An Econometric Analysis of Ocean Freight Rates for Grain Shipments from the United States to Major Importing Countries

This article uses a cross-sectional econometric model to evaluate structural changes and price differentials in ocean freight rates for grain shipments from U.S. ports to various major importing countries. Cost factors included are distance and the ship size, and competitive factors are shipping seasons, shipping frequencies, multiple destinations, commodity types, and characteristics of origins and destinations. Results suggest cost factors play a significant role in determining ocean freight rates, and the ocean shipping industry charges different rates by season and commodity. This study also indicates that ocean freight rate structures have changed during the 1987-1998 period.

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INTRODUCTION

Ocean vessels are used for moving grain to off-shore markets and, consequently, the ocean freight rate is a major factor affecting the shipping patterns of grain from the United States to importing countries. The ocean freight industry differs from the U.S. domestic transportation industry. There are no competing modes of transportation in the ocean freight industry. However, shipping services are highly differentiated on the basis of the ownership of the vessel (Binkley and Harrer, 1981). As a result, the industry is competitive, but it is common for shipping companies to exercise differential pricing policies (Binkley and Harrer, 1981 and Jonnala, Fuller, and Bessler, 2002).

As a result of multilateral and bilateral trade negotiations and global economic growth in the last decade, the total trade volume of grain and oilseeds has increased substantially and the world grain industry remains highly competitive. During the last decade, in every crop year a substantial amount of grain has been shipped from the United States to various importing countries. Table 1 shows that 82.3 and 86 million tons of grain have been shipped from the United States in 1998/1999 and 1999/2000, respectively. As about half of the world grain trade is accounted for by the United States, the U.S. grain transportation industry has played a significant role in world shipments of grain. Grain is generally moved from producing regions to export ports by truck, rail, and barge in the United States and from ports to importing countries by ocean vessels. Because of inter- and intramodal competition among transportation modes, the U.S. domes-tic transportation system is highly competitive compared with those in other grain-exporting countries. Figure 1 shows the primary grain shipment patterns from farms in producing regions to export ports. Although the Upper Great Plains and the Corn Belt are located more than 1,000 miles from major U.S ports, the regions are competitive in the world market because of the efficient grain transportation system in the United States.

Table 1: Annual U.S. and World Grain Shipments (1,000 tons)

Crop Year	93/94	94/95	95/96	96/97	97/98	98/99	99/00
U.S.	72548	89701	99758	78687	73574	82349	86028
World	148223	160149	161702	169743	156530	162884	177622
Percentage US of World	48.9%	56.0%	61.7%	46.4%	47.0%	50.6%	48.4%

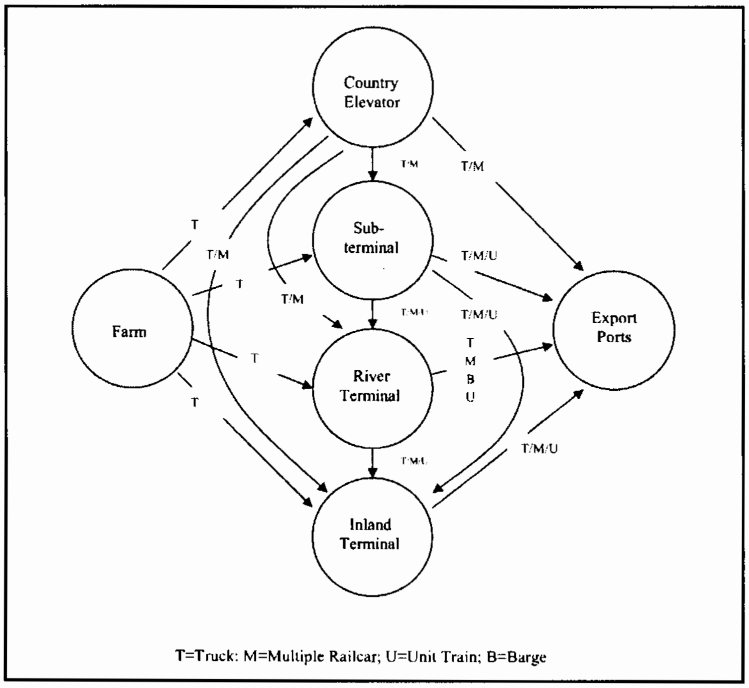
Source: Calculated from International Grain Council (2001), *World Grain Statistics 1999/00.*

Many factors, such as transportation costs, land, capital, and labor endowments affect trade flows of agricultural commodities from exporting countries to importing countries. However, transportation cost is the most significant factor in determining world trade flows of agricultural commodities (Koo, 1987). High ocean transportation rates between exporting and importing countries become a trade barrier, similar in effect to tariffs and institutional constraints (Finger and Yeats, 1976).

A few studies have addressed the structure of ocean freight rates for grain shipments. Some of these studies are Binkley and Harrer (1981); Dunn and Gianoulades (1985); Hsu and Goodwin (1995); Koo, Thompson, and Larson (1988); Jonnala, Fuller, and Bessler (2002); and Olson (1983). These studies focus on the factors affecting ocean freight rates for grain shipments. Some of these factors are shipment size, distance, origin and destination, registry of ships, and terms of the transaction (Binkley and Harrer, 1981). Dunn and Gianoulades (1985) included transport demand factors affected by the overall grain economy. Harris (1983) and Hsu and Goodwin (1995) considered cost factors such as fuel prices and utilization of ships. Koo, Thompson, and Larson (1988) examined the role of ocean freight rates in grain shipments from exporting countries to importing countries. Jonnala, Fuller, and Bessler (2002) demonstrated that voyage distance, ship size, contract terms, flag and season are important explainers of ocean rates.

