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Port Elevator Capacity and National and World Grain Shipments

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An analysis is conducted on the port component of the United States grain export system. A transshipment model is utilized which covers both United States internal and foreign shipments of corn, soybeans, and wheat during the four quarters of a year. The model suggests that there will be quarter to quarter constraints on port capacity but that annual capacity is adequate. Through sensitivity analysis a number of key factors were found which influence the adequacy of the current port system. Port adequacy is found to depend not as much on export market location as it does on domestic transportation rates and policies.

In the last ten years there has been a significant upward trend in the volume of international trade in grains and soybeans, with exports from the United States more than doubling. Rising exports have at times brought about problems in the grain handling system, such as the rail car shortages of the 1970s and occasional congestion in the river system. Difficulties have also been encountered at ports because of delays in transferring grain from rail cars and barges onto ships (Fuller *et al.*). The severity of these problems has varied over geographic areas. Most have been associated with peak periods in demand. Indeed, during times of less active trade (such as currently exists) some facilities have been underutilized.

Although United States trade volume is unlikely to increase in the future at the rate it has in the recent past, world grain trade is expected to continue its upward trend (O'Brien). If this occurs, grain handling problems are likely to continue to be encountered and perhaps worsen. A key element within the grain handling system is the export grain elevator and associated infrastructure (hereafter called ports), since nearly all United States grain and soybean exports are seaborne. Some observers believe that, with continued growth in the grain trade, existing port capacities will be insufficient within the next decade (United States Department of Commerce). This observation is made in spite of recent periods exhibiting relatively idle capacity.

The primary purpose of the study reported in this paper was to conduct an analysis of United States port elevator capacity constraints on United States grain and soybean exports. The major interest was to assess the extent to which such constraints are likely to cause serious grain

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marketing problems under alternative scenarios. This involves both total port capacity and its distribution among port areas. Although there may be sufficient total capacity available to handle likely increases in exports, some ports may experience facility congestion while others have idle capacity. This is particularly true since export growth is expected in the form of increasing demand in specific regions rather than general demand expansion. Moreover, changes in such things as inland and ocean freight rates can affect the use of specific port areas. Thus, we wished to investigate not only the consequences of the current distribution of port capacity but the effects of seasonality and changes in domestic and international transport rates, including effects on the various parties (domestic consumers, international consumers, etc.) involved in the grain market. These are important areas of inquiry, especially in view of the possibilities for increased foreign production and/or marketing efficiency, developments which could erode the United State's comparative advantage in the international grain trade.

A thorough analysis of the effects of port capacity requires a number of features so that the problem can be adequately captured. Many United States ports are affected by seasonal fluctuations in quantity and composition of exports because of such factors as timing of harvest of various commodities, freezing of the Great Lakes, and different levels of supplies from foreign sources caused by different harvest periods. This poses the need to include commodity specific seasonal grain flows in the conceptual model. Thus, the model involves quarterly shipment of multiple grains from United States and foreign supply locations to United States and foreign demand points. The United States export shipments pass through a set of ports which are constrained in total grain handling capacity. Storage options are also included. A model of this scope is potentially very expensive to solve. Thus, we used recently developed software which permits efficient solution of the problem of the size and magnitude developed herein.

Methodological Background

Numerous grain transportation studies have been conducted utilizing transportation and transshipment models (e.g., Leath and Blakely; Fedeler *et al.*). Most of these have dealt with domestic transportation issues, with few including ports as any more than a source of demand. Those explicitly including ports (e.g., Binkley and Shabman; Koo and Cramer) have not captured all of the aspects of the grain transportation system which are important to a port capacity study. Thus, a transshipment model was constructed containing several features which, to the best of our knowledge, have not simultaneously appeared in any other analysis.

First, since ports are the link between the domestic and export transport system, both were included in the model. Simultaneously, world supply was included. Thus, the model contained foreign producing and consuming areas and the connecting transportation system.

