AN ABSTRACT OF THE THESIS OF

Daniel H. Zobrist for the degree of Master of Science in Agricultural and Resource Economics presented on November 30, 1984.

Title: Determinants of International Grain Freight Rates Revisited: The Impacts of Port Facility Characteristics

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Approximately 198 million metric tons of export grains were transported in 1980 by ocean transportation. As a result, the freight rates for transporting grains are important to the export market and may directly affect farm income and commodity prices. The determinants of these freight rates include such things as the distance travelled, the flag of ship, size of cargo, etc., as well as certain port features which allow a larger volume of freight to be moved and serve to shorten ship turnaround time in ports. Recent studies have sought to identify the major determinants of ocean shipping rates for grains, but so far, none have included a sufficient test for the effect on rates of different depths alongside cargo piers or deeper channel dredging. These features are very costly to ports but allow larger vessels to service the

region and perhaps lower transportation costs through economies of scale. Binkley and Harrer (1981) included over 9000 observations in an econometric study of a world-wide sample of ports but aggregated the sample into 16 port origin regions and 34 port destination regions. This did not allow testing for individual port features. Clement (1982) included observations of voyage charters from one port in the Pacific Northwest but could not test the effect of different port depths since the size of all vessels were controlled by the depths of the solitary origin port. This research is intended to fill this gap by testing the effect on marine transportation rates for grain of different features of port development in a world-wide sample of grain importing and exporting ports in 1980. The objective of this study is to examine the effect on freight rates for grains of the depth alongside the cargo piers at both the origin and destination ports and the depth of the approach channel at the destination port.

The results, found by weighted least squares regression, indicate that certain port facility characteristics do influence ocean freight rates for grain. On average, for each meter of draft at the origin port the rate per ton declines by $.79 and for each meter of draft of the approach channel at the destination port, the average rate declines by $.54/ton, _ceteris paribus_. These results were obtained from observations of vessels carrying a minimum of eleven hundred tons and a maximum of fifty thousand tons.

Also, grain that is in bagged form is associated, on average, with higher shipping rates than grain not in bagged form. This change reflects higher costs in loading the bagged grain at the export market as well as "in port" diseconomies, such as increased ship turnaround time at the destination port.

The results of the research should provide some empirical support to those policy-makers and other interested parties who have asserted that investments in port facilities may generate lower freight rates. Development plans which modernize grain offloading facilities to eliminate the need for bagging prior to shipment, and dredging operations in the approach channel and alongside cargo piers do explain significant reductions in ocean transportation rates for grain.

Determinants of International Grain Freight Rates Revisited: The Impacts of Port Facility Characteristics

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CHAPTER I

INTRODUCTION

The value of U.S. agricultural exports has increased from 10% of total cash receipts from farming in the 1950's to over 24% in the late seventies. The U.S. share of world agricultural exports rose from 12% in 1951-55 to over 16% by 1976 and America's share of world grain exports increased from 31% to 49% during the same period. Of the total worldwide increase in grain exports in the 70's, the U.S. contributed 82%. Almost 3 of every 10 acres in the U.S. are harvested for exports. Clearly, the exporting of agricultural products, especially grain, has become increasingly important for the maintenance of domestic farm income.

Approximately 198 million metric tons of export grains were transported in 1980 by ocean transportation. The value of U.S. share of agricultural exports has risen from 2.87 billion dollars in 1950 to almost 23.0 billion in 1976. The U.S. market share has increased from 13.9% to 16.7% (Schmidt, Guither, and Mackie, pg 75). As a result, the freight rates for transporting grains are important to the export market and may directly affect farm

Table 1.

U.S. Crop Acreage Harvested, Total and for Export

Year	For export						Total harvested[2]	Acreage diverted[3]
	Food grains	Feed grains[1]	Oil crops	Cotton	Other crops	Total		
	Million acres							
1950	23	11	4	8	4	50	345	
1951	31	11	3	10	4	59	344	
1952	18	7	2	5	4	36	349	
1953	14	6	3	6	2	31	348	
1954	16	8	4	5	4	37	346	
1955	18	14	7	3	5	47	340	
1956	29	10	8	9	4	60	324	13.6
1957	18	11	9	7	3	48	324	27.8
1958	17	12	8	3	4	44	324	27.1
1959	25	16	11	7	2	61	324	22.5
1960	26	16	11	8	3	64	324	28.7
1961	31	18	10	5	3	67	302	53.7
1962	27	20	13	4	2	66	294	64.7
1963	35	22	12	5	3	77	298	56.1
1964	29	22	16	4	3	74	298	55.5
1965	34	22	15	3	2	76	299	57.4
1966	29	17	15	5	3	69	294	63.3
1967	31	12	16	5	5	69	306	40.7
1968	20	13	15	3	3	54	300	49.3
1969	21	13	20	3	4	61	290	58.0
1970	25	16	23	4	4	72	293	57.0
1971	20	15	21	4	2	62	305	37.1
1972	38	18	27	5	3	91	293	62.6
1973	38	21	27	6	4	96	321	19.1
1974	39	21	28	4	7	99	330	0
1975	40	24	26	4	6	100	336	0
1976	32	23	30	5	6	96	338	0

[1]Includes feed required to produce livestock products exported.

[2]Area in 59 principal crops harvested as reported by USDA's Statistical Reporting Service plus acreages in fruits, tree nuts, and farm gardens.

[3]Total diverted or set aside under various programs, Agricultural Stabilization and Conservation Service, including limited acreage devoted to substitute crops.

Source: Mackie, A. B. "World Economic Growth and Demand for U.S. Farm Products." World Economic Conditions in Relation to Agricultural Trade. U.S. Department of Agriculture, ERS, WEC-12. Washington, D.C.: August 1977, p. 27.

income and commodity prices. The determinants of these freight rates include such things as the distance travelled, the flag of ship, size of cargo, etc., as well as certain port features which allow a larger volume of freight to be moved and serve to shorten ship turnaround time in ports. Recent studies have sought to identify the major determinants of ocean shipping rates for grains but, so far, none have included a sufficient test for the effect on rates of different depths alongside cargo piers or deeper channel dredging. These two features have the advantage that they can be included in an econometric analysis of rates and also serve as indicators of other features which measure port quality, such as the opportunity for superstructure development (specialized piers and cargo-handling equipment) to accommodate increased volume of freight. Dredging operations are very costly to ports but allow larger vessels to service the region and perhaps lower transportation costs through economies of scale. Binkley and Harrer (1981) included over 9000 observations in an econometric study of a world-wide sample of ports but aggregated the sample into 16 port origin regions and 34 port destination regions. This did not allow testing for individual port features. Clement (1982) included observations of voyage charters from one port in the Pacific Northwest but could not test the effect of different port depths since the size of all vessels were controlled by the depths of the solitary origin port. The research herein reported is intended to fill this gap by testing the effect on marine transportation rates for grain of different features of port development in a world-wide sample of grain importing and exporting ports in 1980.

Thesis Objective

The objective of this thesis is to provide an empirical answer to the question: Do ports with deeper drafts alongside their cargo piers and in their approach channels enjoy lower freight rates for grain? This information is important to policy makers who are wrestling with decisions concerning expensive port development plans or others interested in supporting farm income and agricultural prices. Empirical evidence of the effects on freight rates of port infrastructure investments may also provide some guidelines in prioritizing U.S. development assistance to Less Developed Countries (LDC). It is hypothesized that investment in channel and port dredging will allow larger, more modern vessels to service a port and reduce freight rates. A reduction in transportation costs may stimulate grain exports and increase farm prices and income.

The assertion that investments in port development will lead to lower marine shipping rates can be tested by linear regression techniques which relate ocean shipping rates to certain features of export and import ocean ports. In 1981 Binkley and Harrer modeled shipping costs for grain vessels in the tramp shipping market. Using ordinary least squares analysis (OLS) they found that distance, size of shipment and region of origin and destination were variables found statistically significant at the five percent level. Clement (1982) used OLS to estimate the determinants of Lower Columbia River ocean freight rates for grain. He concluded that comparisons of port-specific shipping rates reveal differences for grain shipments of equal size and distance due to different port characteristics.

Utilizing the findings from prior research and variables which either have been hypothesized or empirically estimated as important, the assertion that certain port features affect marine shipping rates is tested in this paper.

Organization of Thesis

Included in the remaining portion of the thesis is a summary of the development of ocean transport, especially the relationship between port and ship technology, since

1945. Following this is a review of the pertinent literature of determinants of freight rates, port development, and port pricing. Next is a discussion of the economics of ocean shipping. The emphasis is on those factors which affect demand and supply in the Tramp shipping market.

The empirical model is next presented along with the identification of and correction for statistical problems. The last section is an interpretation of the empirical results along with a summary and some implications for future research.

Background

The post World War II period in U.S. agriculture was marked by increased productivity and output attained through the substitution of capital inputs, via technological innovations, for land and labor. Labor resources shifted out of the agricultural sector as farm income and prices declined through the interaction of an increased supply of agricultural products and an inelastic domestic demand which expanded somewhat by increased income, but predominantly only with an increase in population. Since any new markets opened up by trade with food importing countries may help boost farm income and prices, any barriers or enhancements to trade are important to the agricultural sector (Jones and Thompson, 1978).

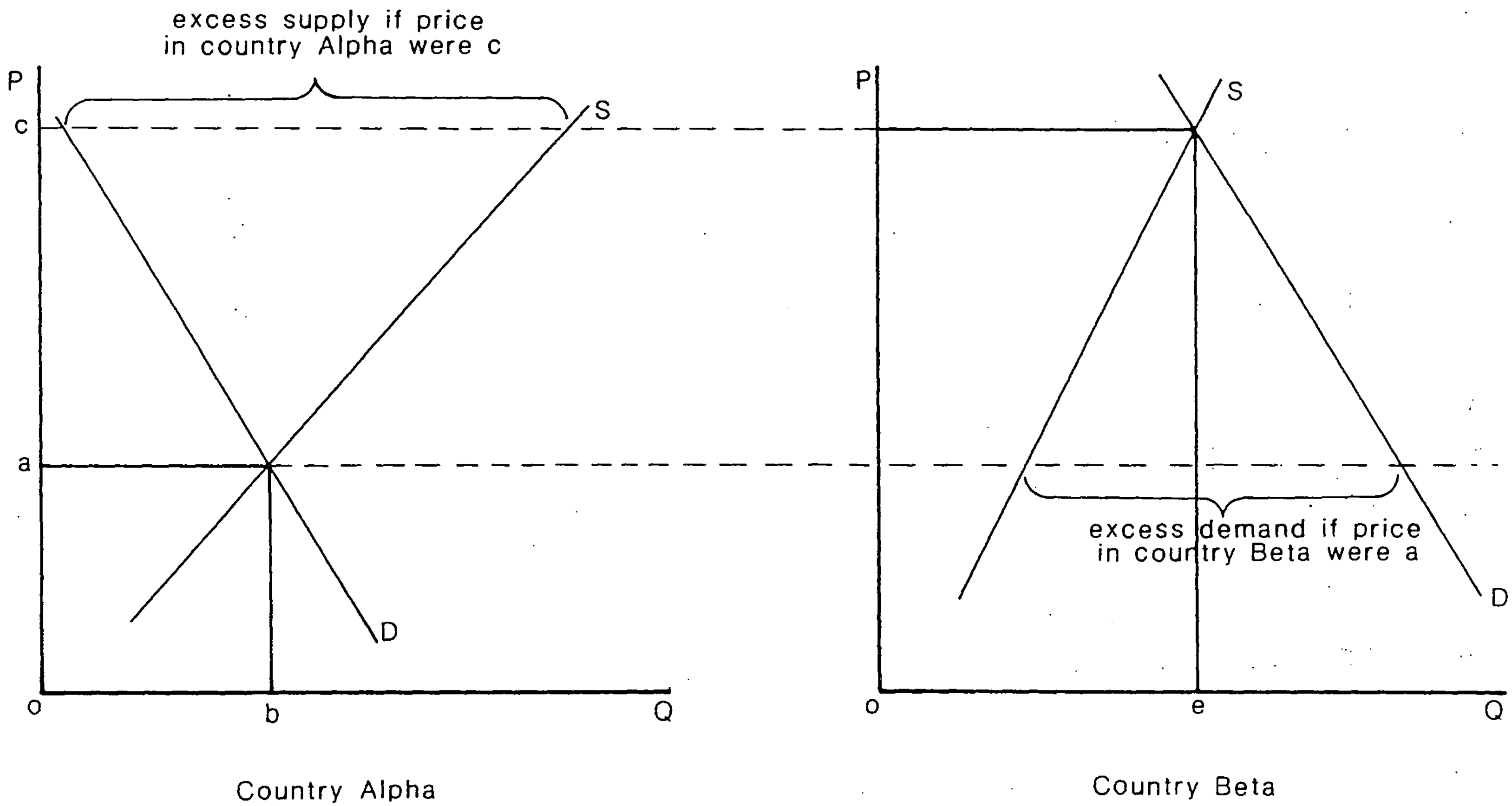

Figure 1. Graphical representation of excess demand and excess supply.

Source: Speaking of Trade: Its effect on Agriculture.

As an example, consider Figures 1 and 2 which illustrate the effects on prices and output of trade between two countries. In this model, the equilibrium price c in country Beta is much higher than the price in country Alpha. If trade is restricted, then there would exist an excess supply if the domestic price in country Alpha were c and an excess demand in country Beta if the price there was a. If trade is permitted, country Alpha would export its product and a world market (in this two country world) for the good would emerge and a world price would dictate the quantities supplied and demanded. In this hypothesized case, as the barriers to trade are lifted, the price rises in country Alpha and falls in country Beta until the amount exported exactly equals the amount imported. Total production in the exporting country rose from ob to of. In this example, a constant exchange rate is assumed and transportation costs are ignored (Figure 2).