Based on a review of the literature, no previous study has obtained an ocean price

Figure 1: Grain Logistics in the United States



differential based on the value of different grain types, and structural changes over time. The main objective of this study is to evaluate pricing differentials and structural changes in ocean freight rates for grain shipments from the United States to various major importing countries. This study empirically examines the major factors affecting ocean freight rates and pricing behaviors of the ocean freight industry. It also evaluates the effect of cost and competitive factors on ocean freight rates for grain shipments to examine structural changes. Cost factors influencing ocean freight rates include shipping distance and cargo size as a proxy for vessel size. Competitive factors include accessibility to U.S. domestic transportation modes, shipping seasons, commodity types, and characteristics of origin and destination ports. The study uses cross sectional data for 1987, 1991, 1995, and 1998 to estimate ocean freight rate functions in each year. Table 2 displays 1995 to 2000

Table 2: Annual Average Ocean Freight Rates for Heavy Grain from U.S. Origins to Major Destinations ($/metric ton) [a, b, c]

Origin and Destination	1995/96	1996/97	1997/98	1998/99	1999/00
From Great Lakes					
EU (Rotterdam/Amsterdam)[c]	33.56	-	-	24.25	-
From Atlantic Ocean					
EU (Rotterdam/Amsterdam)[c]	21.00	20.50	17.33	13.25	17.00
Italy (West Coast)	22.00	21.50	20.00	20.00	20.00
Spain (Mediterranean)	13.76	12.00	11.18	11.38	12.00
FSU (Black Sea)	38.25	21.23	16.00	16.00	16.00
Algeria	-	-	-	-	-
Egypt (Alexandria)	30.00	30.00	30.00	14.17	11.00
From Pacific Northwest					
China	26.90	27.00	27.00	27.00	27.00
India (West Coast)	24.90	24.38	25.50	25.50	25.50
Japan	15.79	12.91	11.81	10.22	12.87
Korea	14.94	12.11	12.42	12.25	13.92
Taiwan	15.45	11.98	10.97	9.03	13.03
Egypt (Alexandria)	29.97	30.00	30.00	30.00	18.75
From U.S. Gulf					
EU (Rotterdam/Amsterdam)[c]	12.82	11.02	9.61	9.42	12.42
Italy (West Coast)	23.76	23.00	17.50	14.00	18.08
Spain (Mediterranean)	15.13	12.44	10.71	8.22	11.60
FSU (Black Sea)	30.00	19.83	18.06	25.45	40.97
Mexico (East Coast)	17.79	10.00	8.69	8.96	11.40
Venezuela	21.19	-	-	11.00	11.42
Jordan	26.13	18.13	18.13	14.56	16.75
Bangladesh	50.48	60.20	60.20	31.55	22.00
China	28.74	22.06	21.03	14.39	20.02
India (West Coast)	34.20	33.00	33.00	33.00	-
Japan	28.15	22.60	20.15	14.38	21.05
Korea	27.71	22.62	22.75	14.99	15.75
Taiwan	26.67	22.06	19.75	13.65	20.11
Algeria	-	11.95	11.95	11.95	11.95
Egypt (Alexandria)	27.00	27.00	27.00	14.54	14.85
Morocco	24.01	15.63	14.29	13.85	19.07
South Africa	22.29	16.92	17.77	18.65	-
Sudan (Port Sudan)	41.58	-	-	-	-

Source: International Grain Council (2001), *World Grain Statistics 1999/00.*

[a]Calculated from estimated mid-month rates for vessels ready to load three to four weeks ahead. Various sizes of vessels. [b]Heavy grain are wheat, maize (corn), sorghum, and soybeans. [c]The rates for Amsterdam are 10 cents/ton higher; and to Hamburg are 25 cents/ton higher.

annual average ocean freight rates for grain from U.S. origins to major destinations.

CHARACTERISTICS OF THE OCEAN SHIPPING INDUSTRY

It is worthwhile to consider the characteristics of the ocean shipping industry and its pricing behavior before examining the main objective of the article. Tramp ship rates, including port fees, a daily operating rate, and demurrage, are set by negotiations between shippers and ship owners and fluctuate with changes in shipping demand and supply. Results of the Augmented Dickey-Fuller (ADF) stationarity tests indicate that freight rates on major ocean transport routes for grain from 1962 to 1995 are non-stationary, indicating that ocean freight rates for grain have fluctuated (Veenstra and Earalambides, 2001).[1] The freight rates for selected grain trade routes illustrate volatility of ocean freight rates (Table 3). The rates between the U.S. Gulf and Japan decreased much more than those from the U.S. Gulf to either Holland or the European continent in 1998.

The worldwide global recession and the financial crisis in Asian countries had a large negative impact on trading volume and ocean transportation demand. Many countries were forced to devalue their currencies, causing a dumping of various commodities at reduced rates for short-haul voyages. In addition, new vessels slightly outnumbered the scrapping of old vessels, causing an additional over-supply of tonnage (Maritime Research Inc. 1998).

There are virtually no restrictions on market entry and thousands of ships are available, owned by a large number of firms located all over the world. Negotiations for tramp ships are usually conducted by brokers working with worldwide communications. Charters are also arranged via personal, though not necessarily face-to-face, negotiations. Trading is accomplished at organized exchanges, such as the Baltic Shipping Exchange in London, or ship markets in New York and Tokyo.