Second, ports handle a number of commodities which compete for port facilities. This study included three major commodities—corn, wheat, and soybeans—as independent commodities at all locations other than ports, where they faced simultaneous capacity constraints at port elevators.[1]

Third, transport model availability is partly seasonal (since some ports and river segments are closed in winter), as is the

[1] We felt we could ignore other grains because of their relatively minor share of port elevator volume. The ratio of corn, soybeans, and wheat exports to total exports of grain and soybeans exceeded .99 for all major port areas during 1976–78 except as follows: Duluth, .87; Texas Gulf, 78; Seattle, .92; Portland, .95; California, .89 (USDA *Grain Market News*).

entry of commodities into markets (because of differing harvest dates in different world regions). Thus, four quarters were considered.

Fourth, with a quarterly model it was necessary to have storage from quarter to quarter. Supply was assumed to be available in the quarter of harvest, and possibilities to store into subsequent quarters were included. However, all storage was assumed to be empty going into the quarter of harvest. Thus, for example, if harvest was in the third quarter, stocks could be carried to the fourth, from the fourth to the first, then in to the second, but not into the third which is the next harvest period. This assumes that the system is in long run quantity equilibrium wherein quantity demanded during the year equals quantity supplied and all quantity is shipped to demand points between harvests (i.e., long run stock accumulation is precluded). We judge this to be appropriate given that we wished to study the effects of relatively major transport system changes under long run average supply and demand conditions.

The model contained a detailed representation of the domestic transportation system. However, internal movements within the foreign supply countries were not modeled because of a lack of data. This posed a problem regarding the use of a traditional cost minimizing transportation method in that grain moving from the United States to foreign destinations incurred domestic, port, and international shipping costs while grain moving from foreign locations did not incur domestic costs. Simultaneously, any differentials in cost of production between countries would not be reflected. Consequently the point of origin price (United States harvest prices or foreign f.o.b. prices, depending on location) was added to the transport costs from each grain originating point. This renders all costs at demand points as the point of production price plus internal transport costs plus port costs (the sum of which are assumed to be in an f.o.b. price) plus international transport cost. Thus, the model objective function represented the minimization of delivered cost with demand locations choosing suppliers not based solely on transport cost, but also on production and internal marketing costs. This differs from a number of previous studies but is necessary to adequately reflect consumers acquiring the cheapest available delivered price.[2]

Thus, the model formulation contained fixed supplies and demands, prices, and transport costs and determined a pattern of shipments from United States and foreign suppliers to United States and foreign consumers which minimized the sum of delivered costs (price plus marketing costs), subject to port capacity constraints on the simultaneous volume of the three grains. This is a classical multicommodity transshipment linear program. However, the model also can be cast as a mutually capacitated network flow problem, which permits usage of efficient software (as reviewed in Kennington). This was the approach used. It is doubtful that the linear programming software readily available to United States researchers would have solved the model in reasonable time and cost: the LP equivalent would entail a 2191 by 22,656 matrix.[3]

[2] The model assumptions then include minimization of delivered price subject to fixed annual supply and demand quantities. These assumptions can be viewed as consistent with several possible competitive situations. The competitive norm appears to be closest.

[3] Using the network flow algorithm, the solutions described herein required about 1,300 seconds of computer time to reach optimality of a CDC6600. Because of the problem size we did not try to solve it on a conventional linear programming algorithm. Thus we cannot make comparative statements regarding solution efficiency. However, Ali *et al.* studied this situation using the same algorithm and indicate that "the specialized multicommodity system . . . [was] approximately three times faster than . . . general LP codes."

Empirical Specification of Model

Considerable effort was devoted to empirical specification. The model depicts world grain supplies and demands in 1985. Transport costs were based on 1976 data, the latest available at the time of the study. This section overviews data pertaining to regional definition, supply-demand, transport costs, prices, storage costs, and port capacities. More detail can be found in Barnett *et al.*

A number of supply and demand regions were specified for each grain. There were 105 domestic supply points for corn, 83 for soybeans, and 105 for wheat. The rest of the world was divided into 16 regions (each potentially containing a number of countries)—East and West Canada, East and West Australia, The Common Market, other Western Europe, Southern Asia, Eastern Europe, Japan-Korea-Taiwan, Central Asia, South America (less Brazil and Argentina), Central Africa, Mexico-Central America, Brazil, Argentina, and Thailand. For each a representation port was selected through which exports/imports passed. Eleven United States ports were included—Duluth, Chicago, Toledo, Baltimore, Norfolk, Charleston, Louisiana Gulf, Texas Gulf, California, Seattle, and Portland.[4]

United States national 1985 domestic production and consumption forecasts by crop reporting districts were obtained from Iowa State University. Foreign import and export quantities for 1985 were determined by trend analysis coupled with adjustments based on discussions with USDA personnel.