When transportation costs are present, as they are in the real world, a wedge is driven between the price received for the commodity in the exporting country and the price paid for the good in the consuming or importing country. The per unit cost of transportation shifts the import demand curve in the world market downward and to the left (Figure 3). The world market price drops from G to A and exports decline from bf to ce. Total production

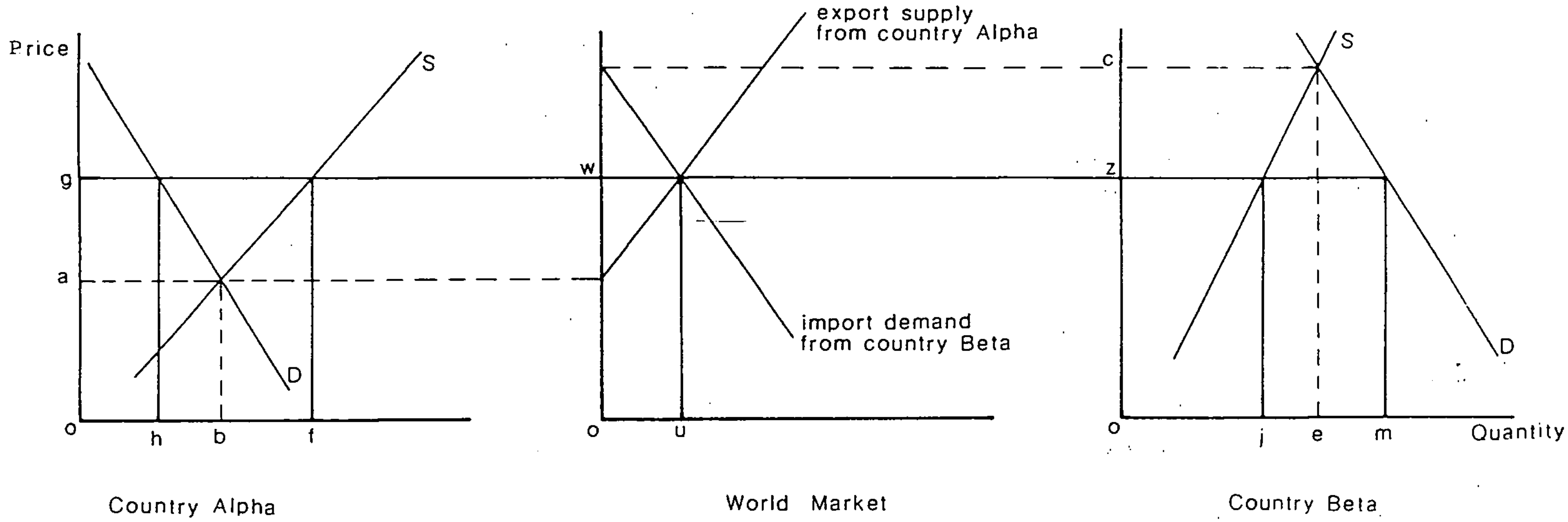

Figure 2. Graphical representation of export supply and input demand.

Source: Speaking of Trade: It's Effect on Agriculture.

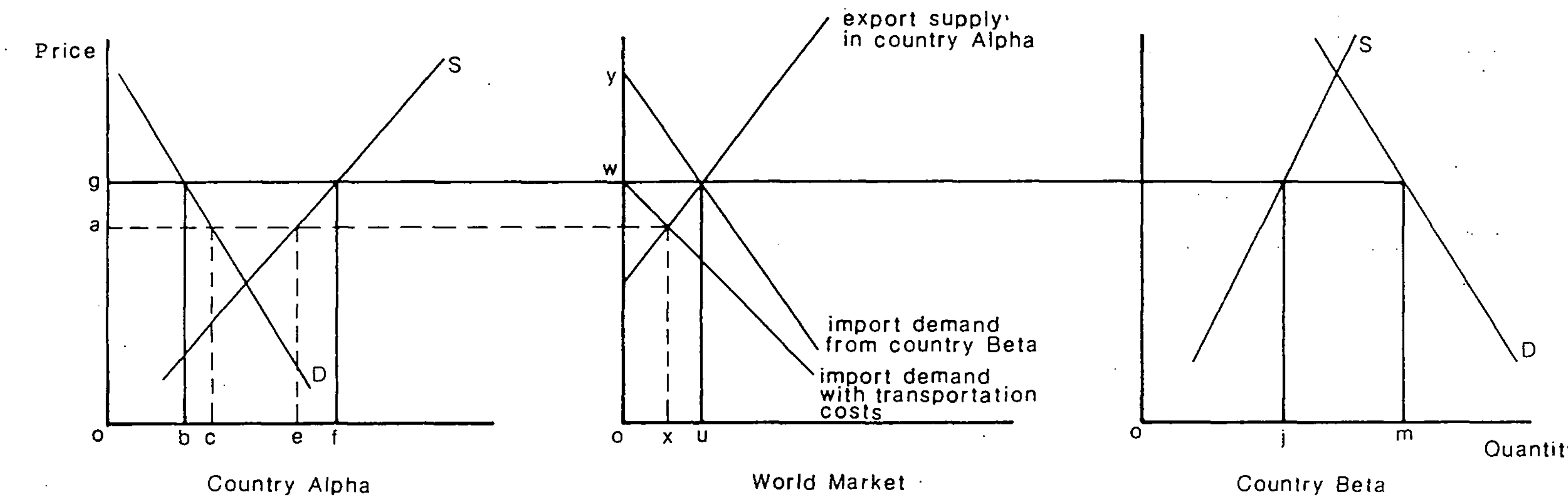

Figure 3. Graph of import demand with transportation costs.

Source: Speaking of Trade: Its Effect on Agriculture.

in the exporting country is reduced by the amount ef. In the absence of any intervention, as farm price in the exporting country drops and production declines, aggregate farm income suffers.

The support of farm income in an agricultural exporting country, then, is especially helped by the international trade of grain. Grain movements by ocean shipping have increased from 89 to 204 million metric tons during the period from 1970 to 1981, accounting for 6 percent of total tonnage moved via ocean transportation in both 1980 and 1981. On a ton-mile basis, grain shipments have increased from 475 trillion ton-miles in 1970 to 1,120 trillion ton-miles in 1981, accounting for 7 percent of total 1981 ton-mile estimates (Maritime Transport, 1981). In the past 30 years important changes occurred with ship technology and port development in the face of increased trade which may strongly affect ocean freight rates.

Development of Ocean Transport

After World War II the world economy began to grow at an impressive average annual rate of six percent. Perhaps spurring this growth in the world economy was a major increase in trading between nations. Post World War II economies required several changes in ship technology.

1) An increase in the concentration of the

Table 2.

World Seaborne Trade Estimates, Tonnage Basis, 1970-81

Year	Commodity														TOTAL	
	Crude oil and oil products		Iron ore		Grain 1/		Coal		Bauxite and alumina		Phosphate rock		Other Commodities 2/			
	Million metric tons	%	Million metric tons	%	Million metric tons	%	Million metric tons	%	Million metric tons	%	Million metric tons	%	Million metric tons	%	Million metric tons	%
1970	1,241	50	247	10	89	4	101	4	34	1	33	1	737	30	2,482	100
1971	1,317	51	250	10	91	4	94	4	35	1	35	1	755	29	2,577	100
1972	1,446	52	247	9	108	4	96	4	35	1	38	1	793	29	2,763	100
1973	1,640	53	298	10	139	4	104	3	38	1	43	1	859	28	3,121	100
1974	1,625	50	329	10	130	4	119	4	42	1	48	2	955	29	3,248	100
1975	1,496	49	292	10	137	5	127	4	41	1	38	1	916	30	3,047	100
1976	1,682	51	294	9	146	4	127	4	42	1	37	1	996	30	3,324	100
1977	1,748	51	276	8	147	4	132	4	46	2	44	1	1,030	30	3,423	100
1978	1,727	50	278	8	169	5	127	4	46	1	47	1	1,097	31	3,491	100
1979	1,817	49	327	9	182	5	159	4	46	1	48	1	1,176	31	3,755	100
1980	1,638	45	314	9	198	6	188	5	48	1	48	1	1,214	33	3,648	100
1981 3/	1,445	42	303	9	204	6	196	5	46	1	41	1	1,228	36	3,463	100

1/ Includes corn, soybeans, sorghum, barley, oats and rye.
2/ Includes all other commodities. This figure includes some minor bulk commodities such as soft wood, sugar, manganese, other non-ferrous ores, scrap and pig iron, salt, gypsum, sulfur, and petroleum coke.
3/ Preliminary.

Source: Maritime Transport, 1981.

Table 3

World Seaborne Trade Estimates, Ton-mile Basis, 1970-81

Year	Crude oil and oil products: Trillion ton-miles	%	Iron ore: Trillion ton-miles	%	Grain 1/: Trillion ton-miles	%	Coal: Trillion ton-miles	%	Bauxite and alumina: Trillion ton-miles	%	Phosphate rock: Trillion ton-miles	%	Other Commodities 2/: Trillion ton-miles	%	TOTAL: Trillion ton-miles	%
1970	6,488	61	1,093	10	475	4	481	5	99	1	33	3/	1,986	19	10,655	100
1971	7,455	64	1,185	10	487	4	434	4	108	1	35	3/	2,026	17	11,730	100
1972	8,650	66	1,156	9	548	4	444	3	109	1	38	3/	2,159	17	13,104	100
1973	10,217	66	1,398	9	760	5	467	3	133	1	43	3/	2,386	16	15,404	100
1974	10,621	65	1,578	10	695	4	558	3	158	1	48	3/	2,729	17	16,387	100
1975	9,730	63	1,471	10	734	5	621	4	168	1	38	3/	2,604	16	15,366	100
1976	11,183	65	1,469	9	779	5	591	3	158	1	37	3/	2,840	17	17,057	100
1977	11,467	65	1,386	8	801	5	643	4	167	1	44	3/	3,009	17	17,517	100
1978	10,646	62	1,384	8	945	6	604	4	162	1	47	3/	3,246	19	17,034	100
1979	10,659	60	1,599	9	1,026	6	786	5	169	1	48	3/	3,388	19	17,675	100
1980	9,405	56	1,613	10	1,087	6	952	6	188	1	48	3/	3,484	21	16,777	100
1981 4/	8,280	53	1,580	10	1,120	7	1,030	7	169	1	38	3/	3,523	22	15,740	100

1/ Includes corn, soybeans, sorghum, barley, oats and rye.
2/ Includes all other commodities. This figure includes some minor bulk commodities such as soft wood, sugar, manganese, other non-ferrous ores, scrap and pig iron, salt, gypsum, sulfur, and petroleum coke.
3/ Less than 1 percent.
4/ Preliminary.

Soucre: Maritime Transport, 1981.

population consuming petroleum products generated the construction of refineries near markets. This caused larger vessels to be used to transport crude oil to refineries. Previously, refineries were near oilfields and the refined products were transported to a variety of smaller markets. This required smaller ships.

2) The growth in trade between consuming nations and producing nations prompted an increase in the average length of shipping voyage to serve the new political entities created after the war. This further supported the building and use of larger ships as studies showed that increases in voyage distance revealed economies of scale in the larger vessels.

As an example, prior to 1944 the largest tanker in the world was the 22,600 ton "John D. Archbold" built in 1921. This maximum-sized ship reflected the economies of the time: shipping refined oil products to numerous, relatively widespread ports. In 1944 the 23,000 ton "Phoenix" was built, eclipsing the size of the largest tanker in 23 years. In 1967 the largest vessel in service was the "Idemitsu Maru" with a 206,000 dwt. The following year

Table 4.

Predicted Vessel Size by the Year 1990

Vessel Type	Largest Vessel in the World Fleet				Average Expected Vessel Size			
	Capacity (000) 1/	Length (ft)	Beam (ft)	Draft (ft)	Capacity (000) 1/	Length (ft)	Beam (ft)	Draft (ft)
Breakbulk	27 dwt	598	82	37	13 dwt	500	69	30
Partial Containership	30+ dwt	668	89	40	13 dwt	509	75	31
Containership	40+ dwt	943	106	42	18 dwt	657	89	32
Barge Carrier	45 dwt	879	103	38	40 dwt	876	103	38
Dry Bulk Carrier	150 dwt	1,000	144	56	35 dwt	660	83	37
Combination Carrier	200 dwt	1,076	164	63	100 dwt	852	111	46
LNG	65 dwt	936	144	36	60 dwt	932	141	36
Tanker	550 dwt	1,315	207	93	40 dwt	671	78	37

Source: Maritime Administration
U.S. Department of Commerce - 1979

1/ Capacity in terms of deadweight tons (dwt).

larger tankers of 276,000 dwt. were launched in Japan (Abrahamsson).

In addition to size the nature of changing world trade has caused a trend for specialization of ships to efficiently handle more specially packaged cargo. Prior to 1945 a merchant ship was designed to accommodate a variety of different type and sized cargo going to multiple ports. The size of the ship was limited to allow entry into smaller ports. The concentration of markets during the following forty years allowed larger volumes of a single type of cargo to be economically feasible to ship. Where the general cargo ship was limited in capacity by on-board cargo cranes and a general purpose designed cargo hold with, perhaps, first and second tween decks, the modern carrier was built to handle only one or two types of bulk cargo. The most specialized of these designs are demonstrated by the roll on/roll off (RO/RO) cargo ships which transport automobiles from Japan to the Pacific coast of the U.S. and the full containership such as the "America Maru" operated by Mitsui O.S.K. Lines. Again, this changing technology in ships was brought about by the longer average distance of voyage and fixed ports of call which boasted, as an example, extended piers designed exclusively for containerships with special loading/unloading facilities.

Designing port technology around the latest ship designs is also a post 1945 phenomena. The investment in capital stocks in ports are larger and have a much longer life than the 25 years or so of a ship. This has always caused ship technology to be developed with an eye toward the existing port accommodations. However, competition between ports to serve a larger regional market has caused port technology to change to serve the larger, more specialized vessels. To reduce the condition of "a ship in port loses the profit she made at sea" much attention was paid to the improvement of cargo handling techniques. While specialized ships carried specially contained cargo (e.g. bulk cargo, mass break bulk cargo) which helped reduce turnaround time in port, ports invested in the cargo-handling equipment and gear to accommodate this newly packaged cargo. Roll on/Roll off ramps were built to load/unload automobiles and palletized cargo and longer cargo piers were constructed to serve the large-sized vessels. The full advantages of containerization accrue to the shipper and consumer only when a "through" system of transportation is available which links ocean ports with rail and other domestic transportation. Port technology was influenced by this revolution in shipping by the development of specialized facilities such as the "optimum coal loading/unloading port" recently being developed at the Port of Portland.

To summarize, the concentrated production and consumption areas which appeared in the world after 1945, along with the increased volume in world trade presented the stimulus for larger, more specialized merchant vessels. Ports began modernizing to accommodate these vessels by investing in faster cargo handling equipment and gear to handle the carriage of cargo in containers and in bulk, as well as increasing the channel depth and the depth alongside cargo piers to accommodate the larger vessels.