In international ocean shipping, ship registry is another element of interest. A ship might be owned by anyone, serve any route, be registered in, and fly the flag of any nation. These nations are called flag of convenience countries. That is, the ship owners receive lower taxes, reduced manning costs, and some relaxed safety requirements by being registered in those countries with minimum restrictions rather than countries with more restrictive requirements. For instance, vessel-manning cost under United States registry is higher than elsewhere in the world ocean transportation industry because U.S. flag carriers must be manned by U.S. citizens (Helmick and Glaskowsky, 1994).

Cost Structure

The waterway used by ocean ships is furnished either by nature or by nature with improvements by various sources. Thus, ocean carriers are not responsible for a large investment needed to provide a way, the payment of a large fixed return on the investment, amortization or depreciation of the investment, large maintenance costs, and property taxes associated with ownership of the way. Ocean carriers have not been required to pay any charges for the use of the

Table 3: Freight Rates for Selected Grain Trade Routes During 1998

Origin-Destination	January	December	Increase/Decrease
U.S. Gulf – Holland	$10.25	$ 7.95	-$2.30
U.S. Gulf - Japan	$21.00	$12.65	-$8.35
U.S. Gulf – European Continent	$14.50	$12.00	-$2.50

Source: Maritime Research Inc. (1998), *Chartering Annual.*

way, with exception of tolls collected as user fees, and hence have little way expense. Ocean carriers pay certain taxes to the government of the nation issuing the flag of the carrier, but they are taxes that any business is expected to pay and are not unique to ocean carriers. At ocean ports there are loading and unloading costs and various service charges. In addition, there may be various charges for entering a harbor such as pilotage, demurrage, mooring, dockage, and harbor master fees.

In deep-water ocean transportation, large ocean-going vessels are used. Ships used in ocean transportation are provided by the carriers through ownership or leasing. Ships for dry bulk commodities are designed to handle the major bulk traffic, such as grain, iron ore, taconite pellets, and coal. When ocean carriers provide vessels through ownership, the investment in vehicles is their main investment. The costs associated with the vessels are both fixed and variable. The wear and tear on the vessels and the fuel and manning expense associated with operating vessels is considered to be variable cost because they are related to the period of operation and the volume of traffic carried. Some vessel costs, including interest on the investment in a vessel, maintenance cost not related to traffic carried, and amortization or depreciation expenses (those not related to use), are fixed costs. Leased vessels have fixed leasing costs for the period of the lease. However, fuel, labor, and maintenance expense associated with operating the vessels are variable costs.

In addition to the expenses associated with way, terminals, and vessels, ocean carriers pay the usual general expenses, including the expenses associated with operating and maintaining office space, salaries of managers, and other administrative people not directly involved in the operation or maintenance of vessels and terminals. These expenses are largely fixed and common.

Pricing

The ocean freight industry in general is less sensitive to excess capacity than the railroad industry because ocean carriers have no direct investment in waterways. Because of the lack of economic regulation in the ocean freight industry, ocean carrier rates fluctuate widely in response to competition, demand for transportation, and supply of vessels. In addition, ocean carriers must face the problem of unbalanced traffic, and low probability of backhaul shipments, which can cause overcapacity. Because a large proportion of ocean carrier systemwide costs are variable, ocean carriers find it is difficult to charge rates much below fully distributed costs for an extensive period.

In general, motivations for differential pricing are a large portion of fixed costs and substantial excess capacity. Ocean carriers have neither of these characteristics, but they carry a fairly wide variety of bulk commodities and serve large geographic areas with many routes between origin and destination points. Thus, ocean carriers have opportunities to differentiate freight rates among seasons, commodities, and routes.

Ocean carriers by nature do not have other competing modes (no intermodal competition), but they compete with each other (intramodal competition). They have an incentive for making profit by competing with other ocean transportation firms by engaging in differential (demand-based) pricing to penetrate markets where or when other firms have a competitive advantage. Where (or when) competition exists, ocean carriers may reduce rates below their average total cost while charging higher rates elsewhere (or at some other time). The loss, if any, suffered in the competitive pricing situation is recovered, in whole or in part, by engaging in differential pricing, whereby rates are set at levels which reflect conditions of demand for vessel size rather than conditions of supply. The practice of "charging what the traffic will bear" may result in differences in commodity rates; for example, wheat will be priced more highly than a low-valued commodity, such as corn, regardless of shipping costs. This is equivalent to Pigou's third-degree price discrimination. Second-degree price discrimination, on the other hand, is based on the volume of traffic (actual or guaranteed), season (peak vs. off-peak), and the regularity of shipments.[2]

SPECIFICATION OF THE MODEL

The ocean freight industry is competitive but freight rates are differentiated on the basis of differences in the operations of shipping companies. The tramp ship carrying grain is hired on a voyage or time basis. Grain exporters will seek a tramp ship that will become empty at a desired port or multiple desired ports and will hire it for one-way movement to a destination port or multiple destination ports. Tramp ship service is irregular with no established routes and operates in an intramodal competitive market environment. Therefore, tramp ship services differ from other transportation modes, such as regular route truck, air, barge, and liner services.