Quarterly domestic shipping costs were formed for transportation utilizing rail, truck, and barge, either individually and/or involving transshipment. These data were derived following Baumel *et al.* and Koo and Cramer. The truck and rail costs were based on mileages between origin and destination and include regional adjustments. Single car shipment equations were used to calculate transportation charges to domestic consumption sites while 85 car shipments were used for port destinations. Barge-truck combination rates also were included based on the procedures used by Binkley and Shabman. Barge movements on the upper Mississippi were not permitted in winter. Ocean freight rates were drawn from the work of Harrer and Binkley and varied by quarter.

United States harvest prices were obtained from USDA state crop statistical bulletins. F.O.B. prices for foreign origins were obtained using series developed by agencies such as the International Wheat Council, the International Monetary Fund, and the Bank of Bangkok. Storage costs were taken from Scheinbein's data and updated. Foreign storage cost data were unavailable, so United States estimates were used as proxies. United States Gulf costs were used for developed countries, and the highest cost (Seattle) for the others.[5]

One of the more difficult exercises in this study was the determination of port elevator ship loading capacity. Capacity is influenced by elevator equipment, ship availability, port congestion, etc. We chose to specify capacity based on observed peak throughout. This was computed as the product of the ship loading rates (from Dezik and Fuller) times the maximum total number of available ship loading hours per quarter adjusted for the quantity of grain other than corn, wheat, and soybeans that pass through each particular port. The key unknown is the maximum number of hours available for grain ship

[4] Nearby port facilities were included for these ports where appropriate. Thus, the Louisiana Gulf includes elevators along the Mississippi River, and Portland includes Columbia River facilities.

[5] Storage and all other costs were assumed to be constant or changing only in strict relation to each other. Further, unit costs were assumed to be invariant with respect to changes in the volume of grain incurring that cost.

TABLE 1. Percentage Distribution of Corn, Soybean, Wheat, and Total Outgoing Port Shipments by U.S. Port: Validation Comparison.

	Corn			Soybean			Wheat			All Grains	
Port	Observed High	Observed Low	Model Solution	Observed High	Observed Low	Model Solution	Observed High	Observed Low	Model	Observed Data	Model
Duluth	2.2	1.2	3.0	.3	.1	.5	11.0	9.2	14.7	4.9	6.1
Chicago	5.0	2.9	9.5	5.7	2.4	.8	1.0	0.0	4.0	2.4	6.1
Toledo	5.3	4.7	1.0	6.8	5.3	4.0	1.3	1.1	0.0	4.0	1.3
Atlantic Coast	19.5	15.0	19.7	13.7	11.4	11.9	4.9	2.0	0.0	11.9	12.2
La. Gulf	52.8	51.2	53.8	72.2	71.6	73.7	18.5	12.6	14.0	43.3	45.6
Tx. Gulf	6.2	5.5	10.0	7.2	6.5	7.9	40.3	30.2	31.4	17.8	16.1
Portland	0.0	0.0	0.0	0.0	0.0	0.0	30.6	27.7	12.5	8.0	3.8
Seattle	10.9	3.5	.2	0.0	0.0	0.0	1.9	.4	20.3	4.5	6.4
California	3.9	2.6	.1	0.0	0.0	0.0	4.6	3.1	3.0	2.9	1.0
Canada			2.7			1.2			1.4		
Total			100.0			100.0			100.0		

Source: USDA, *Grain Market News,* selected issues, 1979–81.