Between 1973 and 1978, nearly 400 million dollars was spent by the U.S. deepwater port industry for modernization and rehabilitation of existing marine terminal facilities. A study titled, National Port Assessment 1980-1990 conducted by the U.S. Department of Commerce concluded that "Tankers and dry bulk ships... are expected to continue to increase in length and draft. Hence, ... a stimulus to improve the size and capability of existing terminal approach channels, loading berths, and storage facilities." Some countries, however, have lacked the resources to make sufficient investments in their ports to take advantage of the lower per unit shipping costs of the larger, more specialized cargo vessels.

The next chapter contains a review of recent literature directed toward shipping and port development issues.

CHAPTER II

LITERATURE REVIEW

Recent research directed toward shipping and port development issues generally focused on either: determinants of freight rates and ship technology to lower transport costs; on port development features to shorten ship turnround time and increase loading rates; port pricing methods to improve port efficiency by reducing congestion, etc.

Goss (1967) examined "the turnround of cargo liners and its effect upon sea transport costs" using a discount cash flow technique to apply sensitivity analysis to liner cost data. Only one theoretical ship design and size (12,500 dead weight ton (dwt)) is assumed throughout the study.

He estimated that cargo liners spend sixty percent of their time in port and, at least in New Zealand, only fifteen percent of the total time in port was occupied in working cargo. The analysis concluded that a reduction of one day in port time, regardless of route length, reduces the shadow price (long-run freight rate) by about .121 (English Pound) per long ton. Further, if the proportion of turnround time spent in port by cargo liners could be reduced from sixty percent to twenty percent, the cost of sea transport could be reduced by eighteen to thirty-five percent.

The maximum size of ship and fifteen year old ship design used in the study is obsolete in comparison to more modern bulk cargo carriers of twenty-five to fifty thousand dwt. For this reason, and the fact that current cargo handling equipment is more specialized, these results may have changed.

Heaver and Studer (1972) conducted the first empirical study of vessel time in port. They examined ship size and turnaround time of 1,305 grain ships in Vancouver, British Columbia, which loaded over five thousand tons per visit during the period 1964-1968. Using ordinary least squares analysis to regress loading rate (tons/day) against both ship size and shipload their model explained up to seventy-nine percent of the variation in loading rates.

The results indicated that large ships spend more time in port than smaller ones, but achieve a higher loading rate. Larger ships are found to be more economic in vessel time costs per ton of cargo loaded.

When a variable was added to show the effect of visiting more than one berth, the statistical fit improved and the effect on cost was positive. This diminished the advantage of a large ship. An important implication for port development then, is that costs rise if either the size of the grain elevator is too small to accommodate the size of the ship, or, if the cargo handling facilities are not useful for diverse cargos.

Different results were published four years later by Ross Robertson (1978) on a study of the turnround time of ships in the port of Hong Kong. A sample of 1,216 general cargo vessels arriving in port in 1973 showed that the turnround time for larger ships was actually <u>faster</u> than for smaller ones. This difference may be attributable to the fact that larger vessels dock at more modern berths located closer to transportation and storage facilities.

To assist ports in assessing the value of port features aimed at improving the contact between ship and port, Goss (1967) outlined a social cost-benefit approach beginning with market research activities to determine potential benefits. He felt that the pricing system was too complex in most ports and reflected neither average or marginal costs, thus, preventing the use of discounted cash flow methods.

Mills (1971) argued that economic analysis hasn't even been used in most port investment planning during the period 1961-1971. Instead, the major role was played by various institutional and political factors.

Kendall (1974) developed a theory of optimum ship size. The objective was to minimize total transport costs and in doing so he asserts that "ports must provide depth of water and facilities according to demand."

Kendall asks the question, "What restrains ship sizes from being as large as ports can accommodate?" He notes that higher valued products are best shipped via smaller ships to minimize transport costs since the penalty of idle large inventory stored on the dock is reduced. While the loading rate of smaller ships is lower, the total loading time is also lower (at least in some ports). He believes that this theory is in accordance with the current practice of shipping lower value cargo, such as grain, in large bulk carriers.

Two years later the "optimum port capacity" was determined by Weille and Ray (1974). This study uses mathematical programming techniques with economic benefit-cost analysis to determine the net benefits of a given port capacity to both the ship owner and the port authority.

The optimum number of berths is estimated with regard to the volume and frequency of traffic, the cost of ship waiting time, and the cost of the berths. Lighterage is mentioned as a possible alternative to additional berths as is reducing the turnround time of ships via investment in more efficient cargo handling equipment.

The authors note that the movement toward containerization reduces by up to 10 fold the need for additional berths to expand port capacity. In view of the inroads made by containerization in the past decade, this model may be less useful now than it was in 1974.

Other authors have outlined the theoretical background to port investment projects (Wanhill (1978)) and their economic impact (McCalla (1979)).

McCalla evaluated the degree of specialization of two ports on the St. Lawrence River and two ports on the Atlantic Ocean by use of a location quotient. The location quotient is used to show whether an area has more than or less than its proportionate share of a particular activity, vis a vis, the rest of the nation. A quotient greater than one indicates specialization in the activity. The analysis was aimed at determining whether a port specialized in either:

a) Type of good handled (either international or coastal) divided between loaded (export) or unloaded (import), or;

b) In interior areas served, both international and coastal and loaded and unloaded.

The policy implication of this research was that duplicate facilities which enhanced competition between ports should be avoided. Instead, new facilities should be located in the areas where the expertise and advantage already exist.

More recently, both researchers and industry leaders have widened their attention from the point of contact between ship and port to the entire transport network. Frankel (1983) advises that the major objective in modern shipping technology is to develop an integrated system which will minimize point to point transportation time and costs. The goal is not necessarily to optimize shipping costs, but to optimize total transport costs.

Similarly, Shneerson (1983) developed a mathematical programming model to optimally distribute a country's total imports and exports among all its ports. Pricing policies and direct control over traffic movement were viewed as the tools to meet this objective. A case study of Nigeria focused on including ports along with the rest of the country's transportation system to minimize total transport costs. An additional feature of this type of model is that it provides an estimate of the cost of deviating from the least-cost solution, such as when traffic is allocated to a particular port for political reasons.

The Deputy General Manager, Port of Antwerp, Suykens (1983) advises that the increase in productivity in Northern European ports since WWII is attributable, at least partly, to the treatment of the "chain of transport" as one whole. His "holistic" approach stresses the importance of the integration of the ocean shipping, cargo handling at the dock, and transportation of the goods to the interior.

The methods used by ports to price its services, as well as the level set, have found the attention of researchers. Button (1979) asserts that ports should be priced as all public utilities, i.e., equal to the full marginal social opportunity cost of the resources they use. Gilman (1978) offers the idea that pricing be based on the sale of terminal capability per unit of time. This system would encourage port productivity.

Heggie (1974) argues that tariff structures were established before the turn of the century and do little to relate specific revenues to costs. He supports pricing policies which:

a) measures the aggregated demand for each service;

b) leads to the most efficient use of existing facilities in the short-run, and;

c) shows what existing services should be continued and guides innovation and investment policies in the long-run.

The impact on transport cost of the level of port prices was estimated by Thomas (1978). He determined that port charges incurred at both ends of a voyage represent approximately twenty to thirty percent of ocean freight rates. Of this, cargo-handling charges may account for up to ninety percent. Up to ten percent of the total annual cost of a vessel may be attributable to port charges.

Ocean freight rates for liner shipments were analyzed by the Organization for Economic Co-Operation and Development in 1968. They conducted a pilot study showing the share of ocean freight rates in total transport costs from inland point of origin to ultimate inland point of destination. They used a sample of 235 general cargo liner shipments between North America and Western Europe & vice versa. The results were:

Ocean Freight	62%
Inland Freight	28%
Port Charges	10%

	100%

The relative higher proportion attributed to ocean freight as compared to the other components, especially port charges, may partly be blamed on the noncompetitive nature of the liner market. Bryan (1974) determined that competition from tramps tended to lower freight rates on certain routes that were affected. Bryan used OLS to analyze the effect on liner rates of stowage, distance, quantity shipped, and the number of competitors on the route.

In the early and mid 1970's Harrer and Binkley modeled shipping costs for grain vessels in the tramp shipping market. Using OLS, their hypothesized independent variables of distance, size of shipment, volume of trade, flag of registry, terms of shipping, season, and region of origin and destination were all statistically significant. The regression coefficient for the variable, "lay days" was not significantly different from zero. Goss and Jones (1977) estimated that the "extra cost per ton of cargo with one more day in port" (layday) did influence rates and was highest for the smallest vessels. This would imply that port development features which improved turnaround time for smaller vessels may yield the greater return.

Binkley and Harrer (1981) analyzed the major factors accounting for cross-sectional differences in 9,356 voyage charters occurring between 1972-76. One of their objectives was to estimate the effects of major port areas on rates. Ports were aggregated into 16 origin and 34 destination regions. The empirical results of the study suggested that the importance of distance is declining as large vessels are used and that "a critical factor in shipping advantage is the nature of port systems at origins and destinations". The inadequate ports of the Less Developed Countries (LDC) were thought to be at least partly to blame for the fact that the average rates to LDCs are more than twice that of the developed ports of

Northern Europe and Japan and above the average to all other areas. The authors suggest that investments in improved grain-handling facilities and the ability of ports to handle larger vessels will be the primary source of future cost savings.

Cost functions for ocean vessels in the grain, coal and iron ore trade were estimated in a 1981 report by de Borger and Nonneman. Their report used OLS regression to make direct statistical estimates of the main determinants of sea transport costs.

The authors argue that the structure of freight rates is determined by the cost structure of the producers, yet, the level of freight rates is determined by the forces of demand and supply. They present an example of the tramp shipping market which demonstrate that short-term variations of freight rates are due more to shifts in the demand curve than to shifts in supply.

In Figure 4 on the following page short-run supply curves s',s'' and s''' are influenced by the existing capacity c', c'', & c''', respectively. In the short-run, as the demand curve shifts from D_0 to D_1 the short-run rate increases from a to b'. In response to the increase in demand, capacity is increased via vessels increasing speed or ships coming out of lay-up, and the new capacity generates a different supply curve such as S''. The rate

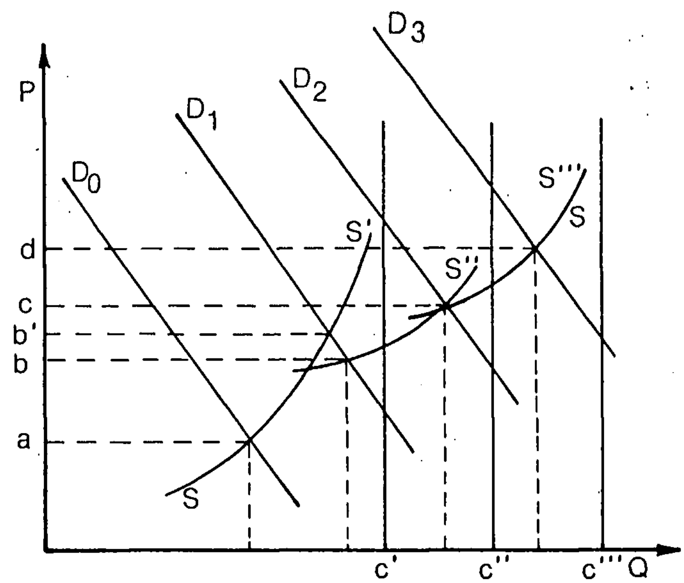

Figure 4. Graphical representation of short-term variations of freight rates in the tramp shipping market.

drops to b which is still higher than the original price of shipping. The long run supply curve SS, as the envelope of the short-run supply curves, is more elastic. Clearly, from this example it is apparent that short-run shifts in the freight rate are influenced predominantly by a shifting demand curve intersecting with a relatively inelastic supply.

Bennathan and Walters (1967) in a book titled, The Economics Of Ocean Freight Rates, previously outlined this view of the tramp shipping market. They argue that tramp rates are "demand-determined" while liner rates are "cost-determined". Since tramp vessels are ones which are defined as having no set route or schedule and operate on negotiated charters, the changes in their freight rates may reflect short-term changes in demand.

Liners, however, are defined as vessels which operate on fixed routes and schedules. Their rates are determined by conferences and the authors speculate that they practice "full-cost" pricing (price equals average cost plus mark-up). Therefore, rate changes in the liner trade may be the result of long-run cost changes in the industry.

One of the findings by de Borger and Nonneman that is especially important in port investment decisions is the lower relative effect of distance on freight rates, as compared to previous cost engineering functions developed by Goss and Jones (1977) and Heaver (1970). This difference may lead to inaccurate results in cost-benefit analysis of port projects intended to serve larger vessels. If longer distances are expected, the benefits of the project may be overstated if the engineering functions are used. (de Borger & Nonneman)

Clement (1982) estimated a port-specific rate structure and analyzed the determinants of Lower Columbia River ocean freight rates for grains. He concluded that comparisons of port-specific shipping rates reveal major differences for grain shipments of equal size and distance due to different port characteristics. He speculated that international ocean freight rates for grains are influenced by regional port investment decisions. Research remained to be done on the impact of port depth on ocean freight rates. Clement reasoned that research on port-specific rates do not test the importance of port depth on rates since the depth at the origin port limits the number of destination ports that can be evaluated.

Kirsten Ruth Olson (1983) analyzed ocean freight rates for grain moving from U.S. ports relative to grain moving from other grain shipping ports with an eye toward discriminatory rate setting policies. She points out that the average rate charged for grain shipments in 1975-79, over all routes, was $18.47 per metric ton. During the same time period, the average rate charged from U.S. Gulf to Egypt was $34.99.

Since North America experiences a trade imbalance between incoming and outgoing dry bulk movements, she hypothesizes that rate differentials reflect the lack of back-haul opportunities. Additionally, the cause may be the use by U.S. shippers of the more restrictively regulated U.S.-flag carriers.

Using a weighted OLS, she extended the work of Binkley and Harrer (1981) by including variables that reflected the effects of annual fluctuations of the demand curve for freight rates, as well as variables showing some port characteristics and the back-haul potential of cargo vessels. Olson's results indicated that grain shipments originating in the United States experience rate differentials primarily due to U.S. policies. The high cost of strict regulations that U.S. flag-of-registry vessels are subject to and the requirement that certain grain cargos must be transported under U.S. flag, results in a more than doubling of the average rate. The variable representing back-haul potential was insignificant in explaining rate variations.

The study included some port characteristics that were tested and found significant. Characteristics of destination ports were more important than origin ports. Perhaps this coincides with the result that ports located in less developed countries are associated with higher ocean rates than in developed countries. Ports in coastal harbors experienced lower freight rates than those located in a river, canal, or lake harbor, and ports whose grain unloading facilities required the bagging of grain experienced higher rates.