In a competitive market environment, the price of a commodity is determined by the demand and supply of the commodity. Similarly, equilibrium prices of ocean transportation services for grain are determined by demand and supply of ocean transportation services. The demand for ocean transportation service (Q_d) provided by a firm is defined as a function of the price of the service (p_1), prices of other ocean transportation firms' services ($p_2, p_3, \ldots$), and other variables affecting demand for the ocean transportation service (Z) as follows:

$$(1) \qquad Q_d = f_d(p_1, p_2, p_3, \ldots, Z)$$

The supply of ocean transportation service by a firm is defined as a function of the price of the service (p_1), prices of all ocean transportation firms' services ($p_2, p_3, \ldots$), cost factors, such as distance (D) and vessel size (or shipment size) (S), and other variables affecting cost of ocean transportation service (X) as follows:

$$(2) \qquad Q_s = f_s(p_1, p_2, p_3, \ldots, D, S, X)$$

Equilibrium price of ocean transportation service can be derived by combining Equations (1) and (2) under an equilibrium condition. The price equation for ocean transportation firm 1 is derived as follows:

$$(3) \qquad P_1 = f_1(p_2, p_3, \ldots, D, S, Z, X)$$

where all variables are previously defined.

Defining prices of other ocean transportation firms ($p_2, p_3, \ldots$) as intramodal competition, Equation (3) can be expressed as follows:

$$(4) \qquad P_1 = f_1(C, D, S, Z, X)$$

where C represents intramodal competition.

The empirical model for this study is developed on the basis of Equation (4). Independent variables, such as distance (D), ship size (S), shipping terms, and bunker fuel price were used in Binkley and Harrer (1981), Dunn and Gianoulades (1985), Hsu and Goodwin (1995), and Jonnala et al. (2002). Binkley and Harrer (1981) and Hsu and Goodwin (1995) used shipment volume and fuel price as a proxy for intramodal competition and as a cost factor, respectively. It is obvious that the cost of fuel is one of the major considerations in the operation of ocean vessels. According to the previous literature, there are mixed research results for the role of fuel price in ocean grain transportation. Dunn and Gianoulades (1985) found that bunker fuel price was insignificant and negatively corre-lated with freight rates, but Hsu and Goodwin (1995) concluded that ocean grain freight rates were found to be responsive to fuel prices.

This model does not include variables representing input costs in vessel operation, such as fuel cost and labor, mainly because the distance variable reflects cost components in cross sectional analysis. In this study, shipment frequency between origins and destinations is used as a proxy for intramodal competition. Shipment frequency is the quarterly number of shipments from the same origins to the same destinations.

In this study, we used ocean freight rates for grain from major ports in the United States to various major destinations as the dependent variable.[3] To select major grain shipment routes, those routes which have more than four shipments from a specific origin port to a specific destination port in each quarter were included. Independent variables are nautical distance between origin and destination ports, cargo size, and shipment frequency between origin and destination ports. The cargo size of grain shipped in each voyage serves as a proxy for ship size. It is hypothesized that ocean freight rates vary over seasons, grain types, cargo sizes, characteristics of shipping routes, and single/multiple destination(s). Thus, we included a set of dummy variables representing shipping seasons, grain types, characteristics of origins and destinations, and multiple destinations. The empirical model specifies ocean freight rates as

(5) $OFR = f(D, S, SF, V1, V2, V3, V4, V5, \varepsilon)$

where

D = distance in nautical miles between origin and destination ports

S = total cargo size for the shipment

SF = shipment frequency between origin port and destination port

V1 = a vector of dummy variables representing seasons

V2 = a vector of dummy variables representing grain types

V3 = a vector of dummy variables representing origin regions of ports

V4 = a vector of dummy variables representing destination regions of ports

V5 = a vector of dummy variables representing multiple destination ports

ε = the random error term

It is hypothesized that the ocean freight rate is positively related to distance and inversely related to the cargo size and frequency of shipments on a route. The cargo size ranges between 1,490 and 107,000 tons in this study. Shipment frequency between origin port and destination port is used as a proxy for intramodal competition because higher shipment frequency implies more competition on a route.

To identify seasons, grain types, origin regions, destination regions, and multiple destinations, various dummy variables are used. It is hypothesized that the ocean freight rate is positively related to the number of ports (destinations) that a vessel has to visit and unload grain. For identifying seasonality in the ocean shipping industry, the model employs seasonal dummy variables, SN1, SN2, SN3, and SN4 for first, second, third, and fourth quarters, respectively. Grain types included are barley, corn (maize), sorghum, bagged rice, and wheat, and dummy variables, G1, G2, G3, G4, and G5 are used to identify barley, corn, sorghum, bagged rice, and wheat. There is no priori expected sign for seasonal and commodity dummy variables.

There are five U.S. origin regions including Pacific Northwest (PNW) and West Coast (including Columbia River, Portland, San Francisco, and San Diego), U.S. Gulf (including Corpus Christi, Houston, Galveston, Lake Charles, and New Orleans), South Atlantic (including Tampa, Charleston, and Savannah), North Atlantic (including Albany, Baltimore, and Norfolk), and Great Lakes (including Chicago, Duluth, Toledo, and Milwaukee). Dummy variables, OR1, OR2, OR3, OR4, and OR5, are used to identify origin regions, PNW and West Coast, U.S. Gulf, South Atlantic, North Atlantic, and Great Lakes, respectively. Origin ports are charac-terized on the basis of grain handling facilities, modes of transportation available at in-dividual ports, and distances from major grain producing regions. The Gulf of Mexico ports handle more grain than any other ports, mainly because the Gulf ports can receive grain from railroads, trucks, and barges, have efficient handling facilities, and are located relatively closer to major grain producing regions than other ports. There is no a priori expected sign for the origin region dummy variables.

