUSIONS

A spatial model was used to determine the ability of a revenue-maximizing Panama Canal management to increase toll rates on United States grain transiting the Canal and to evaluate the impact of this policy on United States port volumes. The analysis reveals a relatively inelastic relationship between toll rate levels and quantity of United States grain traversing the Canal. Thus, there appears to be a substantial opportunity for increasing toll rates and revenues if Canal management adopted a revenue-maximizing philosophy. Given the ship rate structures which existed between 1975 and 1982, the revenue-maximizing toll rates on soybeans, sorghum, and corn would range from 6 to 24 cents per bushel. Revenue-maximizing tolls would be greatest when Gulf and Pacific port ship rates to Asia are similar and smallest when Gulf port rates to Asia are relatively high. The analysis shows toll rates established by a revenue-maximizing Canal management would substantially exceed actual toll rates which increased from about 1.0 cent per bushel in the early 1970's to the current 2.5 cents per bushel.

A monopolizing Canal operator would have the ability to increase tolls; thus, ship rates on routes linking Gulf ports to Asia would increase. Analysis shows that this would redirect grain to Pacific ports through internal routes. A revenue-maximizing Canal toll rate structure would have moderately altered flows to Gulf and Pacific ports in the mid-1970's. Ship rate levels increased in 1980-81 and rates linking Gulf ports to Asian importers increased relative to rates from Pacific ports. The imposition of revenue-maximizing Canal tolls during this period would have redirected significant portions of United States grain exports to Pacific ports. Although the Gulf ports would continue to dominate as a point of embarkation, the projected proportion of corn, soybeans, and sorghum redirected to Pacific ports would have exceeded historical levels.

The current Panama Canal toll is levied "per net vessel ton of 100 cubic feet of actual earning capacity"; i.e., tolls are closely related to ship grain carrying capacity. To implement the revenue-maximizing grain toll rates, Canal management would need knowledge of originating country, type of grain, and ship rates. Information on originating country and grain type would be available from ship documents. General ship rate information would be available from international ship freight exchanges; however, the recent wide intrayear fluctuations of interport rate differentials would require the monopolist to establish constantly changing toll rates, thus making it difficult to implement the revenue-maximizing toll at all times.

In conclusion, this study shows Panama Canal toll rates could be substantially increased above historic and current levels if Panama's increasing sovereignty over the Canal resulted in a desire to maximize revenues. If a revenue-maximizing toll structure was adopted, increasing quantities of United States grain exports would be directed away from Gulf ports. In those periods when the Pacific ports' rate advantage to the major Asian importers is relatively large (as in 1980-81), projected Pacific port flows would exceed historic volumes.

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