Olson's work suggested additional research on how rates are affected by other characteristics of destination ports. The adequacy of the inland transportation system serving a port may affect port congestion and increase costs through a longer ship turnround time. Likewise, inadequate grain elevator storage capacity in a country may increase costs.

CHAPTER III

ELEMENTS OF OCEAN SHIPPING

There are five modes, or general forms, of transport. These modes are: railroad, highway, air, water, and pipeline (Abrahamsson). More than one of these modes are generally used in the movement of seaborn foreign trade. By combining modes of transportation a transportation system is constructed which carries the goods that comprise international ocean trade.

There are five components to this system: land carriers serving the domestic ports; domestic ports with their piers, tugs, storage, cargo handling equipment, etc; domestic or foreign flag-ships that are the ocean carriers; the foreign port where the cargo is unloaded, and; the receiving country's transportation system (Abrahamsson).

The cost of each of these components may be summed to account for the total transportation cost involved in seaborn trade. The ocean freight rate charged for transporting grain in the tramp shipping market accounts for the expense of the "ocean transportation system." The elements of this system are the middle components listed above: the ocean carrier and the domestic and foreign ports.

The Economics Of Ocean Shipping

The ocean transportation system operates within the environment of two types of markets: the competitive tramp market and the noncompetitive liner market. As mentioned in chapter II, the liner market is controlled by the members of a conference which set rates and fix schedules. The purpose of these formal agreements is to control competition and avoid price wars (Abrahamsson).

The tramp market is composed of vessels which go anywhere in the world a contract may take them. Their shorter terms are established by market forces (Bennathan and Walters) (Abrahamsson). Traditional cargo for liner services are small-lot, high-value goods which benefit from the economics associated with the frequency, regularity, and reliability of liner service. Tramps primarily carry homogeneous, low-value bulk cargoes such as coal or grain. In recent years over ninety percent of international trade in grain was transported in the tramp market (Olson).

Characteristics of the Tramp Market

The tramp market is generally considered as possessing the characteristics of a perfectly competitive market, that is:

a) large number of buyers and sellers,

b) product homogeneity,

c) free entry and exit of firms,

d) profit maximization,

e) absence of government regulation,

f) perfect competition in the markets of factors of production,

g) perfect knowledge.

(Koutsoyiannis, pg. 154-155)

However, Abrahamsson reports of many efforts in the past to control competition. The Sailing Ship Owners International Union in 1905 attempted to set minimum rates for long voyages such as the grain hauling routes out of Australia. In 1935 the British Shipping Assistance Act provided subsidies to British tramp shipping and led the way for international cooperation in maintaining higher ocean freight rates. Until 1939, tramp rates were regulated for the grain trades from Australia, Rio de La Plata (Argentina), and U.S. Gulf and Atlantic ports to Europe (Abrahamsson, pg. 116).

Although some "bulk shipping pools" emerged in the dry cargo trades during the '60's, it is generally thought that this cooperation between shippers has led to a more competitive market through the standardization of charter parties.

Charter parties are the contracts used in tramp shipping. There are two types of charter parties: time and voyage. Time charters are for ships hired for a specific period of time, regardless of the number of voyages, and may last from only a few months to perhaps twenty years. The rates on time charters are quoted per dwt carrying capacity. Voyage charters are for a specific trip or number of trips and the rates are based on the actual tonnage of cargo shipped.

Various trade journals (e.g. Fairplay International Shipping Weekly) publish information from the charters on sales of space and terms (together called "fixtures") and information on demand and supply is readily available. A central market such as the Baltic Mercantile and Shipping Exchange in London is used by brokers who have information on ship characteristics and availability so they may complete a charter without actually having seen the ship.

Abrahamsson argues that the factors which contribute to competition out weigh efforts to reduce it and that tramp shipping is commonly regarded as a free market. He writes, "On balance,...the tramp market evidences all the characteristics of a highly competitive market: there are many buyers and sellers; exit and entry are relatively easy,...; products shipped and services rendered are largely homogeneous; and information is easily and quickly available." (pg. 118)

Demand for Tramp Shipping

The demand for tramp shipping services is a derived demand. It is a complement to the demand for something else, such as, ore, coal or grain. For example, as the demand for grain increases in one part of the world, the demand for tramp shipping services increases so that grain may be transported from the grain producing region to the area where the commodity is in demand.

The price elasticity of demand for tramp shipping is influenced by the relative importance of the transport cost to the cost of the final product. For grain on all routes from 1975-79, Olson estimated that transportation costs comprise about 13 percent of the import price for corn. Large increases in the cost of transport, therefore, can significantly influence the import price of grain. As demand for tramp shipping is derived from the demand for the transported cargo, and that demand is now responding to a significant price increase, the long-run response of the quantity of tramp services demanded to shipping rates is elastic.

The theoretical derivation of the demand curve for tramp shipping can be illustrated by using a spatial equilibrium model developed by Samuelson (1952). Additionally, some potential welfare gains or losses to exporting countries can also be shown with this example.

The back-to-back diagram in figure 5 illustrates the opportunity for trade between two hypothetical regions that are spatially separated. The excess supply and demand curves are constructed by altering the price in each region and taking the difference (laterally) between the domestic demand and supply curves. Since the pretrade price is lower in region I than II, trade will flow from region I to region II if the difference in prices is greater than the per unit cost of transporting goods from I to II.

An equivalent depiction of spatial equilibrium is shown in figure 6 where the original supply and demand curves are ignored and the constant per unit cost of transportation is depicted by the constant slope line, yy. The curve NN represents the net excess supply curve and is constructed by taking the vertical difference between the excess demand and supply curves. This curve crosses the horizontal axis and becomes zero at point b, the level of trade where excess supply equals excess demand.

If the assumptions of perfect competition hold, then the equilibrium amount of trade will occur where the net excess supply curve intersects the curve of constant

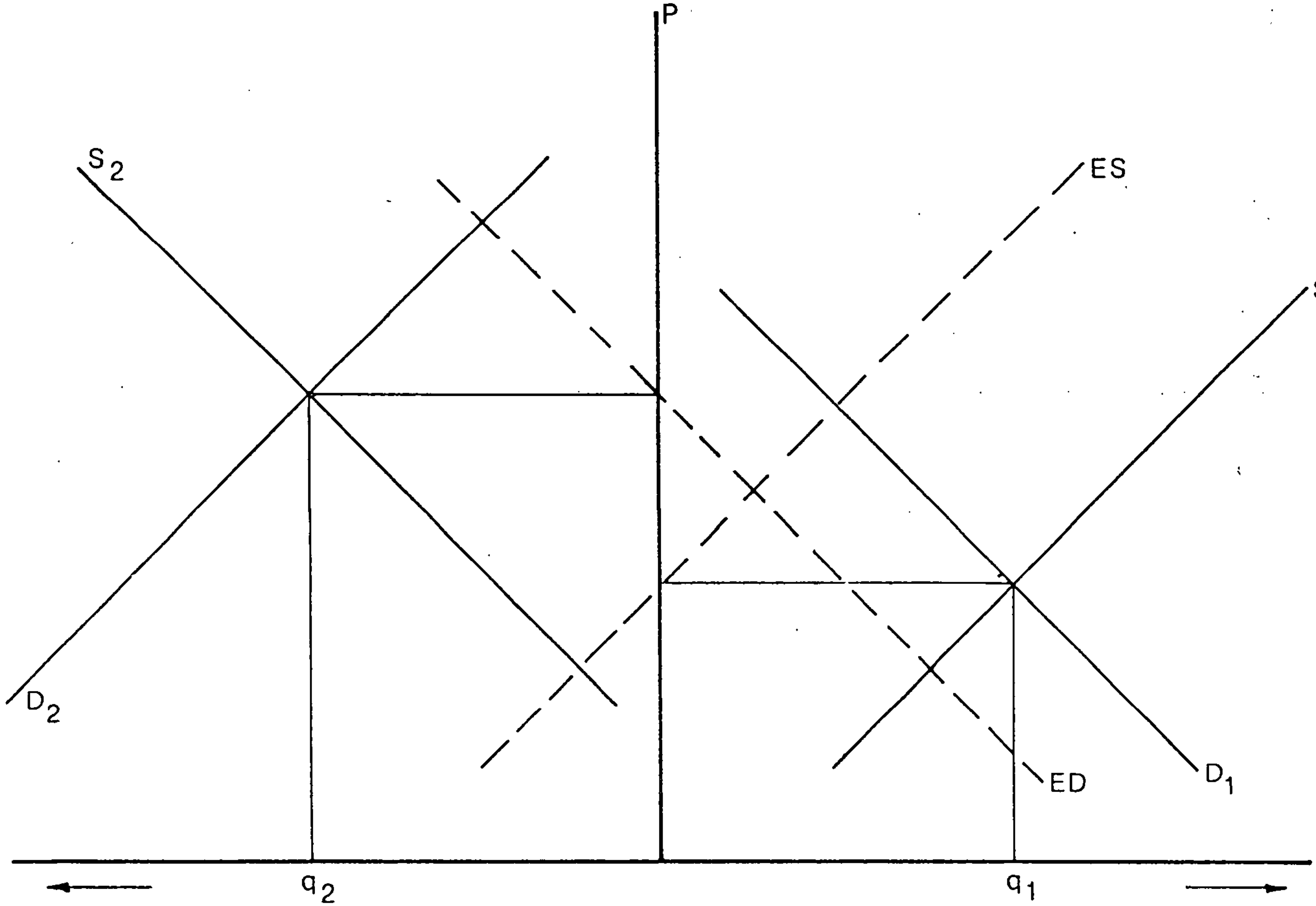

Figure 5. Back-to-back diagram showing trade between two countries.

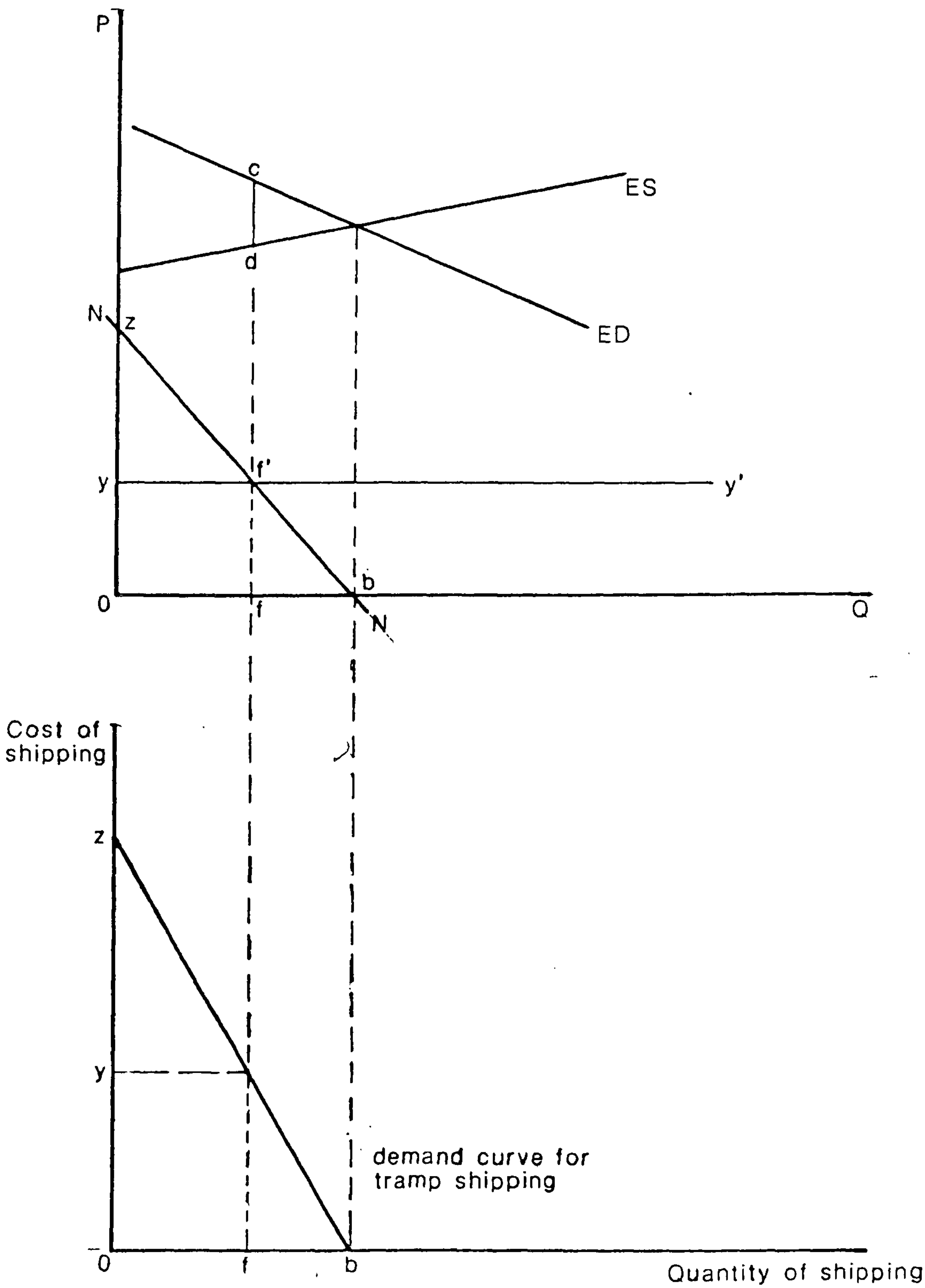

Figure 6. Graphical derivation of demand curve for tramp shipping.

transport costs. At this margin the difference in prices between the two spatially separated regions will differ by only the amount equal to the per unit transport cost (due to arbitrage) and the amount of excess supply will equal the amount of excess demand. Total quantity traded is of.

The demand curve for tramp shipping can be traced by increasing the per unit cost of transport from zero to y to z and plotting the reduction in the amount shipped from b to F to o.

Figure 5 helps illustrate the loss in welfare to both the exporting and importing countries as a result of increased transportation charges. Samuelson used this model to illustrate how an equilibrium level of trade between two markets which minimizes transportation costs would result in maximizing the net social welfare. Welfare is defined as the "social pay-off" of a region and is measured by the area under an importing region's excess demand curve which lies above the price, and the area above an exporting region's excess supply curve and below the price.