The model includes 174 destination ports in 70 countries divided into 13 regions and uses 13 dummy variables to identify destination regions. These regions and countries appear in Table 4. DR13 (South Asia) is the base. These destination ports are differentiated on the basis of distance from export ports and regional similarity.

Previous research suggests other variables such as shipping terms must be included in an analysis of determinants of ocean freight rates for grain. Binkley and Harrer (1981) and Jonnala et al. (2002) show the free-in-and-out (FIO) term yields the lowest rate since the charterer (shipper) is responsible for all port loading and unloading charges not the ocean carrier, while the free discharge (FD) term results in a higher rate than FIO because the ocean carrier (ship owner) is responsible for port loading charges under the FD term. The berth or gross term (BT) is found to yield the highest rate since the ocean carrier (ship owner) is responsible for all port loading and unloading charges.

However, in this study shipping terms are not included because origin and destination dummies can explain them. There are significant facility and shipping term differences among grain shipment routes. An examination of the raw data indicates that FD and FIO tend to be involved with major grain shipment routes, while BT tends to be involved with minor routes. For instance, all grain shipments from OR1 (PNW) to DR5 (Far East) in 1987, 1991, 1995, and 1998 have FIOs as their shipping terms.

DATA AND ESTIMATION PROCEDURE

The model is estimated using cross sectional data for 1987, 1991, 1995, and 1998. The

Table 4: Destination Regions and Countries

Destination Region	Geographical Area	Countries
DR1	Asia	China, Taiwan
DR2	East Africa	Ethiopia, Kenya, Mozambique, South Africa
DR3	West Asia	Bangladesh, Pakistan, Sri Lanka
DR4	Europe	Belgium, Bulgaria, Denmark, Finland, FSU(Former Soviet Union), France, Germany, Greece, Holland, Italy, Norway, Poland, Portugal, Romania, Spain, England, Yugoslavia
DR5	Far East	Korea, Japan, FSU(Former Soviet Union)*
DR6	Latin America	Belize, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Jamaica, Nicaragua, Trinidad, Venezuela
DR7	Middle East and North East Africa	Cyprus, Egypt, Iran, Jordan, Kuwait, Lebanon, Saudi Arabia, Sudan, Turkey, Yemen
DR8	North Africa	Algeria, Morocco, Tunisia
DR9	West Africa	Cameroon, Cape Verda, Guinea, Liberia, Nigeria, Republic of Zaire, Sierra Leon
DR10	North West America	Mexico (West Coast)
DR11	South East and South West America	Argentina, Brazil, Chile, Peru, Uruguay
DR12	North East America	Mexico (East Coast)
DR13	South Asia	India, Indonesia, Malaysia, Philippines, Thailand

*Petropavlovsk and Vladivostock of FSU are included in the Far East region.

years are selected at three- to four-year intervals to examine structural changes in the ocean freight rate for grain during the 1987-1998 period. A sample of grain shipments was obtained from the *Chartering Annual for Grain* published by Maritime Research Inc (MRI). The data set includes date of shipment, origin, destination, cargo size, commodity, terms, rate, and charter. The numbers of observations are 1,182, 578, 672, and 485 for 1987, 1991, 1995, and 1998, respectively. The data indicate that vessel size increased substantially over the period.

Origin ports were aggregated into five groups with 19 ports and destination ports were aggregated into 13 groups with 174 ports. The nautical mileage between origin and destination ports is calculated from a publication by National Imagery and Mapping Agency (1999). The nautical mileage in the Great Lakes is calculated by using *Distances Between Ports* published by the U.S. Naval Oceanographic Office (1964).

Two different functional forms of the model are considered to reflect the effects on ocean freight rates of distance, cargo size, intramodal competition, characteristics of origin and destination ports, value of commodities, and number of final destination ports. One is a linear model which includes variables in equation 5 as

(6) $OFR = b_1 + b_2D + b_3S + b_4SF + b_5V + \varepsilon$

where

D = distance between origin and destination ports

S = total cargo size for the shipment

SF = shipment frequency between origin and destination ports

V = vector of dummy variables

ε = the random error term

The other equation is in the double logarithm functional form as follows:

(7) $\ln OFR = b_1 + b_2\ln D + b_3\ln S + \varepsilon$
$b_4\ln SF + b_5V +$

To choose a functional form between equations 6 and 7, the P_E test was used.[4] The test rejects a null hypothesis of a linear function at the 5% significance level, indicating that the model is not linear. The test also rejects the null hypothesis of a double logarithm function at the 5% significant level, indicating the model is not a double logarithm functional form. However, a double logarithm functional form was chosen mainly because it performs better than a linear functional form in terms of R^2 and t statistics.

The White test was conducted to examine if the chosen model (Equation (7)) for individual years contains heteroscedasticity.[5] The values for the White test are 142.90, 121.84, 151.33, and 68.97 for 1987, 1991, 1995, and 1998, respectively, while the critical value is 11.1 at the 5% significance level. This indicates that there is heteroscedasticity for all four years. The generalized regression estimation, therefore, is used to estimate the model.

RESULTS

The models were estimated in a double logarithm functional form for 1987, 1991, 1995, and 1998. Table 5 reports the results of the models. R^2s range between 0.68 and 0.77, indicating that independent variables in the models explain variations of ocean freight rates in individual years. The estimated parameters are generally significant at the 10% level or greater, but the magnitudes and signs of the parameters are not consistent among the four models, depending upon quantities of grain shipped in a month of the year from the United States to various importing countries.

