IMPACT OF CHANGES IN OCEAN FREIGHT RATES ON UNITED STATES RICE EXPORTS

By

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The direction and magnitude of the future world rice market is of vital consideration for the rice industries of both exporting and importing countries. Many studies have analyzed the international rice trade; however, there has been no published research that attempted to examine the effects of ocean freight rates on international rice trade.

The major objective of this study was to analyze the effects of ocean freight rates on the flows, supplies, demands, and prices of world rice shipments. A reactive programming model, within a spatial equilibrium analysis framework, was developed to obtain equilibrium level estimates of the variables mentioned above, to investigate the competitive position of major rice exporting countries, and to evaluate the effects of ocean freight rates in four different scenarios.

The 1990 calendar year was used as the base year for the analysis. Optimum shipping patterns of rice exports from the U.S. to world markets in 1990 was obtained to compare with models of the four different mentioned scenarios.

The results show that the competitive position of the U.S. rice industry would be reduced from its actual level in the world rice market under some trade conditions. That is, the U.S. rice industry would lose its export volumes under an optimum minimum cost trade market structure, while the position of U.S. competitors, such as China, Vietnam, and Thailand, would improve significantly. Also, the U.S. cargo preference policies did little to affect the world rice trade market structure.

Likewise, the results indicated that even when ocean freight rates have an important influence on the international rice trade, its effect is significantly different in each exporting country. China would be the most sensitive country to changes in ocean freight rates, not only in terms of its level of exports, but also in terms of the configuration of its rice trade pattern. Vietnam and Thailand rice exports and trade patterns also would respond significantly to changes in ocean freight rates, while the response of the U.S., in the same terms, could be considered relatively minor.

Changes in ocean freight rates are not recommended policies to enhance the competitive position of the U.S. rice industry. Other issues of policy, such as support to rice production and exports, and price policy, could be considered as more influential mechanisms to help the U.S. rice industry.

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CHAPTER I

INTRODUCTION

Rice is one of the world's most important cereals for human consumption. In the densely populated countries of Asia, especially Bangladesh, China, India, Indonesia, Iran, Japan, Korea, Pakistan, and Sri Lanka, rice is the most important staple food. As much as 80 percent of the daily caloric intake of people in these Asiatic countries is derived from rice (Luh, 1991).

Approximately 91 percent of the world's rice was also produced in Asia in 1989, and China alone harvested almost 35 percent of the global crop (Zhang, 1990b). However, despite the importance of rice as a staple food for a third of the world's population, the volume traded is relatively small (Chang and Luh, 1991).

Among the non-Asian rice producers the most important are Brazil and the United States (U.S.). Although the U.S. is tenth in world rice production, it is second to Thailand in world rice exports (U.S.D.A., 1991). As such, this grain is important for the U.S. in terms of its participation in the agricultural world trade.

Exporting is a major activity for the U.S. rice industry; however, as rice production has expanded in the U.S. and in other major producing countries, U.S. rice exports have diminished in the world market during recent years (U.S.D.A., 1992). Transportation cost is one of the reasons for this decline in U.S. rice exports. As it is shown in this study, transportation costs affect the competitive position of the U.S. rice industry in the international rice market.

Nature of the Problem

Over the years, numerous efforts have been made to analyze the international grain trade. Generally, it is believed that the level and magnitude of the trade of grain and other commodities are influenced by supply and demand. Some academicians argue, however, that international trade of commodities depends not only on demand and supply conditions, but also on so called "trade resistance" factors, which can reduce or nullify comparative advantages.

These trade-resistance factors include transportation costs, trade arrangements, tariffs and quotas, non-quantitative barriers, and political considerations. Analysis of these factors, along with demand and supply conditions could provide a better understanding of trade flow patterns of a particular commodity (Pinar, 1983).

Most studies concerning comparative analyses of "trade resistance" factors are primarily related to the study of effects of tariffs and other barriers on international trade, with remarkably little attention to transportation costs and freight rates profiles of individual countries[1], and their influence on international trade flows.

Ocean freight rates represent an important influence on the direction and type of traded products. Without the analysis of ocean freight rates, it is difficult to formulate intelligent trade policies, since the effects of tariffs and quotas can be confounded with those due to transportation. Total effective protection (tariffs, quotas, and transportation costs) may differ greatly from effective tariff and quota protection. Failure to include the influence of transportation costs in the calculations may seriously bias any result leading to policy action (Sampson and Yeats, 1978). The importance of transportation costs was pointed out by Mundell (1952), who found that transportation costs depend basically on the distances between countries, and if the distances were sufficiently large, the opportunity for trade gains would be eliminated.

To a certain extent, transportation costs are not controllable by policy makers, and are essentially administered issues. Obtaining an optimum flow among the exporting and importing countries can reduce transportation costs, because buyers and sellers are free to choose markets based on free market trade.

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[1] Ocean freight rates are defined as the costs of transferring commodities from an exporting country to an importing country. Ocean freight rate and ocean transportation costs are interchangeable terms in this study.

The review of literature reveals that no studies exist concerning the specific effect of ocean freight rate changes on the optimum flows of rice in international trade. Some studies have been conducted to evaluate the effect of trade liberalization on international rice trade (Chaitip, 1989, Angel and Rosson, 1991; Haley, 1991; Cramer et al., 1993), or the specific effect of some other "trade-resistance" factors (Yoon, 1988; Grant and Williams, 1990).