loading per week. To acquire an idea of the number of hours of grain loading operation each week, 1980 monthly USDA *Grain Market News* data were used. The maximum export flow for any month at each port was divided by the loading rate at that port to yield an approximation of the hours required to load that level of exports. This calculation showed only two ports exceeding a forty-hour week. The Louisiana Gulf operated at about 59 hours/week during the peak month and Toledo operated at 44 hours. Chicago had the lowest operating time, 13 hours/week. Based on these results, all port operating hours were set at 40 hours/week, except at Toledo and the Louisiana Gulf, which were left at their values of 44 and 58, respectively.[6]

The Base Solution: Model Validation

Model validity was examined primarily based upon a comparison of the base model grain flows with historical USDA data (*Grain Market News*) and the 1977 grain flow results of Hill *et al.* Some differences should be expected due to the use of 1985 forecasted supplies and demands; however, it was assumed that the proportional distribution of interregional grain flows were comparable. Validation comparisons were done on shipments (a) to United States ports, (b) to domestic consumption sites, (c) from United States ports, and (d) from foreign exporters. Only part of the validation comparisons is presented here.

Data in Table 1 provide a comparison between base model flows and actual 1978–80 shipments by commodity and port region. Although there are discrepancies, the pattern of exports among ports in the model solution for the most part parallels the pattern existing during this period. The largest differences occurred at less important port areas and at the Pacific Northwest. The latter reflects two things. First, since Seattle is slightly closer to most producing areas than is Portland, the distance-based method of transport cost calculation leads to slightly lower costs for Seattle-bound shipments. This minor difference is not reflected in actual rates. Consequently, it is more reasonable to compare the combined shipments for these

[6] The sensitivity of the model to these assumptions is examined implicitly when the port capacities are changed in the runs below. The model was not found to be sensitive to the capacity assumptions.

ports, which yields a model vs. actual of 32.8 vs. 32.5 percent. Secondly, the model data predate the establishment of unit train rates between the Upper Midwest and Northwest. These influence the 1978–80 flows, particularly for corn. (See footnote 7.)

Space does not permit presentation of validation comparisons for shipments from United States producing regions nor from United States ports to points of consumption abroad (see Barnett *et al.*). Generally, the model performed about as well for these as it did for those presented. The model was less successful in replicating shipments from foreign producing areas (although this is difficult to validate because of a scarcity of historical data). It is expected that the model be least accurate for these, since trade policies, which play a significant role for many trading partners, were not included.

The base model results indicated that the model was able, within reason, to predict a fairly accurate level of port capacity utilization. The broad pattern of capacity use was quite similar to that of 1978–80, with most discrepancies explainable. The scenario analysis below suggests these are unlikely to affect our conclusions. Generally, given the simplifications that must be imposed in a model such as this, and given the variability in actual export patterns (particularly in recent years) the model performed at least as well as could be expected. Thus, we feel comfortable in using the model for the purposes of the study.

Capacity Results from the Base Model

The base model solution contained considerable information relative to capacity expansion. Two sets of information—shadow prices and capacity utilization—can be used to draw inferences about the adequacy of existing capacity. The shadow prices—measures of the marginal value product of capacity to handle an additional ton at each port—appear in Table 2. Zeros indicate that capacity was not fully utilized in the quarter in question. Generally, the shadow prices suggest that current levels of export elevator capacity on the Great Lakes and West Coast are ample to excessive, while that on the East and Gulf Coasts may be insufficient. However, they also suggest that costs of insufficient capacity are not likely to be large. For example, the maximum shadow price, $5.04, is only 2.6 percent of the average cost of delivered grain. Further, shadow prices are values for marginal grain and would be expected to decline as capacity was expanded. As an illustration, although the Georgia port had the highest shadow price in the base solution, its exports only expanded by 12 percent (leading to insubstantial cost savings) when capacity constraints were removed (see Barnett *et al.* for elaboration). The temporal pattern of the shadow prices reflects the interdependencies among port areas. The East and Gulf Coast shadow prices are highest in the winter quarter, when the Great Lakes are closed to navigation. The winter East Coast shadow prices reflect the effect on the Gulf of the upper Mississippi River winter freeze.

TABLE 2. Shadow Prices of Ports ($/MT).