With transportation cost DC, the producer's and consumer's surplus in the importing country is equal to the area in triangle abc and in the exporting country in triangle fde. When transportation charges are increased to xy, the total surplus in the importing country is only

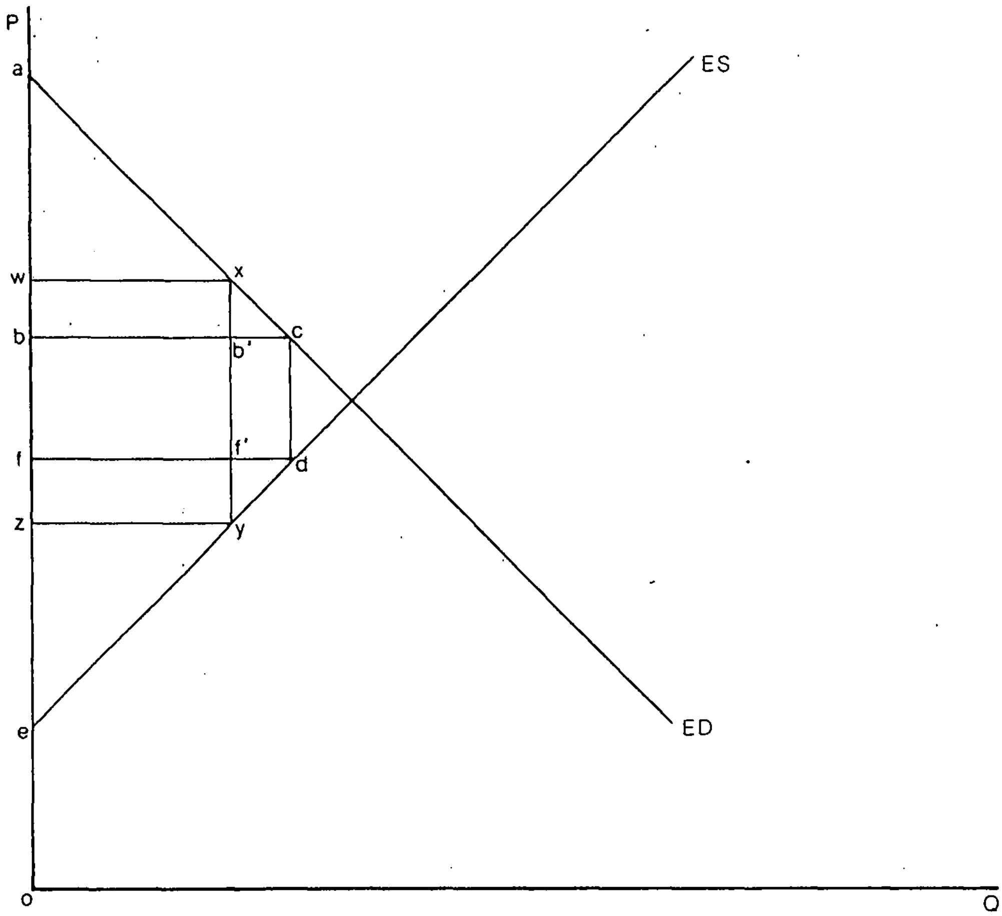

Figure 7. Loss of welfare due to increased transportation charged.

awx, and in the exporting country the surplus has been reduced to the area bounded by zye.

If the increase charges are the result of tariffs imposed by the importing country then their total surplus increases if rectangle ff'yz is greater than triangle xb'c. That is, if the amount of the tariff collected from the exporting country (assuming no cost of collection) exceeds the amount of surplus lost from the reduction in trade.

Supply of Tramp Shipping

The short-run supply of tonnage available in the tramp market for dry bulk cargo depends on the deadweight capacity and operational capacity of the existing fleet of ships. The deadweight capacity is a stock concept that refers to the carrying capacity of a ship. The operational capacity is a flow concept that adds the characteristic of speed. The operational capacity is greater than what would be indicated by just the deadweight tonnage.

At any moment of time, the existing supply of ships are either on a time or voyage charter, in the process of looking for a charger, or in lay-up. Abrahamsson estimates that only about ten percent of the tramp tonnage is at any one time available for spot fixing. The short-run response to an increase in freight rates is the bringing out of lay-up of the more efficient ships (those which are now able to cover variable costs and make some contribution to fixed costs) in addition to an increase in speed in current ships under charter.

The stock of ships increases over time with new orders which may take up to eighteen months to fill. The stock decreases when ships are lost at sea or scrapped. Some addition to the stock of ships available for any specific trade may occur as a result of ships leaving one trade for the opportunities available in another. An example of this is tankers leaving a depressed oil trade and hauling grain in competition with the conventional dry bulk carriers. Olson (pg.108) found that grain shipments made in tankers are associated with freight rates that are lower, on average, by $3.58 per metric ton than those not made in tankers. Perhaps this is the result of the exceptionally large size of most tankers vis a vis dry bulk carriers.

The short-run supply curve for tramp shipping services is most often characterized as being inelastic. The lower portion of the curve is more elastic than the upper portion due to the ability of the fleet to respond to higher freight rates by increasing vessel speed, cross overs from other trades, and recommissioning ships that have been laid up. However, the time lag of one year to

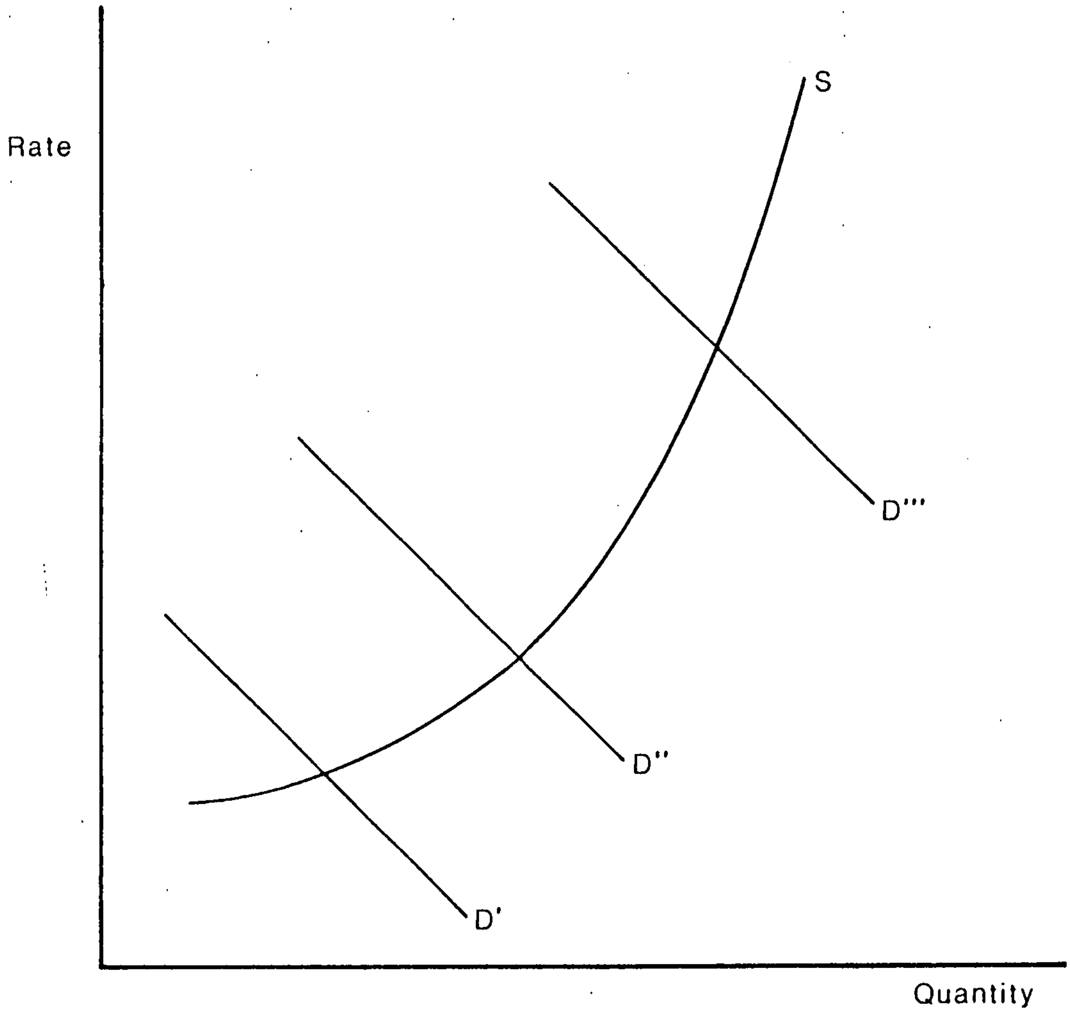

Figure 8. Theoretical supply and demand curves for tramp shipping.

eighteen months to construct new ships presents a barrier to entry which may drive up prices in the short-run as the upper portion of the supply curve becomes more inelastic.

Factors In Rate Determination

International ocean freight rates for grain in the tramp shipping market are determined through the competitive forces of supply and demand. Several factors have been hypothesized as influencing these competitive forces.

Flag of Ship: Prior research has found that U.S. flag vessels carrying grain in the tramp shipping market experience higher rates, on average, than vessels not registered in the Unites States (Binkley and Harrer) (Clement). Higher ship-building costs, increased wages and other compensations, and excessive manning requirements are the most often cited reasons for the higher rates. In the sample selected for this present study no U.S. flag vessels happened to be included, therefore, the influence of this variable on freight rates was not tested.

Distance: The distance a cargo is shipped is positively related to the amount of fuel used and the manning time on board ships. The influence of the cost of these inputs would contribute to a linear relationship between rate and distance. However, terminal charges and cargo handling costs do not increase proportionately with distance. These costs per mile become smaller as the total transport distance increases. The influence of these charges would contribute to a quadratic functional relationship.

Bagged Cargo: Grain which has been bagged prior to ocean transport does not avail itself to modern loading/offloading equipment. Bagged cargo requires the conventional systems of derricks and winches which are relatively slow. Modern grain terminals, such as that planned for the Port of Vancouver, USA, can load bulk grain cargo at a rate of 80,000 bushels per hour, considerably faster than the conventional method of slings. The rates associated with bagged grain are expected to be, on average, higher than those that are not bagged.

Terms: The terms of shipping include assigning responsibility for unloading and/or loading the cargo. The cost of unloading the cargo is generally higher than that of loading. The charter party terms in the sample data used in this study were either Free-in-and-Out (charterer pays both unloading and loading) or Free Discharge (charter pays for the unloading and shipowner pays for the loading). Freight rates are expected to be higher when the shipowner must pay the cost of loading.

Size: The size of cargo shipped is an indicator of the size of bulk carrier under charter. Economies of scale have been identified in the construction and operation of large drybulk carriers. The building cost per deadweight ton declines with size as does depreciation and interest. Insurance per ton of cargo carried at full capacity also declines with size. Since the efficient size of engine does not increase proportionately with deadweight tonnage, the rate of fuel consumption also declines with increases in size (Abrahamsson).

Port & Channel Draft: In order to realize the economies of scale found in larger ships ports, and the approach channels to them, must have sufficient draft. It is expected that lower rates will be associated with deeper drafts up to the point of optimum size ship. An upper limit on ship size occurs where the higher port charges of large ships outweigh the "at sea" economies they experience.

Grain Storage Capacity: Delays in ship turnaround can occur if a country's storage capacity is insufficient to avoid bottlenecks in offloading. Increased time spent in port raises the cost to the shipowner and is expected to result, on average, in higher ocean freight rates.

Quantity of Grain Imports: Ports which import a great amount of a particular commodity may be expected to have economic incentives to modernize the facilities which offload that commodity. Modern facilities may reduce ship turnaround time and lower offloading costs, resulting in lower average rates for transporting grain.

Domestic Transportation Facilities: As with inadequate storage facilities, bottlenecks in offloading can result due to limited transportation systems. This would tend to increase rates as costs to shipowners climb along with any unnecessary time spent in port.

Importing Country's Per Capita Income and Growth Rate: The ability to modernize port facilities so as to reduce ocean freight rates is related to a country's wealth. Many grain importing nations are considered "less developed" and may be at a disadvantage in their ability to fund those port developments, such as channel dredging, that can result in lower freight rates. It is hypothesized that countries with lower per capita incomes experience, on average, higher transportation rates for grain.

Member of Organization of Petroleum Exporting Countries (OPEC): OPEC countries are recent importers of large amounts of grain. As a result of possible new port development projects, or large-lot purchases, these countries may experience lower freight rates for grain, on average, than non-OPEC countries.

A model is developed using the variables (factors) listed above and alternative forms are fit to a sample of ocean charters for grain in 1980. The empirical results of this study are presented in the following chapter.

CHAPTER IV

EMPIRICAL MODEL

An empirical sample was constructed of one-hundred-sixty-four voyage charters for the calendar year 1980 for grain shipments reported in New York and London and published in Chartering Annual by Maritime Research, Inc. This sample included a cross section of fifty-six origin ports and sixty-five individual destination ports. The variables rate per long ton (Rate), size of shipment (Size), form of cargo (Bagged), charter party terms (Terms), and the associated names of the individual origin and destination ports were listed in Chartering Annual. The individual port features of depth alongside the cargo pier at origin port (DPORIG), depth alongside pier at the destination port (DPIER), and depth of approach channel at destination port (DPCHAN) were found in Ports Of The World 1981, published by Benn Publications, Limited. The distances bewteen ports was calculated from the material in Publication 151 of the U.S. Defense Mapping Agency, Distances Between Ports.

The values of three variables were collected from a 1980 publication of the International Wheat Council, Problems In Grain Handling And Transportation. The variables were grain storage capacity (STORE), average grain imports over the years '74-'78 (IMPORT), and an indicator variable measuring the adequacy of a country's domestic grain transportation and storage system (TRANS).

The information for the indicator variables which categorize a destination country into one of five per capita income levels for the year 1978, along with its average annual real growth rate gnp/capita for '70-'78, and whether it is a member of the Organization of Petroleum Exporting countries (OPEC) was acquired from a World Bank Publication Annual Report.