Distance and Cargo Size

The distance and cargo size variables are significantly different from zero at the 10% level or greater in the four equations. This implies that these two variables are major factors affecting ocean freight rates (Table 5). The sign of the distance variable is positive, indicating that shipping costs per metric ton from exporting ports to importing ports rise as distances between the two ports increase.

Table 5: The Estimated Ocean Freight Rate Results for 1987, 1991, 1995 and 1998[a]

Variable	1987	1991	1995	1998
Intercept	3.417(8.43)***	0.693(0.90)	4.819(9.72)***	1.770(1.85)*
Distance	0.278(6.78)***	0.568(7.38)***	0.423(10.04)***	0.614(6.89)***
Cargo Size	-0.177(-8.57)***	-0.178(-5.39)***	-0.451(-18.35)***	-0.400(-9.29)***
SF	0.055(2.81)***	0.082(1.58)	-0.019(-0.82)	-0.046(-2.45)**
SN1	-0.206(-8.87)***	0.048(1.25)	0.137(6.36)***	0.036(0.92)
SN2	-0.029(-1.24)	0.062(1.69)*	0.171(6.94)***	-0.042(-0.96)
SN3	-0.128(-5.73)***	0.038(1.09)	0.189(9.02)***	-0.176(-4.44)***
G1	-0.411(-6.92)***	-0.573(-4.20)***	-0.220(-1.73)*	b
G2	-0.122(-3.24)***	0.149(3.01)***	-0.073(-1.88)*	-0.191(-2.21)**
G3	-0.423(-16.65)***	-0.289(-6.72)***	-0.236(-8.87)***	-0.213(-4.49)***
G4	0.609(10.05)***	0.528(3.66)***	-0.095(-0.46)	1.590(6.97)***
OR1	-0.611(-13.69)***	-0.703(-6.55)***	-0.456(-4.80)***	-0.129(-1.16)
OR2	-0.525(-12.92)***	-0.597(-4.32)***	-0.156(-1.49)	-0.183(-2.57)**
OR3	b	b	-0.245(-2.11)**	b
OR4	-0.392(-6.22)***	-0.352(-3.48)***	-0.224(-2.43)**	-0.439(-2.81)***
DR1	-0.501(-8.02)***	-0.310(-1.47)	-0.456(-0.37)	0.001(0.01)
DR2	0.068(0.79)	0.536(2.57)**	-0.197(-2.58)***	0.955(6.56)***
DR3	-0.099(-1.44)***	0.252(1.22)	0.115(1.91)*	0.591(4.98)***
DR4	-0.832(-11.38)***	-0.444(-1.77)*	-0.343(-5.55)***	0.074(0.67)
DR5	-0.652(-9.29)***	-0.390(-1.57)*	0.071(1.18)	0.176(2.00)**
DR6	-0.296(-2.99)***	0.193(0.69)	-0.254(-2.60)***	-0.608(-3.35)***
DR7	-0.456(-7.59)***	0.018(0.08)	-0.157(-2.73)***	-0.142(-1.32)
DR8	-0.662(-9.31)***	-0.323(-1.40)*	-0.241(-3.77)***	0.174(1.36)
DR9	0.050(0.56)	0.430(2.06)**	-0.425(-6.10)***	0.457(2.15)**
DR10	-0.370(-4.12)***	-0.065(-0.29)	b	0.378(1.55)
DR11	0.100(1.20)	0.030(0.14)	-0.340(-5.03)***	0.682(3.60)***
DR12	-0.594(-4.54)***	0.403(1.31)*	-0.159(-1.13)	0.836(3.00)***
MD	0.091(2.30)**	0.137(2.14)**	-0.015(-0.31)	0.110(1.17)
R^2	0.7599	0.6873	0.7688	0.6827

SF represents shipment frequency; SN1-SN3 represent seasonal dummy variables; G1-G4 represent grain type dummy variables; OR1-OR4 represent origin dummy variables; DR1-DR12 represent destination dummy variables; and MD represents multi-destination dummy variables. a. t-values are in parentheses. b. No data available for the year. One, two, and three asterisks indicate statistical significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

These results are consistent with those of Binkley and Harrer (1981) and Jonnala et al. (2002) which found that distance of haul is an important explainer of ocean grain rates. The distance variable reflects cost components, including fuel cost and labor, in cross sectional analysis.

The cargo size variable, a proxy for vessel size, has a negative sign as hypothesized, indicating that freight rates per metric ton from exporting ports to importing ports decrease as the size of cargo increases. Binkley and Harrer (1981) and Jonnala et al. (2002) obtained the same results. According to the sample data set, the average grain-carrying ocean vessel cargo size has risen from 33,000 metric tons in 1987 to 40,000 metric tons in 1998. In general, a larger vessel generates lower rates. However, the negative coefficient on the cargo size variable does not guarantee unlimited economies of vessel size. Port cost rise with size of vessel and optimal vessel size depends upon the trade-off between at-sea economies and port diseconomies. The cargo size was found to reach a minimum freight rate for grain at 72,108 metric tons (Jonnala et al., 2002).

Shipment Frequency

The shipment frequency variable has positive signs in the 1987 and 1991 models and negative signs in the 1995 and 1998 models, although the variable is not significant in 1995. It was hypothesized that more frequency tends to lower the ocean freight rate because more frequency indicates more volume, more competition, and more backhaul opportunities. The negative coefficients in 1995 and 1998 models imply that increasing shipment frequency on a route would tend to be associated with a rate reduction. Part of the effect identified may reflect the presence of efficient port facilities, which are associated with origin and destination region dummy variables. On the other hand, shipment frequency may generate lower rates because of more backhaul opportunities.