	Quarter of Year			
Location	Winter	Spring	Summer	Fall
Duluth	0	0	0	0
Chicago	0	0	.20	.70
Toledo	0	0	0	0
Georgia	5.4	2.17	2.17	1.98
Norfolk	3.38	.41	.41	.41
Baltimore	2.96	0	0	0
La. Gulf	1.71	.93	.25	.25
Tx. Gulf	2.17	2.29	0	0
Portland	0	0	0	0
Seattle	.65	0	0	.65
California	0	0	0	0

Port capacity may also be examined in

TABLE 3. Percent of Total U.S. Port Elevator Handling Capacity at Each Port and Percentage of Capacity Utilization in Base Solution during the Year.

Port Area	Percentage of U.S. Capacity[a]	Percentage of Annual Capacity Utilization
Duluth	10.1	45.6
Chicago	4.7	91.3
Toledo	4.5	20.2
Georgia	.5	100.0
Norfolk	2.8	100.0
Baltimore	10.5	48.7
La. Gulf	32.0	100.0
Tx. Gulf	14.6	77.7
Portland	8.7	31.1
Seattle	6.3	70.6
California	5.3	12.6

[a] Capacity used for corn, soybeans, and wheat. Great Lakes ports are corrected for winter closing.

terms of capacity utilization. Table 3 presents the percentage distribution of United States port elevator grain handling capacity by port area and the capacity utilization percentage for each port area. This information suggests that capacity problems on the East Coast are unlikely to be as serious as implied by the shadow prices, since the high shadow price ports have lesser volumes. The information also shows that the entire United States port elevator system operated at slightly under 70 percent of capacity in the base solution. While this can only be viewed as an approximation (because of the necessity of making arbitrary choices in calculating the capacity available), it does suggest that sufficient capacity exists in the system as a whole to handle expanded exports. The shadow prices indicate that any capacity problems which do occur are likely to be localized and seasonal. The fact that total capacity may be adequate while some areas are overtaxed and others are underutilized implies that redistribution of exports among ports may be an alternative to outright capacity expansion should handling difficulties occur.

Port Expansion Scenarios

A number of scenarios were run in which selected port capacities (Louisiana (LA), Texas (TX), and Norfolk (NOR)) were expanded. In addition, the Texas and Louisiana (LA-TX) expansions were combined and run under both base conditions and with a ten percent reduction in rail rates to the Gulf (LA-TX-Rail). Finally, an additional run was made in which all capacity constraints were removed (UCAP).

Table 4 shows the grain volume by port for each scenario, relative to the base solution. In the Texas scenario (TX) the addition of 12 percent more capacity led to a five percent expansion in exports which was concentrated in the winter and spring quarters. This increase in volume came primarily from a decrease in Great Lakes exports. There were simultaneous increases in exports at Baltimore due to a multi-port change in destinations. Shipments to the Near East were shifted from the Great Lakes to Texas, while shipments to Russia were transferred from Texas to Baltimore. This illustrates the interdependence (and competition) among distant port areas—they are all potential suppliers of the same consuming regions.

The increase in Louisiana's capacity (LA) drew exports not only from the Great Lakes but also from Texas and the East Coast. The latter reflects increased use of barges to Louisiana from the Midwest. Capacity expansion at Norfolk (NOR) reduced exports at Baltimore and Toledo, drew away some of the grain destined for Louisiana, and altered the pattern of shipping to domestic regions. This in turn permitted flows originating in the central states to shift from the Texas Gulf to Louisiana, primarily to make use of barge transportation. This illustrates how domestic transportation costs can be important in directing grain toward port areas: barge tends to be the lowest cost mode of transportation to Louisiana from the cen-

TABLE 4. Port Expansion Scenario Results.