The full model specification is:

$$\begin{aligned} RATE = {} & B_1 + B_2 DIST + B_3 DIST2 + B_4 BAGGED + B_5 TERMS \\ & + B_6 SIZE + B_7 DPORIG + B_8 DPIER + B_9 DPCHAN \\ & + B_{10} OPEC + B_{11} IMPORT + B_{12} STORE + B_{13} Y1 \\ & + B_{14} Y2 + B_{15} Y3 + B_{16} Y4 + B_{17} GROW + B_{17} TRANS \\ & + E \end{aligned}$$

VARIABLE NAME	DESCRIPTION
RATE	= U.S. dollars per long ton (2,240 lbs.)
DIST	= Distance between origin and distination ports - nautical miles
DIST2	= Squared distance between origin and destination ports - nautical miles
BAGGED	= Indicator variable = 1 if grain is bagged = 0 otherwise

VARIABLE NAME	DESCRIPTION
TERMS	= Indicator variable = 1 if charter terms are FIO = 0 otherwise
SIZE	= Volume of shipment - long tons
DPORIG	= Depth alongside cargo pier at origin port-meters
DPIER	= Depth alongside cargo pier at destination port - meters
STORE	= Grain storage capacity in country of destination port - thousand tons
IMPORT	= '74-78 average import of grains by destination country - thousand tons
GROW	= average annual real growth rate (gnp/capita) '70-'78
TRANS	= Indicator variable = 1 if grain storage and transportation facilities at destination country is adequate = 0 otherwise
Y1	= Indicator variable = 1 if destination country '78 per capita income is less than 300 = 0 otherwise
Y2	= Indicator variable = 1 if destination country '78 per capita income is between $300 and $699 = 0 otherwise
Y3	= Indicator variable = 1 if destination country '78 per capita income is between $700 - $2,999
Y4	= Indicator variable = 1 if destination country '78 per capita income is between $3000 - $6999.
OPEC	= Indicator variable = 1 if destination country is a member of OPEC

The procedure used in estimating the effects on ocean freight rates of the above hypothesized determinants was OLS. The assumptions underlying this multiple regression model are as follows (Pindyck and Rubinfeld, p. 76):

i. The model specification is

$$Y_i = B_1 + B_2X_{2i} + B_3X_{3i} + \text{---} + B_kX_{ki} + e_i$$

where Y = the dependent variable,

B's = The regression coefficient associated with variables 2-K,

X's = independent or explanatory variables,

e = error term.

X_{2i} represents, as an example, the i^{th} observation on explanatory variable X_2 . B_1 is the intercept of the equation.

ii. The X's are nonstochastic and no exact linear relationship exists between two or more of the independent variables.

iii. a. The error term has 0 expected value and constant variance for all observations.

b. Errors corresponding to different observations are uncorrelated.

c. The error variable is normally distributed.

EQUATION I

$$\begin{aligned} \text{RATE} = {} & B_1 + B_2\text{DIST} + B_3\text{DIST2} + B_4\text{BAGGED} + B_5\text{TERMS} \\ & + B_6\text{SIZE} + B_7\text{DPORIG} + B_8\text{DPIER} + B_9\text{DPCHAN} \\ & + B_{10}\text{OPEC} + \text{E} \end{aligned}$$

Equation I was fit to the sample data with the following results.

RIGHT-HAND VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC
DIST	.879367E-02	.12976E-02	6.77502
DIST2	-.469165E-06	.133010E-06	-3.52728
BAGGED	12.5396	2.29768	5.45753
TERMS	-2.49914	2.03712	-1.22680
SIZE	-.499163E-03	.830304E-04	-6.01181
DPORIG	-.871167	.255382	-3.41123
DPIER	-.191480	.235533	-.812965
DPCHAN	-.570283	.181033	-3.15016
OPEC	1.52225	2.13969	.711432
CONSTANT	35.4716	5.263	6.73981

$\bar{R}^2$ = .71 F-STATISTIC (9., 154.) = 47.04

OBSERVATIONS = 164 DURBIN-WATSON STATISTIC = 1.9461

The adjusted R^2, $\bar{R}^2$, measures how much of the variation in freight rates is explained by the variables in the model. Given the cross-section nature of the sample, this model is very satisfactory in that it explains over seventy percent of the variation in ocean freight rates. This represents an improvement of twenty-two percent over the results obtained by Binkley and Harrer (1981). The F statistic is used to test the hypothesis that all of the variables in the model do not explain the variation in rates. Since the observed F is quite larger than the theoretical value for F with 9 degrees of freedom (df) in the numerator and 154 df in the denominator, this hypothesis is rejected.

Test for Multicollinearity

Multicollinearity in a regression model indicates that a linear relationship exists between some of the independent variables. A high degree of multicollinearity can be harmful because it causes the variance of the least squares estimators of the regression coefficients to be large. Large variances make the acceptance region for the null hypothesis that the coefficients are zero too large and the power of the test weak (Kmenta).

Possible multicollinearity exists in various parts of the model. Depth of the approach channel may be related to the depth alongside the cargo piers. Size of cargo (as a proxy for size of ship) may, and hopefully is, related to the other variables since larger ships often go longer distances and require deeper water at ports.

A Farrar-Glauber test for multicollinearity was conducted. This is a series of three tests:

a) A Chi-Square test for the detection of the existence and the severity of multicollinearity.

b) An F test for locating which variables are multicollinear.

c) A t test for determining the pattern of multicollinearity. (Koutsoyiannis, pg. 242).

The results of this test indicated that BAGGED and OPEC variables were highly collinear. Since the estimate for the regression parameter for OPEC was not significantly different from zero at a five percent level, while the regression coefficient for Bagged was significantly different from zero, the variable OPEC was dropped from the model.

Test for Heteroscedasticity

The problem of heteroscedasticity in a model reduces the efficiency of the estimates of the regression coefficients. In addition, the problem of nonconstant error variances will lead to biased estimates of the variances of the estimated parameters so the statistical tests will not be accurate. Cross-sectional data, such as in this sample, is most prone to this type of error where the variance of the error term is different for different classes of observations.

One method of discovering this problem is to observe a graph which plots the residuals $(\hat{Y}_i - Y_i)$ against each independent variable to determine if the variance of the residuals vary with different values. This effect was seen in the plot of residuals vs. SIZE. This seemed to make sense as shipping rates are more volatile for small shipments than for larger ones.

This problem was corrected using a technique recommended by Pindyck and Rubinfeld (pg. 145). The relationship between the regression error variance and SIZE is assumed to be:

$$\text{Var}\ (\Sigma_i) = \frac{K}{\text{size2}}$$

The regression equation was transformed by weighting each variable by the reciprical of SIZE so as to make the regression equation homoscedastic, where:

$$\text{Var}\ (e_i) = \text{Var}\ (\text{size}\,\Sigma_i) = (\text{size})^2\ \frac{K}{\text{size2}} = K$$

Test for Autoregression

Statistical cost functions based on cross sectional data are not prone to problems of autocorrelation. However, this statistical problem was tested since if autocorrelation did exist, it would be due to the sequence in which the data was ordered and a reordering of the observations would become necessary.

When errors from different observations are correlated with each other the least squares estimators are still unbiased and consistent but they are not efficient. The estimates of the standard errors will be smaller than the true values so the standard error of the regression will be biased downwards. Thus, the R^2 of the regression equation will be unduly optimistic in its interpretation as an indicator of the goodness of fit of the model.

The Durbin-Watson test is used to determine the presence of autocorrelation and involves a test statistic based on the residuals calculated from the sample.

$$d = \frac{\sum_{i=2}^{n} (e_i - e_{i-1})^2}{\sum_{i=1}^{n} e_i^2}$$

The null hypothesis is that the error terms are not correlated. If the alternative hypothesis is that they are positively correlated, the decision rules are:

a) reject if $d < d_L$

b) do not reject if $d > d_u$

c) inconclusive if $d_L < d < d_u$

The D-W statistic for equation I is 1.9. The five percent upper significance point for one hundred observations and five variables is 1.78 (Kmenta pg. 625). Although this sample included more variables and observations than offered in the table the test result is at best pointing to not rejecting the null hypothesis of uncorrelated error terms and at worse the test would be inconclusive. It was decided that no corrections were necessary for autocorrelation.

Equation I was fitted to the sample data after corrections were made for multicollinearity and heteroscedasticity. The results were similar to the original model and are listed below.

RIGHT-HAND VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC
DIST	.779257E-03	.12591E-02	6.18858
DIST2	-.350375E-06	.125175E-06	-2.79907
BAGGED	14.1855	2.17740	6.51488
TERMS	-1.23801	1.91936	-.645012
SIZE	-.441687E-03	.654033E-04	-6.75329
DPORIG	-.793826	.224213	-3.54050
DPIER	-.182593	.204291	-.893792
DPCHAN	-.544581	.181039	-3.00809
CONSTANT	33.5794	5.26334	6.37986

$\bar{R}^2$ = .725　　F-STATISTIC (8., 155.) = 54.98

OBSERVATIONS = 164　　DURBIN-WATSON STATISTIC = 1.93

A plot of the residual variances against the independent variable SIZE showed no evidence of heteroscedasticity.

Some data are available on other variables and their significance was tested by using the following form:

EQUATION II

$$RATE = B_1 + B_2DIST + \text{------} + B_{10}OPEC + B_{11}IMPORT + E$$

All the variables that were significant in equation I were also significant (5% level) in this form of the model. The added variable, IMPORT, was not significant at the 5% level. The summary statistics were:

RIGHT-HAND VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC
IMPORT	-.221456E-03	.380123E-03	-.582591

R^2 = .81 F-STATISTIC = 50.06

(9., 94.)

OBSERVATIONS = 104 DURBIN-WATSON = 1.27

EQUATION III

$$RATE = B_1 + B_2DIST + \text{---} + B_{10}OPEC + B_{11}STORE + B_{12}Yi$$
$$+ B_{13}Y_2 + B_{14}Y3 + B_{15}Y4 + B_{16}GROW + B_{17}TRANS + E.$$

RIGHT-HAND VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC
DIST	.849847E-02	.155314E-02	5.47181
DIST2	-.315707E-06	.165247E-06	-1.91052
SIZE	-.603864E-03	.895403E-04	-6.74405
BAGGED	10.4398	2.55550	4.08524
TERMS	5.56986	2.75495	2.02176
DPORIG	-1.29496	.303361	-4.26871

RIGHT-HAND VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC
DPIER	-.207649	.205710	-.702203
DPCHAN	-.446215	.233530	-1.91074
OPEC	4.89102	3.29055	1.48638
STORE	-.517334E-04	.156596E-03	-.330362
Y1	-1.42583	8.32199	-.171333
Y2	-.269299	4.52310	-.5953E-01
Y3	-.846421	4.29344	-.197143
Y4	-.694152	2.98011	-.232928
GROW	-.308021	.502025	-.613557
TRANS	-.907945	2.28566	-.397235
C	32.9391	7.24338	4.54748

R^2 = .79 F-STATISTIC = 29.2

OBSERVATIONS = 121 DURBIN-WATSON = 1.5

None of the new variables that made up equations II or III were significant in explaining the variation in ocean freight rates for grains. Equation I is retained as the model to be used in reaching conclusions as to the results of this research since it is fitted to more observations relevant to the significant variables than either equation II or III.

Interpretation

DISTANCE

The results of this research show that distance has a positive influence on rates up to a point and then declines. Both the distance variable and the distance squared variable were significant at the one percent level, but with opposite signs. This supports the theory that ocean freight rates increase with distance but at a decreasing rate. This functional form of the effect of freight rates on distance is consistent with Binkley and Harrar (1981) and Clement (1982). This model shows that rates increase by $7.79 for the first 1000 miles (7.7925 - .00035). This compares with $6.29 for grain hauled from the Lower Columbia River during '78-'80 (Clement).

Clement found that the "portion of ocean freight rates ... attributable to distance reaches its maximum at 11,743 miles, approximately halfway around the world". When the coefficients of this model are used in his formula the result is quite similar

$$= .00779 - 2\ (.00000035) \qquad \begin{array}{l} \text{Dist} = 0 \\ \text{Dist} = 11{,}129 \end{array}$$

These results are contrary to those reached by Olson (1983). After correcting for heteroscedasticity the distance squared term in that model was not significant. Olson speculated that it was the correction for heteroscedasticity that prompted the linear relationship of distance to rate, rather than the quadratic one. However, this study has been corrected for statistical problems and the distance squared term is significant at the one percent level in agreement with Binkley and Harrer.

BAGGED

Grain shipments that are in bagged form are destined for ports that do not have more modern bulk cargo unloading facilities. This variable was highly significant and the coefficient was positive, indicating that, on average, grain that is bagged will experience an increase of approximately $14.19 per long ton. This represents forty percent of the mean value of the freight rate found in this sample. The variable BAGGED was highly correlated with shipments to OPEC countries indicating that in this sample those countries experienced higher average rates for grain than countries elsewhere. The positive influence on rates of bagged cargo reflect increased handling charges as a result of inadequate port facilities. Investment in port improvements that avoid this charge may result in significantly reduced ocean freight rates.

TERMS

The charter party terms reflect who pays for the loading or unloading of the cargo. In the shipment of grain, three arrangements are most common:

a) FREE IN AND OUT (FIO) - The party who charters the voyage pays both loading and unloading.

b) FREE DISCHARGE (FD) - The charter pays for the unloading and the shipowner is responsible for the loading.

c) GROSS or BERTH TERMS - The shipowner pays for both the loading and the unloading.

The data in this sample included only FIO or FD terms so the indicator variable is associated with a coefficient that reflected a difference in freight rates depending on who pays for the loading. The coefficient for this variable is not significantly different from zero.

Binkley and Harrer and Olson found this variable to be significant but Clement's results were similar to those found here. Clement argues that the presence of multicollinearity may have obscured the importance of charter terms in his data. In this data, however, the number of voyage charters under the terms of free discharge represented less than ten percent of the sample and this low representation may be the cause of its lack of significance. Binkley and Harrer found that the increase in rates associated with loading was $2 ton.

SIZE

Ceteris paribis, ocean freight rates for grain will be reduced $.44/ton for each additional thousand tons of cargo. This result is consistent with other studies showing economies of scale in ocean shipping of grain. Clement found that rates declined by $.36/ton for each additional thousand tons shipped from ports out of the Lower Columbia River. Binkley and Harrer also found scale economies of similar size up to 50,000 tons, and scale diseconomies beyond that, reflecting, perhaps, increased port costs of larger ships. The largest shipment in the sample in the present study is 50,000 tons.

DPORIG - DPIER - DPCHAN

These three variables were included in the model to measure the effect on ocean freight rates for grain of the depth alongside the cargo pier at the origin port (DPORIG), the destination port (DPIER) and the depth of the approach channel of the destination port (DPCHAN). Two of the variables were significant at the one percent level (DPORIG and DPCHAN) and one of the variables was not significant (DPIER).