In addition, the shipment frequency variable interacts with the cargo size variable; a big vessel can ship a large volume of grain that would require multiple small vessels. The average cargo sizes for 1987 and 1991 are 33,000 and 36,000 metric tons, respectively, while those for 1995 and 1998 are 42,000 and 40,000 metric tons, respectively. Another factor is changes in the ocean shipping industry. In the 1970s and 1980s, the supply of ocean vessels was limited, which resulted in increased ocean freight rates with increased volume of grain shipped (Maritime Research Inc. 1998). However, the supply of ocean vessels increased substantially in the 1990s and, as a result, the increased capacity of ocean transportation for grain shipments lowered ocean freight rates (Maritime Research Inc. 1998). It is difficult to determine whether the negative correlation between shipment frequency and rates is direct or due to joint correlation with other factors.

Seasonality

The seasonal dummy variables (SN1, SN2, and SN3) have mixed signs and statistical signi-ficance (Table 5). The fourth quarter (SN4) is the base. The null hypothesis that ocean freight rates for shipments of grain do not vary among seasons is tested by using the F-test (Table 6). The test results reject the null hypothesis at the 5% level in all of the models except the 1991 model. In addition, the signs of the seasonal dummy variables are different among models, and the absolute magnitudes of parameters associated with the seasonal dummy variables are relatively small, ranging between 0.03 and 0.2.

It is expected that rates in the last quarter of the year are highest because of the heightened transport demand that results from the crop harvest in the Northern Hemisphere (O'Loughlin, 1967). Previous researchers, using time series data, obtained similar results. Binkley and Harrer (1981) found that rates in the last quarter of the year are highest. Thus

Table 6: F-Test Results in Ocean Freight Differential on Dummy Variables

Year	H_o: No Rate Differential by Seasons		H_o: No Rate Differential by Grain Types		H_o: No Rate Differential by Origin Regions		H_o: No Rate Differential by Destination Regions	
	F-Value	Inference at 5 %	F-Value	Inference at 5 %	F-Value	Inference at 5 %	F-Value	Inference at 5 %
1987	33.59	Reject	105.70	Reject	71.70	Reject	30.58	Reject
1991	1.05	Accept	27.77	Reject	14.53	Reject	13.49	Reject
1995	31.33	Reject	20.42	Reject	21.20	Reject	20.23	Reject
1998	10.55	Reject	18.77	Reject	2.97	Reject	14.12	Reject

the results of their study are consistent with the conventional assumption. However, Jonnala et al. (2002) found rates in the last quarter are lower than the first and second quarter and higher than the third quarter.[6]

It is interesting to compare the seasonality results of this study with those estimated by previous researchers. The estimated co-efficients in the 1987 model indicate that the freight rates for grain in the fourth quarter are highest, while rates in the first quarter are lower than other quarters. Binkley and Harrer (1981) obtained the same results as our 1987 model. In the 1991 and 1995 models, the estimated coefficients indicate that the freight rates for grain in the fourth quarter are lowest. In the 1998 model, the estimated coefficients indicate that the freight rates in the second and third quarter are lower that the fourth quarter, while rates in the first quarter are higher than the fourth quarter. The results for the 1991, 1995, and 1998 models are different from Binkley and Harrer (1981) and Jonnala et al. (2002), indicating that seasonalities vary among years with cross sectional analysis.

Commodity Type

In this study, a special effort is made to examine ocean price differentials based on value of different grain types. The dummy variables representing different commodities, such as barley (G1), corn (G2), sorghum (G3), and bagged rice (G4), differ significantly from zero at the 5% level or better except barley, corn, and bagged rice in 1995 (Table 5). Wheat (G5) is the base commodity. The dummy variables for barley, corn, and sorghum have negative signs, except corn in 1991, indicating that ocean freight rates for these crops are lower than ocean freight rates for wheat. The dummy variables for bagged rice have positive signs, except in 1995, indicating that ocean freight rates for this crop are higher than ocean freight rates for wheat. The null hypothesis that ocean freight rates for shipments of grain do not vary among commodities is tested by using the F-test (Table 6). The test results reject the null hypothesis at the 5% level in all of the models. These results are consistent with differential pricing: high-value commodities are usually charged higher rates than low-value commodities. The dummy variables for bagged rice have positive signs, except in 1995, indicating that ocean freight rates for bagged rice are higher than those for other grains.

Origin and Destination Ports

To capture rate differences resulting from different origin regions, the dummy variables (OR1, OR2, OR3, and OR4) are used (Table 5). The Great Lakes region (OR5) is the base region. The dummy variables are statistically significant at the 5% level or better except OR2 (U.S. Gulf) in 1995 and OR1 (PNW and West Coast) in 1998 and have negative signs, indicating that ocean freight rates from the Great Lakes region are higher than those of other regions. The null hypothesis that ocean freight rates do not differ among origin regions is tested by using F-tests (Table 6). The test results reject the null hypothesis at the 5% level in all years, indicating that ocean freight rates for grain differ among origin regions during the period. This is mainly because ports in different regions in the United States have different characteristics in terms of grain handling capacity, distance from major producing regions, and modes of transportation accessible at the port. For instance, the Gulf ports can receive grain by rail, truck, and barge and are closer to major producing regions, including the Southern Plains and Corn Belt regions. Thus, ocean freight rates from the Gulf to importing countries are generally cheaper than those from Chicago and the Great Lakes which have disadvantages in vessel size, the tolls on the St. Lawrence Seaway, and limited navigable days during the winter season.