Port	Percent of Base Solution Exports in Various Scenarios[a]					
	LA	TX	NOR	LA-TX	LA-TX-R	UCAP
Chicago	89	89	98	82	72	77
Duluth	100	100	100	100	97	98
Toledo	77	77	77	77	77	54
Great Lakes	92	93	93	97	90	84
Georgia	100	100	100	100	100	112
Norfolk	98	100	156	98	100	215
Baltimore	96	104	82	96	104	55
Atlantic	97	102	108	97	102	112
La. Gulf	106	100	100	105	98	95
Tx. Gulf	92	105	97	99	121	127
Gulf	103	101	99	104	104	102
Portland	97	97	97	87	87	76
Seattle	100	100	100	100	100	106
California	100	100	100	100	100	100
Pacific	99	99	99	96	96	96

[a] Scenarios:
LA —Capacity Expansion at Louisiana Gulf
TX —Capacity Expansion at Texas Gulf
NOR —Capacity Expansion at Norfolk
LA-TX —Capacity Expansion at Louisiana and Texas Gulf
LA-TX-R —Same as LA-TX, along with reduced rail rates to Gulf ports
UCAP —Removal of all port capacity constraints

tral states, at least given the model's assumption of no barge capacity constraints. It also suggests that port capacity can be a factor in inhibiting further usage of barges.

The mutual increase at the Gulf had about the same total effect as the sum of the two individual Gulf scenarios. This was true for the scenarios with and without the rail rate reduction. The rail rate reduction only changed the distribution between the two areas. With lower rail rates, Texas exports increased while those at Louisiana declined; with rail rates unchanged, the opposite occurred. This simply reflects the fact that barge shipping gives the Louisiana Gulf a comparative advantage. This advantage is reduced when rail rates are lowered.

When all capacity constraints were eliminated (the UCAP scenario) exports were drawn from the Great Lakes to the East Coast and Gulf. This is precisely what one would expect given the information in Tables 2 and 3. Thus, under an unconstrained distribution of capacity slightly more exports would be expected at these locations. However, in the unconstrained solution, the proportion of exports for the grains at these locations fell within the observed ranges of historical data. While there was shifting of exports among quarters in the UCAP solution, causing unrealistic differences in exports between quarters, these did not lead to significant cost reductions. Thus, the distribution of exports among ports and port system capacity are apparently close to optimal. The cost comparison below indicates this.

In summary, the addition of capacity at individual ports did not bring about large changes in the proportion of shipments from each port. The additional capacity tended to be used seasonally and not in all quarters. While this increases the flexibility of the system, in reality such benefits

TABLE 5. Comparison of the Objective Function Values for the Port Scenarios ($1,000).

Scenario[a]	Value	Total Savings	Savings Per Ton
BASE	38,092,737	—	—
LA	38,090,472	2,265	1.6¢
TX	38,091,713	1,024	.7¢
NOR	38,090,151	2,586	1.9¢
LA-TX	38,088,251	4,486	3.2¢
LA-TX-Rail	38,037,186	55,551	40.2¢
UCAP	38,074,367	18,370	13.3¢

[a] See Table 4 for scenario descriptions.

would have to be balanced against the cost of idle capacity during the rest of the year.

Cost Analysis

The objective function values and differences between the scenarios and the base solution are shown in Tables 5 and 6. Table 5 shows the total value of the objective function. Table 6 decomposes it into components.

An examination of Table 5 indicates that changes in total costs across scenarios are not large. The largest savings resulting from port capacity changes is 13.3 cents/metric ton (UCAP solution), which is small relative to the value of grain (wheat, for example, is worth approximately $190/metric ton), indicating that United States port capacity is fairly well situated at present. Regarding the three individual port expansion scenarios, Norfolk seems to yield the best possibility for expansion within the model. However, the estimated annualized cost of this port expansion net of handling is $7.1 million (based on Nichols and Updaw), while the model predicts a $2.5 million savings. Hence, it would not be profitable to invest in this size elevator at this location. This result is supported by Nichols and Updaw, who found that it would not be privately profitable to build a new export facility at a similar level of exports.

The largest change in total cost was realized in the LA-TX rail scenario, which entailed a reduction in rail rates. This is not surprising, since even with unchanged shipping patterns, cost would decline for the shipments involved.

The distribution of cost changes is also interesting (Table 6). The labels refer to the cost of shipments made to a particular final demand group. The results illustrate several points. First, improvements in the export marketing system can have adverse impacts on domestic consumers, in the same manner as can an export subsidy. (This is a relatively standard result in the gains from trade literature.) Second, in almost all of the scenarios, the transportation bill to ports rose, but costs from United States ports to world consumers declined

TABLE 6. Cost Components of the Objective Function for Various Scenarios ($100,000).