Ports that are deeper alongside their piers and in their approach channels allow larger vessels to serve the port. The results of this research has agreed with others (Binkley and Harrer, Clement, etc.) in finding that shipments of larger size experience economies of scale. Ports can be serviced by these larger ships carrying the large cargo only if their physical characteristics can accommodate the larger vessels. Past research has not found significant relationships between lowered rates and increased depth of ports. Binkley and Harrer did not test for this relationship since their ports were aggregated into sixteen origin and thirty-four destination regions. Clement's test for any significance of destination port's depth was found to be insignificant but he explains that his model of port specific ocean freight rates does not provide an adequate test of this relationship since the depth of the one origin port controls the size economies in shipping.

Olson tested specifically for a relationship between draft limitations at both origin and destination ports and freight rates and found them to be insignificant. The data collected in the study represented the actual depth of the individual ports, as reported in Ports Of The World, 1980, except in charters where a geographical area was indicated as an origin/destination port. In those cases a weighted average of the grain handling ports included in the area was used (pg. 67). It was not reported how many observations were assigned the weighted data and how many others the actual data, but a count of the grain voyage charters in any issue of the Chartering Annual indicates that the majority of charters report regions rather than individual ports. This may be the reason the variables were found to be insignificant.

On average, for each meter of draft at the origin port the rate per ton declines by $.79 and for each meter of the approach channel at the destination port the average rate declines by $.54. The insignificance of the coefficient for DPIER was unexpected but may be explained by the practice of lightering. Ports of shallow draft may still service larger ships who anchor away from the port and unload their cargo into smaller, more shallow draft vessels, which then transport it to the cargo pier. This method would work well for bagged grain shipments. The additional costs associated with lightering would not be reflected in the freight rate unless the charter terms were gross or berth rates where the shipowner pays for the unloading. No gross or berth rates were represented as charter terms in the data for this study.

STORAGE AND TRANSPORTATION

As mentioned previously, one factor which may reduce economies of scale in the ocean transportation of grain is "at port" diseconomies. These may take the form of delays in unloading due to bottlenecks in storing and transporting large amounts of grain. In a 1980 study on the problems of the grain trade, a special committee of the

International Wheat Council found that "the principal problems in importing countries usually stem from limited facilities to load road or rail vehicles at the ports, and insufficient storage capacity, particularly at mills on inland collection points" (Problems In Grain Handling And Transportation, p. 5).

To test the effect that storage and transportation facilities have on ocean freight rates for grain, two independent variables were examined. The first is the amount of storage capacity available at port areas and inland storage points. The second is an indicator variable measuring the adequacy of the importing country's storage and transportation system for grain based on replies to a 1979 questionnaire sent to members of the International Wheat Council.

Neither of the two variables were significant in explaining the variation of freight rates for grain. Perhaps this is due to the accuracy of the data in the voluntary questionnaire. Further research is warranted in this area.

IMPORTS

The volume of imports to a country was thought to have some influence on rates since port facilities may expand and be upgraded in response to increased activity.

The variable IMPORT, measuring a five year average of grain imports to the destination port's country was the correct sign but not statistically significant. Olson found that the amount of grain imported by a country explained one percent of the variation in ocean freight rates for grain (pg. 112).

PER CAPITA INCOME AND GROWTH RATE

The independent variables measuring a destination country's per capita income and rate of growth were included to determine if the relative wealth of a country or its rate of development were manifested in lower ocean freight rates. However, these variables were all statistically insignificant in explaining the variation in ocean freight rates for grain.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this thesis is to determine the impact on international ocean freight rates for grains of certain port facility characteristics. A worldwide sample is selected of 164 voyage charters, in 1980, hauling grain between fifty-six individual origin ports and sixty-five individual destination ports. A weighted form of ordinary least squares analysis is used to statistically measure the extent to which certain port facility characteristics explain the variation in ocean freight rates for grain.

After correcting for statistical problems of multi-collinearity and heteroscedasticity, the results of the regression were encouraging. The factors of distance, shipment size, and form of cargo were found to be significant and of the same sign and similiar functional form and magnitude to prior research (Clement, 1982) (Binkley and Harrer, 1981). This feature, in addition to the relatively high explanatory power of the model (73%), lends confidence to the results. The factors describing the port infrastructure characteristics of channel and port drafts were all of the correct sign and, except for one, highly significant. A review of the literature in this area did not reveal any other instance where these port characteristics were found to be significant in explaining the variation in ocean freight rates for grains.

The regression results indicate that distance has a positive influence on rates up to a point and then declines. This is demonstrated by the quadratic form of the distance variable which was significant in explaining rate variation. This result is similiar to Clement's finding that a maximum is reached at a distance of half-way around the world, approximately 11,000 miles. The meaning of this finding is unclear, however, as there were no observations of voyage charters in this sample which exceeded 9500 miles.

The model estimated that rates increase by $7.79 per ton for the first one thousand miles. This is somewhat higher than Clement's results of $6.29 for grain hauled from the Lower Columbia River during '78-'80.

This functional form is consistent with Binkley and Harrer (1981) and Clement (1982) and supports the theory that ocean freight rates increase with distance but at a decreasing rate. This may be due to the effect of the relatively larger "at sea" economies vis a vis "at port" diseconomies experienced by large bulk carriers.

If the size of shipment may be accepted as a proxy for ship size, then the theory of "at sea" economies is supported by the regression result that rates are reduced by $.44/ton for each additional thousand tons of cargo. Beyond 50,000 tons, Binkley and Harrer found scale diseconomies. The largest shipment in the sample of the present study is 50,000 tons.

Grain that is in bagged form is associated, on average, with higher rates than grain not in bagged form. This increase is $14.19/ton or forty percent of the mean rate in this sample. This charge reflects higher costs in loading the bagged grain at the export market as well as "in port" diseconomies (increased ship turnaround time) at the destination port.

Two other port characteristics were significant at the one percent level. On average, for each meter of draft at the origin port the rate per ton declines by $.79 and for each meter of draft at the approach channel at the destination port the average rate declines by $.54/ton, *ceteris paribus*. The range of observations which provided these relationships between freight rates and draft limitations were for vessels carrying a minimum of eleven hundred tons and maximum of fifty thousand tons.

The results listed above should provide some empirical support to those policy-makers and other interested parties who have asserted that investments in port facilities may generate lower freight rates. Development plans which modernize grain offloading facilities to eliminate the need for bagging prior to shipment and dredging operations in the approach channel and alongside cargo piers do explain significant reductions in ocean transportation rates for grain.

These results may have important implications for the future of U.S. grain exports. There is a growing dependence of LDC's on importation of grain from the U.S. LDC's have increased their importation of grains from the U.S. from 41.3% of total grain imports in 1956-60 to 50.3% in 1971-75 (Schmidt, Guither, and Mackie, pg 89). The exporting of grain to LDC's with poorly developed ports have higher transportation charges which may present a barrier to trade. As shown in chapter one, the volume of U.S. grain exports may suffer as a result of those higher charges.

While improvements in the port infrastructure are associated with lower rates, it is also important to recognize the impact of developing a port's superstructure and domestic transportation and grain storage system. It was earlier noted the advise of the Deputy General Manager, Port of Antwerp, that the key to port productivity is the "holistic" approach which integrates the development of the ocean shipping system, cargo dock-handling and transportation of the goods to the interior.

Opportunities for future research exist in collecting accurate data on the storage and transportation facilities located at import markets, and evaluating their impact on rates. While the variables examined in this model were not statistically significant in explaining rate variations, the accuracy of the data collected via voluntary questionnaire, sent out by the International Wheat Council, was not verified and may have caused this result.

The largest shipment in this sample is 50,000 tons and it would be interesting to know if larger shipments experience the same effects on rates of the port characteristics tested in this model.

Future research should also be directed at quantifying the impact on future U.S. grain exports of inadequate ports. The benefits of efficient grain import ports may accrue backward to U.S. producers in the form of higher export prices and volume. By measuring the impact on rates of U.S. financed port and transportation development to U.S. customers of grain exports, guidelines may be developed on prioritizing U.S. assistance.

BIBLIOGRAPHY

Abrahamsson, Bernhard J. 1980. International Ocean Shipping. Westview Press, Inc., Boulder, Colorado.

Bennathan, E. and A. A. Walters. 1969. The Economics of Ocean Freight Rates. Praeger Publishers, New York.

Binkley, J.K. and B. Harrer. 1981. "Major Determinants of Ocean Freight Rates For Grains: An Econometric Analysis." American Journal of Agricultural Economics 63(1):47-57.

Bryan, I.A. 1974. "Regression Analysis of Ocean Liner Freight Rates On Some Canadian Export Routes." Journal of Transport Economics and Policy.

Button, K.J. 1979. "The Economics of Port Pricing." Maritime Policy and Management, Vol. 6, No. 3:201-207.

Clement, David. 1982. "An Economic Analysis of Ocean Freight Rates For Lower Columbia River Grain Exports." Unpublished M.S. Thesis, Department of Agricultural and Resource Economics, Oregon State University.

de Borger, B. and W. Nonneman. 1981. "Statistical Cost Functions for Dry Bulk Carriers." Journal of Transport Economics and Policy (May).

Frankel, A. 1983. "Shipping - Choice of Technology." Journal of Maritime Policy and Management, Vol. 10, No. 1:1-15.

Futrell, Gene A. 1982. Marketing For Farmers. Doane-Western, Inc., St. Louis, Missouri.

Goss, R.O. 1967. "The Turn-Round of Cargo Liners and Its Effect Upon Sea-Transport Costs." Journal of Transport Economics and Policy (January).

Goss, R.O. and C.D. Jones. 1977. "The Economics of Size in Dry Bulk Carriers." Advances in Maritime Economics, R.O. Goss ed. Cambridge University Press, New York.

Heaver, T.D. 1968. The Economics of Vessell Size: A Study of Shipping Costs and the Implications for Port Investments. National Harbours Board. Ottawa, Canada.

Heaver, T.D. and Keith R. Studer. 1972. "Ship Size and Turnaround Time. Some Empirical Evidence." Journal of Transport Economics and Policy.

Heggie, Ian. 1974. "Charging for Port Facilities." Journal of Transport Economics and Policy.

International Wheat Council. 1980. Problems in Grain Handling and Transportation. London.

Jansson, J.O. and D. Shneerson. 1982. "The Optimal Ship Size." Journal of Transport Economics and Policy. May.

Jones, B.F. and R.L. Thompson. 1978. "Interrelationships of Domestic Agricultural Policies and Trade Policies." Speaking of Trade: Its Effect on Agriculture. Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota.

Kendall, P.M.H. 1972. "A Theory of Optimum Ship Size." Journal of Transport Economics and Policy 6:128-46.

Kmenta, J. 1971. Elements of Econometrics. Macmillan Publishing Company, Inc., New York.

Koutsoyiannis, A. 1983. Modern Microeconomics. 2nd edition. St. Martin's Press, Inc., New York.

Maritime Research, Incorporated. 1980. Chartering Annual. Maritime Research, Incorporated, New York.

McCalla, R.J. 1979. "Specialization and Economic Impact of the Ports of Montreal, Quebec, Saint John, and Halifax." Maritime Policy and Management, Vol. 6, No. 4:285-92.

Mills, G. 1971. "Investment Planning for British Ports." Journal of Transport Economics and Policy.

Neter, J., W. Wasserman, and M.H. Kutner. 1983. Applied Linear Regression Models. Richard D. Irwin, Inc., Homewood, Illinois.

Olson, K.R. 1983. "Determinants of Ocean Freight Rates For Grains." Unpublished M.S. Thesis, Department of Economics and Business, North Carolina State University, Raleigh, N.C.

Organization for Economic Co-operation and Development. 1968. Ocean Freight Rates As Part of Total Transport Costs. Paris.

Organization for Economic Co-operation and Development. 1980. Maritime Transport. Paris.

Pindyck, R.S. and D. L. Rubinfeld. 1981. Econometric Models and Economic Forecasts. McGraw-Hill. New York.

Ports of the World. 1981. Benn Publications, Limited, London.

Robinson, Ross. 1978. "Size of Vessels and Turnaround Time. Further Evidence From the Port of Hong Kong." Journal of Transport Economics and Policy.

Samuelson, P.A. 1952. "Spatial Price Equilibrium and Linear Programming." American Economic Review (42):283-303.

Schmidt, Stephen C., Harold D. Guither, and Arthur B. Mackie. 1978. "Quantitative Dimensions of Agricultural Trade." Speaking of Trade: Its Effect on Agriculture. Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota.

Shneerson, D. 1983. "Short Term Planning for a Ports System." Maritime Policy and Management. Vol. 10, No. 4:217-250.

Thomas, B.J. 1978. "Port Charging Practices." Maritime Policy and Management (5):117-32.

U.S. Defense Mapping Agency, Hydrographic Center. 1976. Distances Between Ports. Washington, D.C.

U.S. Department of Commerce, Maritime Administration. 1980. National Port Assessment 1980/90. Washington, D.C.

WanHill, S.R.C. 1978. "On the Cost-Benefit Analysis of Port Projects." Maritime Policy and Management (5):315-26.

Weille, J. and R. Anandarup. 1974. "The Optimum Port Capacity." Journal of Transport Economics and Policy.