The dummy variables for destination regions have inconsistent signs and statistical significance over various years. The null hypothesis that ocean freight rates do not differ among destination ports is tested by using F-tests (Table 6). The test results reject the null hypothesis at the 5% level in all years, indicating that ocean freight rates for grain differ among destination regions during the period. This is mainly because some destinations have various factors affecting total cost. Some destinations have more backhaul opportunities, better unloading facilities, and/or less port congestion than other destinations. These destinations may have lower ocean freight rates than those with less backhaul opportunities, poor unloading facilities, and/or heavier port congestion.

Multiple Destinations

The dummy variable representing single destination and multiple destinations (MD) is significantly significant at the 5% level in 1987 and 1991, but is not significant in 1995 and 1998. They have positive signs, except in 1995, indicating that ocean freight rates for multiple destinations are higher than those for single destination.

Structural Changes

Based on a review of the literature, no previous study has obtained structural changes in ocean freight rates for grain. It was hypothesized that the ocean freight rate structure for grain has changed over time because of many factors affecting the ocean transport industry. The results of the study indicate that structural changes have occurred in ocean freight rates for grain from the United States to major importing countries.

To examine structural change(s) over the four years (1987, 1991, 1995, and 1998), six different unrestricted F-tests were conducted for the equality of coefficients in a pair of years between 1987 and 1991, 1987 and 1995, 1987 and 1998, 1991 and 1995, 1991 and 1998, and 1995 and 1998 (Table 7). To test the null hypothesis of no structural change(s) (i.e., all corresponding coefficients are the same between pairs of years), the F-statistic was used. The F-values range from 9.27 to 57.7, while the critical value is 1.46 at the 5%

Table 7. F-Values for Structural Change Tests (5% significance level)

Years	H_0: No Structural Changes Over Years	
	F-Value	Inference at 5 %
1987-1991	23.51	Reject
1987-1995	57.70	Reject
1987-1998	11.80	Reject
1991-1995	9.27	Reject
1991-1998	26.78	Reject
1995-1998	32.82	Reject

significance level. These test statistics reject the null hypothesis of no structural change in ocean freight rates between paired years, indicating that ocean freight rate structures for grain shipments have changed over the given time period. Therefore, we would conclude that the importance and role of each independent variable and/or intercept has changed, and the variables interacted with each other to determine the ocean freight rates for grain shipments over the given time period.

In explaining factors affecting ocean freight rates for grain, each factor does not play the same role in every time period. For example, the role of cargo size, a proxy for vessel size, has become more important over time. One of the parameters of particular interest with respect to structural change is the cargo size elasticity – the percentage change in ocean freight rate as a result of a 1% change in cargo size. In 1991 and 1995, the elasticities are -0.178 and -0.451, respectively, indicating that a 1% increase in the cargo size or vessel size would decrease the ocean freight rates by 0.178% and 0.451%. This result shows that there is a structural change in cargo size or vessel size between 1991 and 1995. Among the possible explanations for the change in freight rate structure is the shift to larger vessels which in some of the larger grain markets such as the Far East (DR5) and South Asia (DR13) has resulted in lower grain rates. These markets have shifted from a Handysize vessel (27,000 to 40,000 dwt) to a Handymax vessel (40,000 to 55,000 dwt) and/or a Panamax vessel (60,000 to 75,000 dwt). Although not apparent from the statistical results, an examination of the raw data indicates that the average grain-carrying ocean vessel cargo size has risen from 36,000 metric tons in 1991 to 42,000 metric tons in 1995.

CONCLUSIONS

The pricing behavior and structural changes of ocean transportation in shipping grain from U.S. ports to various importing ports are quantified by using an econometric technique with cross-sectional data in 1987, 1991, 1995, and 1998.

Major findings of this study are: (1) cost factors, such as distance and cargo size, play a significant role in determining ocean freight rates; (2) advantages and disadvantages of ports due to geographical locations and port facilities affect determination of ocean freight rates; (3) the ocean shipping industry charges different rates for different commodities; i.e., higher rates for wheat than corn; (4) in general, ocean freight rates vary by season; and (5) the ocean freight rate structure for grain shipments has changed over the 1987-1998 period.

Endnotes

1. For the ADF test, US Gulf-Europe, US Gulf-Japan, US Gulf-Far East, and US Gulf-South America routes of grain shipments are tested and test statistics are -1.25, -2.67, -1.39, and -1.29, respectively. Critical values are -3.67, -2.96, and -2.62 for the 1%, 5%, and 10% level, respectively. The null hypothesis is that the series is non-stationary. If the ADF statistic is smaller in absolute value than the reported critical values, we cannot reject the hypothesis of nonstationary.

2. The Pigouvian price discrimination assumes that cost-of-services is equal regardless of value-of-product, volume guarantee, season, regularity, and so on.

3. They are US dollar per metric ton.

4. The P_E test is modified from J test by MacKinnon et al. (1983). The P_E test can be used to test a linear specification against a log-linear model.

5. Heteroscedasticity implies that the variance of the disturbance may vary for each year and poses potentially severe problems. Among heteroscedasticity test methods, including White test, Bartlett's test, Goldfeld-Quandt test, Breush-Pegan test, the White test is extremely general.

6. For a detailed discussion of the seasonality of the ocean grain freight rates, see Jonnala et al. (2002).

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