Scenario[a]	U.S. Direct to Consumption[a]	U.S. Shipments to Ports	Total U.S. Domestic Shipments[b]	From U.S. Ports	From World Ports
Base	64,281.9	196,119.1	263,034.8	16,101.8	97,594.4
UCAP	64,228.0	196,322.4	263,081.9	16,003.4	97,551.4
LA	64,307.9	196,161.9	263,103.5	15,996.8	97,618.2
TX	64,265.9	196,180.2	263,079.8	16,010.5	97,617.9
NOR	64.245.1	196,168.3	263,047.0	16,040.9	97,617.9
LA-TX	64,304.9	196,147.7	263,086.2	15,992.5	97,618.2
LA-TX-Rail	74,240.5	195,795.9	262,670.1	15,940.5	97,618.7

[a] See Table 4 for scenario descriptions.
[b] Includes rail shipments to Canada from U.S.
NOTE: All columns except "From U.S. Ports" include the harvest price (for the U.S.) or f.o.b. price (for foreign suppliers) and storage, transport, and loading. "From U.S. Ports" is only transport.

by a greater amount. Greater port capacity permitted more efficient use of ocean transport, partially offset by higher domestic freight in reallocating grain among ports. Third, the transportation bill for the foreign exporting regions increased slightly with United States port expansion, but fell slightly when United States ports were allowed to expand freely (i.e., with port capacity constraints removed). These results indicate that the major impact of United States port capacity augmentation is an improvement in global shipment timing. Generally the results suggest that port elevator capacity problems are not currently diminishing United States comparative advantage. Thus, this should not be a major consideration in decisions regarding the level of port elevator capacity. Marketing advantages are more likely to accrue from navigation improvements permitting usage of more efficient ships (See Binkley and Harrer), or from improved domestic transport.

Other Scenarios

The results from a number of other scenarios will be briefly mentioned. One scenario entailed reducing rail rates to the Pacific Coast and ocean shipping rates from the Pacific Coast by ten percent. This generated a 39 percent increase in West Coast export volume. Another scenario involved a ten percent increase in Asian demand with supply in United States regions uniformly increased so so that demand could be satisfied. West Coast shipments increased by 12 percent. However, when Asian demand was increased by ten percent, and the rest of the world demand uniformly decreased by an equal amount to maintain a supply and demand balance, West Coast exports were virtually unchanged. These results given an indication that the ports are not as subject to the vagaries of shifting foreign demand as they are to the structure of domestic and international shipping rates, although more study is required before concluding this.

In the final scenario, all quantities available for supply/demand in the model were increased by ten percent. The resulting increase in United States exports was necessarily directed through ports that had not yet reached capacity in the base solution. Thus, Baltimore's exports increased by 45 percent, Texas by 16 percent, and Portland by 55 percent. By dividing the objective function value for this scenario by 1.10 to correct for increase in cost solely because of demand increase, it was found that the cost of "congestion" was only $13.4 million, or 96¢/MT for each additional ton exported from the United States. As before, this cost is not very high compared to the total per unit value of the grain product.[7]

Summary and Conclusions

A large mutually capacitated grain transshipment model was used to analyze the potential effects of United States port capacity constraints. The model included

[7] Since the transport costs used in this study reflect the 1976 transport system, it is pertinent to briefly mention possible effects on the results from recent institutional changes. These primarily relate to the rail system. The most significant recent change that might affect broad shipment patterns is the introduction of unit train rates to the West Coast. As previously indicated, failure to include this in the model led to a shortfall in model movements from that port area relative to actual movements. However, when rates to the West Coast were reduced in the model, this did not generate capacity problems at that port area. This, along with recent evidence that the Staggers Act is not likely to bring major changes in the structure of export rail rates (Fuller), suggests that our use of 1976 data does not invalidate the applicability of our results to the current situation. This is not to say, however, that if significant changes were to occur in the relative costs of shipping grain to alternative ports, this might not create capacity problems in some area. Indeed, our results suggest that the pattern of shipments is relatively responsive to changes in transport costs. But there is no evidence that this has recently occurred, nor is it likely to occur in the near future.

corn, soybean, and wheat shipments, a relatively detailed United States domestic and export component, and a foreign sector with producing and consuming regions. The model was solved using a highly efficient multicommodity network flow algorithm. The base model solution replicated the patterns of historical grain flows fairly well. We feel this model has validation characteristics at least as good as previous studies, and its comprehensive nature allowed us to develop quantitative insights relative to interdependencies between transport rates, seasons, and port capacity. It permitted quarterly treatment of three grains in a world model, particularly important in an analysis of export patterns.