APPENDIX

LEGEND FOR DATA FILE

Column	
1- 4	Distance (autical miles)
6	Bagged cargo
8	Terms
10-14	Size of shipment
16-20	Rate
22-26	Depth alongside pier at origin port
28-32	Depth alonside pier at destination port
34-38	Depth of approach channel at destination port
40-44	Grain storage capacity
46	Per capita income less than $300
48	Per capita income between $300 and $699
50	Per capita income between $700 and $2,999
52	Per capita income between $3,000 and $6,999
54	Destination country is a member of OPEC
57-59	GNP/capita growth rate of '70-'78
61	Adequate transportation indicator variable
63-66	'74-'78 average import of grains

.PORTS

3154	0	1	20500	23.50	09.00	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
3000	0	0	13000	22.00	08.84	05.00	18.00	00000	0	0	1	0	0	2.1	0	0000
1311	0	1	21000	14.50	10.00	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
4024	1	1	10000	37.00	15.50	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
4286	1	1	12500	47.00	16.30	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
4696	1	0	13000	48.25	13.00	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
5803	1	0	23600	51.45	10.67	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
0844	0	1	20000	13.60	09.00	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
0597	0	1	15000	13.50	08.23	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
3000	1	1	05700	48.60	13.00	09.45	10.36	00340	0	0	0	1	1	4.9	1	0542
3310	0	1	09000	34.50	09.14	13.50	19.81	31000	0	0	0	0	0	2.3	0	3000
6799	0	1	12000	30.60	10.97	08.00	15.00	00000	0	0	0	0	0	0.0	0	0000
4080	0	0	14000	28.00	09.14	09.80	20.00	00000	0	0	0	1	0	6.6	0	0000
6544	0	1	12000	42.00	10.40	09.15	10.60	00000	0	0	1	0	1	7.7	0	0000
7441	0	0	21000	52.00	10.20	12.80	14.80	00000	1	0	0	0	0	-0.1	0	0000
8869	0	1	25000	36.25	15.00	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
8869	0	1	50000	35.50	15.00	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
0842	0	1	14500	13.25	08.30	06.10	10.67	00710	0	0	1	0	0	2.0	1	0364
6249	0	0	14000	33.50	12.80	09.14	09.14	05700	0	0	1	0	1	3.1	0	0000
2943	0	1	14500	29.00	09.14	12.00	15.00	00710	0	0	1	0	0	2.0	1	0364
7325	1	1	12000	50.00	07.92	09.50	08.00	00000	0	0	1	0	1	6.0	0	0000
3615	1	1	10000	36.50	15.01	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
1888	0	1	12800	28.50	12.20	07.31	09.14	00000	0	0	1	0	1	3.6	0	0000
9110	0	1	08500	43.00	09.00	07.31	08.31	00000	0	1	0	0	0	5.3	0	0000
0751	0	1	01100	11.50	10.40	09.00	27.40	14500	0	0	0	1	0	3.1	1	6500
0690	0	0	07700	23.50	12.80	09.45	10.06	00000	1	0	0	0	0	-5.5	0	0000
2082	0	1	15000	17.25	10.40	10.00	10.06	05700	0	0	0	1	0	2.0	0	0000
1144	0	1	10500	16.25	07.00	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
7167	0	0	25000	54.00	12.20	09.14	08.23	00000	0	0	0	1	1	0.0	0	0000
3771	0	1	25000	18.75	12.60	15.00	15.00	31000	0	0	0	0	0	2.3	0	3000
3468	0	1	45000	17.90	07.92	13.00	13.90	21000	0	0	0	1	0	1.9	0	7000
4927	0	1	20000	40.50	08.23	14.50	14.50	20000	0	0	0	0	0	3.1	0	0000
1761	0	1	15000	32.50	12.19	09.14	09.14	5700	0	0	1	0	1	3.1	0	0000
6664	0	0	16000	42.00	07.92	10.00	16.30	22000	0	0	0	0	0	2.4	0	0000
2603	0	1	45000	22.00	15.24	11.29	11.29	00000	0	0	0	1	0	4.8	0	0000
4183	0	1	24000	32.20	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
4183	0	1	26000	32.25	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
4777	0	0	16750	45.45	08.20	09.75	09.75	00000	0	1	0	0	0	-3.0	0	0000
6503	1	1	10500	46.50	16.75	14.00	15.00	00340	0	0	0	1	1	4.9	1	0542
3052	0	1	15000	24.00	10.40	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
2772	0	1	14000	24.50	15.01	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
3447	0	1	16000	26.50	11.70	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
4834	0	1	21000	34.50	10.00	06.00	13.00	14500	0	0	0	1	0	3.1	1	6500
6009	0	0	14000	46.00	07.92	09.00	12.50	20000	0	0	0	0	0	3.1	0	0000
6924	0	0	24000	33.00	12.80	15.20	07.50	20000	0	0	0	1	0	1.9	0	7000
4183	0	1	15000	43.33	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
4648	0	1	16000	47.50	08.23	09.50	10.00	31000	0	0	0	0	0	2.1	0	3000
5259	0	1	15000	50.00	08.23	11.00	11.00	00000	0	0	1	0	0	5.7	0	0000
7186	1	0	16073	79.75	10.67	10.67	11.28	00000	0	1	0	0	0	2.6	0	0000
1272	0	1	08500	18.25	10.40	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
1272	0	1	14250	17.50	10.40	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

4482	0	1	15000	36.00	10.00	10.00	15.00	00710	0	0	1	0	0	2.0	1	0364
4183	0	1	16000	40.63	08.23	16.76	11.66	31000	0	0	0	0	0	3.0	0	3000
7351	0	1	25000	48.00	12.20	10.06	08.53	00000	0	0	0	0	1	0.6	0	0000
3389	0	1	35000	17.50	12.20	15.20	07.50	20000	0	0	0	1	0	1.9	0	7000
6595	0	1	13000	60.00	10.00	10.21	15.00	01800	0	0	1	0	0	4.1	1	0324
6855	0	1	19500	37.00	06.40	10.00	16.30	22000	0	0	0	0	0	2.4	1	0000
1203	0	1	08400	18.00	13.00	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
1272	0	1	15000	18.25	10.40	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
3664	0	1	12000	43.00	08.23	08.80	13.00	00000	0	0	0	1	0	2.3	0	0000
4183	0	1	25000	30.45	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
7048	0	1	07821	46.60	15.01	09.75	9.75	00000	1	0	0	0	0	-5.5	0	0000
6248	1	1	10000	57.00	15.01	14.00	15.00	00340	0	0	0	1	1	4.9	1	0542
6248	1	1	12300	56.75	15.01	14.00	15.00	00340	0	0	0	1	1	4.9	1	0542
6248	1	1	11000	57.00	15.01	14.00	15.00	00340	0	0	0	1	1	4.9	1	0542
8040	1	0	07000	70.00	11.00	08.5	10.67	00000	0	0	0	1	0	1.6	0	0000
3841	0	1	25000	27.00	10.05	14.00	16.00	00000	0	0	0	0	0	0.0	0	0000
3652	0	1	25000	28.50	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
9410	0	1	10200	48.00	08.85	11.58	11.58	00000	0	1	0	0	0	3.7	0	0000
6509	1	1	09500	54.50	16.75	14.00	15.00	00340	0	0	0	1	1	4.9	1	0542
1230	0	1	07500	19.00	10.40	10.67	10.67	01100	0	1	0	0	0	3.9	1	1225
3052	0	1	15000	20.00	10.40	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
4024	1	1	08800	41.50	16.75	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
3052	0	1	20000	21.25	10.40	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
6248	1	1	09500	60.00	15.01	14.00	15.00	00340	0	0	0	1	1	4.9	1	0542
7100	0	0	30000	31.00	12.20	14.00	15.00	00340	0	0	0	1	1	4.9	1	0542
3200	0	1	31900	18.75	08.20	11.29	11.29	00000	0	0	0	1	0	4.8	0	0000
1205	0	1	15000	14.90	15.01	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
6248	1	1	12000	52.75	15.01	14.00	15.00	00340	0	0	0	1	1	4.9	1	0542
4442	0	1	10000	45.00	08.23	10.30	12.29	21000	0	0	0	1	0	1.9	0	7000
4183	0	1	23000	28.00	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
2813	0	1	14200	18.94	08.20	13.50	13.50	31000	0	0	0	0	0	3.0	0	3000
5030	0	1	41000	19.75	10.97	10.00	16.30	22000	0	0	0	0	0	2.4	0	0000
2116	0	0	01587	65.00	11.00	07.31	07.31	00000	0	0	1	0	0	1.7	0	0000
3091	0	1	15000	22.00	10.00	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
4024	1	1	11000	42.00	16.75	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
6248	1	1	09800	52.00	15.01	14.00	15.00	00340	0	0	0	1	1	4.9	1	0542
7351	0	0	25000	42.00	12.20	10.06	08.53	00000	0	0	0	0	1	.6	0	0000
2603	0	1	41000	17.75	15.24	11.29	11.29	00000	0	0	0	1	0	4.8	0	0000
4927	0	1	19500	38.00	08.23	14.50	14.50	20000	0	0	0	0	0	3.1	0	0000
3200	0	1	21500	21.00	08.20	11.29	11.29	00000	0	0	0	1	0	4.8	0	0000
4024	1	1	09500	42.00	16.75	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
3240	0	1	11430	24.00	16.75	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
1404	0	1	16000	16.00	10.70	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
3577	0	1	07000	25.00	10.40	08.50	11.00	00000	0	0	1	0	0	0.0	0	0000
1272	0	1	15000	15.50	10.40	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
1230	0	1	05000	18.75	10.40	10.67	10.67	01100	0	1	0	0	0	3.9	1	1225
5658	0	1	14200	42.78	10.67	09.76	18.29	00000	0	0	1	0	1	7.0	0	0000
6401	0	0	09000	34.25	07.92	13.50	19.81	31000	0	0	0	0	0	2.4	0	3000
4862	0	1	30500	27.25	08.20	11.58	11.58	00000	0	0	1	0	0	9.6	0	0000
6248	1	1	10000	51.75	15.01	14.00	15.00	00340	0	0	0	1	1	4.9	1	0542
6252	1	1	12000	57.92	10.70	12.80	14.80	00000	1	0	0	0	0	-0.1	0	0000
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

3488	0	1	14000	59.00	07.92	09.78	18.29	00000	0	0	1	0	1	7.0	0	0000
3662	0	1	25000	18.75	12.60	13.50	13.50	31000	0	0	0	0	0	3.0	0	3000
3615	1	1	10000	41.75	15.01	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
979	1	1	08000	30.00	09.75	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
7587	0	1	33000	30.35	12.20	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
3652	0	1	25000	27.00	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
5967	0	1	04750	63.75	07.92	10.50	10.50	00000	0	1	0	0	0	1.7	0	0000
3419	0	1	20700	20.00	16.76	11.58	11.58	00000	0	0	1	0	0	9.6	0	0000
4024	1	1	10000	40.00	16.76	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
3850	0	1	12500	37.00	07.92	12.20	11.70	21000	0	0	0	1	0	1.9	0	7000
3695	0	1	10000	44.00	08.23	08.53	06.40	00000	0	0	0	1	0	2.3	0	0000
7170	0	1	10000	69.00	07.92	06.40	09.14	00000	1	0	0	0	0	-2.2	0	0000
4088	0	1	19500	35.25	08.23	14.00	15.00	14500	0	0	0	1	0	3.1	1	6500
3355	0	1	22000	24.50	12.80	11.00	12.00	00000	0	0	1	0	0	0.0	0	0000
2992	0	1	07000	20.50	10.40	09.45	09.45	05700	0	0	0	1	0	2.0	0	0000
1272	0	1	14000	15.50	10.40	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
1272	0	1	05800	16.50	10.40	07.31	18.29	01100	0	1	0	0	0	3.9	1	1225
1230	0	1	07500	18.00	10.40	10.67	10.67	01100	0	1	0	0	0	3.9	1	1225
3052	0	1	13250	22.00	10.40	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
4088	0	1	20000	34.25	08.23	14.00	15.00	14500	0	0	0	1	0	3.1	1	6500
3743	0	1	22500	34.50	08.23	05.64	05.64	14500	0	0	0	1	0	3.1	1	6500
3703	0	1	33000	18.00	12.60	13.00	13.90	21000	0	0	0	1	0	1.9	0	7000
5252	0	1	08000	33.75	10.00	14.50	14.50	20000	0	0	0	0	0	3.1	0	0000
4289	0	1	17500	43.00	07.92	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
4183	0	1	24800	43.50	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
4289	0	1	13500	50.00	07.92	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
5033	0	1	26000	37.50	07.92	14.50	14.50	20000	0	0	0	0	0	3.1	0	0000
5033	0	1	22500	38.00	07.92	14.50	14.50	20000	0	0	0	0	0	3.1	0	0000
5963	0	1	15750	52.22	07.92	05.18	05.18	05700	0	0	0	1	0	2.0	0	0000
5049	0	1	33000	23.75	10.97	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
5062	0	1	-12600	29.25	07.00	11.89	11.90	20000	0	0	0	0	0	3.1	0	0000
3442	0	1	22500	24.00	12.80	11.58	11.58	00000	0	0	1	0	0	9.6	0	0000
0515	0	1	15000	10.25	11.89	10.00	10.00	05700	0	0	0	1	0	3.1	0	0000
2772	0	1	10250	24.15	15.01	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
6248	0	1	10000	58.00	15.01	14.00	15.00	00340	0	0	0	1	1	4.9	1	0542
4289	0	1	25000	32.50	07.92	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
4208	0	1	27000	34.00	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
4208	0	1	21000	32.50	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
3662	0	1	24000	21.50	12.60	13.50	13.50	31000	0	0	0	0	0	3.0	0	3000
6547	1	1	11465	65.00	12.19	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
3442	0	1	17500	24.00	12.80	11.58	11.58	00000	0	0	1	0	0	9.6	0	0000
9162	0	1	20000	38.50	16.76	06.55	08.23	00000	0	1	0	0	0	4.5	0	0000
3996	0	1	14000	57.50	08.23	10.00	15.00	00710	0	0	1	0	0	2.0	1	0364
4183	0	1	20000	35.00	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
6234	0	1	-15000	77.00	07.92	07.31	10.00	00000	0	0	0	1	0	5.7	0	0000
2755	0	1	-35000	20.50	08.20	13.00	13.90	21000	0	0	0	1	0	1.9	0	7000
3615	0	1	10000	42.50	15.01	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
4183	0	1	15500	54.50	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
5099	0	1	35000	24.10	11.58	10.70	13.50	31000	0	0	0	0	0	2.4	0	3000
3240	0	1	17000	24.00	16.76	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
3240	0	1	16000	24.00	16.76	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
7015	0	1	10000	24.00	[illegible]	08.45	08.45	05700	0	0	0	1	0	2.0	0	0000

[illegible]	0	1	10000	24.00	10.00	09.45	09.45	03700	0	0	0	1	0	2.0	0	0000
4183	0	1	25000	30.50	08.23	16.76	11.60	31000	0	0	0	0	0	3.0	0	3000
4027	1	1	05000	48.00	10.70	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
2982	1	1	12420	42.00	10.00	12.00	10.97	00600	0	1	0	0	0	6.3	0	3750
6503	1	1	10000	50.00	16.76	14.00	15.00	00340	0	0	0	1	1	4.9	1	0542
2353	0	1	05000	32.00	12.19	09.75	08.23	00000	0	0	1	0	0	5.6	0	0000
4024	1	1	10000	43.55	16.76	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
0979	1	1	10100	32.85	09.75	08.00	20.00	00340	0	0	0	1	1	4.9	1	0542
7351	0	0	25000	55.00	12.20	10.06	08.53	00000	0	0	0	0	1	0.6	0	0000
1158	0	1	18000	20.50	18.29	11.89	11.89	00000	0	0	1	0	0	1.3	0	0000
3355	0	1	22400	27.00	12.80	10.50	12.00	00000	0	0	1	0	0	0.0	0	0000

NCOUNTERED.