Given the assumptions of the model (for example, the method used for calculating port capacity), the results suggest that while there may be port elevator capacity constraints in the future, port capacity does not appear to be a major current problem, at least for projected 1985 export levels and even for a ten percent increase beyond that. Any costs due to capacity constraints appeared to be low. The model indicated that capacity expansion opportunities were confined to East and Gulf Coast areas. Many involved the timing of shipments through the year. From an overall point of view capacity expansion did not prove profitable. Expanded capacity led to idle facilities during some periods, and investment in "peaking" capacity was not cost-effective.

As the results suggest, port expansion in one area can have detrimental impacts on other areas. For example, increased capacity at the East and Gulf coasts drew exports away from the Great Lakes as well as from ports along the same coast of the expanded port. Thus, new facilities at a particular port may create idle capacity and thus increase costs elsewhere, an effect not accounted for by those making the investments. This may have policy relevance. Under the perfectly competitive norm, private costs equal social costs. However, this norm may not apply to grain exporting, because of the declining cost nature of transport and grain handling; the fact that rail and barge rates reflect the effects of regulation, subsidization, geographic price discrimination, and perhaps market power; and the nonmarginal nature of port investments. In addition, significant distributional effects across regions can occur. And as the study results suggest, should investment in elevator facilities occur, there are likely to be differential effects on various groups within society, e.g., domestic consumers could be made worse off. Generally, then, it may not be desirable to leave decisions on port investment entirely in the hands of the private sector.

In the cases studied it was found that changes in relative transport rates are more influential than changes in the location of export demand in determining the distribution of exports among United States ports. Assuming this finding holds generally, improvements in a port area which lead to reduced transport costs are likely to generate the volume to justify the investment. Furthermore, from a policy perspective a relatively strong response to transport costs is fortuitous because transport rates are more of a control variable than are, say, investment decisions by individual firms. For example, changes in rail rates could be used to direct grain from congested ports to those with idle facilities. Such a redistribution is likely to be a more viable solution to capacity problems than an expansion of fixed plant. With rail deregulation, however, this may not be feasible.

The last point suggests that port capacity problems can be alleviated or worsened by domestic transport policies. For example, our scenario analysis illustrates the role of barge transport in creating capacity problems at Gulf ports (and underutilized capacity at the Great Lakes). This suggests that port capacity use could markedly change with significantly higher inland navigation user changes. Thus, concern with the adequacy of the nation's port system perhaps should be directed as much toward the supporting transport system as toward questions such as where capacity "should" be located. "Optimal" capacity location depends upon the nature of the transport system. Similar considerations apply to proposals to impose deep draft waterway user fees at port areas. If such fees are calibrated on a cost per vessel basis, they will vary inversely with usage. Thus, they would tend to exacerbate problems associated with overuse of some ports and underuse of others, since the fees for the latter would be higher, other things the same. Furthermore, results here—that any capacity problems for port elevators tend to be local rather than systemwide—hold *a fortiori* for other port problems. Taxes and fees provide a potentially important instrument to redistribute port activity; it may be desirable that this factor be considered in setting such fees rather than merely basing them on local cost factors.

A general conclusion from this study is that the capacity of the current United States port system does not appear inadequate to handle likely future exports, at least in the next decade. Possible costs from capacity limits appear to be low. The entire system is unlikely to be overtaxed, at least for any length of time. Any problems that develop are likely to arise from surges in demand and seasonal fluctuations. Thus, efforts to stabilize levels of international trade in grains (a topic of much current interest), along with efficient use of existing facilities, may go much farther in relieving any capacity problems than increased investment in port elevators.

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