Objectives

1. To describe international trade flow of U.S. and major world exporting countries for rice.

2. To describe the volume of rice shipped and rates charged by different terms of shipping, distance, size of shipment, and flag of registry.

3. To estimate optimum distribution of rice, from U.S. and major competing countries, to importing countries, by maximizing market net prices.

4. To analyze the impact of changes in different levels of ocean freight rates on rice trade, equilibrium prices, and the potential for social and monetary gain from optimum flows.

Importance of This Study

Rice is an important commodity for the commercial balance of agricultural products of the U.S. Therefore, maintaining low ocean transportation costs for this product, will enable the U.S. to be more competitive in international markets by lowering prices of its exports.

This study offers information about how alternative levels of ocean freight rates affect rice exports, which will be useful for rice producers, carriers, and exporters in order for them to make appropriate decisions on rice production, transportation, and marketing. U.S. policy-makers can also use the information provided by this study to help develop suitable domestic programs and international trade policies to improve the U.S. competitive position in the world rice markets through production adjustments.

Review of Literature

Even though the influence of ocean transportation costs has been theoretically recognized by many academicians since the early 1950's (Wolfe, 1959; Moneta, 1959; Mundell, 1952), the empirical analysis of ocean transportation costs in international trade has been relatively limited. Main reasons probably are: (i) the presumption that transportation costs are very small or absent in international trade[2], and (ii) the lack of available data considering this variable.

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[2] For many years, zero transportation cost was one of the main assumptions of the modern theory of international trade (Chacholiodes, 1990).

Some empirical studies have evaluated the importance of ocean transportation costs as a main factor explaining the direction, magnitude, and benefits of trade flows, as well as the types of commodities exchanged internationally. For instance, Finger and Yeats (1976) demonstrated, for the U.S., that the effective protection due to international transportation costs were at least as high as that due to tariffs. Moreover, they showed that freight rates had increased at a faster pace than productivity during the 1960's, deserving special attention as a main non-tariff barrier in the international trade of commodities.

Sampson and Yeats (1977, 1978) also showed that trade barriers of international trade, imposed by transportation costs exceeded barriers due to tariffs for the Australian and the United Kingdom exports to the U.S. markets. They studied large groups of agricultural and non-agricultural commodities, concluding that nations may gain much more from trade expansion with policies aimed at reducing transportation barriers than from any other policy aimed at tariff reduction or elimination.

Geraci and Prewo (1976) used a cross-section of aggregate bilateral flows among 18 countries to estimate the elasticity of exports with respect to transportation costs. The authors found that the U.S. elasticity was -1.57; the highest elasticity was reported for Australia (-2.75), and the general average elasticity was -1.15. This study pointed out the existence of a significant impact of transportation costs over the direction and level of aggregate bilateral trade flows.

Studies considering transportation costs of specific commodities or groups of commodities also have emphasized the importance of this variable on international and interregional trade, as well as the major determinants of ocean freight rates. For example Davis (1968) developed a transportation model to determine a least-cost shipping pattern for U.S. grain exports. In the model, the author used the data developed on the cost per ton of shipping grain for three bulk grain vessel sizes from U.S. ports of origin to specific ports of destination. The resulting transportation model indicated that the law requiring 50 percent of government sponsored shipments to be carried on U.S. flag vessels[3] cost $200 million dollars per year in added transportation costs.

Likewise, Sharp and McDonald (1971) determined the impact of ocean vessel size on the transportation costs of U.S. exports of grain to seven foreign demand regions, and the associated impact of vessel size upon the US export grain facility requirements. They concluded that such a system must incorporate the utilization of large-scale, low-per-unit-cost vessels which would enable the U.S. to

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[3] The Cargo Preference Act is a U.S. law which mandates that a given percentage of the volume of commodities financed by the U.S. Government be shipped on U.S. flag vessels.

maintain a competitive position in the world trade of grains by minimizing transfer costs.

Harrer (1979) pointed out that shipping rates of agricultural commodities are basically a nonlinear decreasing function of distance. Other important variables explaining ocean freight rates are size of shipment, volume of trade, and seasonality. He also used a spatial equilibrium trade model to analyze effects of reductions in shipping rates on agricultural trade, concluding that while decreasing shipping rates for certain exporters does increase export receipts for the exporters, the percentage increases in export receipts are not large.

Binkley and Harrer (1981) concluded that the U.S. and Canada dominate the international trade of grains, based not only on production efficiencies, but also on transportation advantages. These transportation advantages come from their location with respect to the major markets and their relatively efficient ports. They also concluded that ship size and trade volume are of approximately equal importance as distance in determining ocean freight rates for grains, and that the role of transportation costs in trade analysis should not be ignored.

Joerger (1984) found that ocean transportation costs account for about 37 percent of the total transportation costs of the spring wheat marketing system. In general, decreases in U.S. ocean freight rates led to increases in the wheat prices of the different U.S. export ports analyzed. Likewise, when ocean freight rates increase, the U.S. export price decreases and the price in the importing country increases. It was estimated that importing countries absorbed about two-thirds of increases in ocean rates.

It was also reported by Joerger (1984) that the shipment patterns from the U.S. ports to foreign importing regions remained unchanged when ocean freight rates at the individual ports were altered. However, the volume shipped from each port was affected to a limited extent. In fact, generally a 10 percent change in ocean rates led to a one to two percent change in trade volume.

Pinar (1983), using a transportation model, analyzed the effects of ocean transportation costs and tariff barriers on the flows of international cotton shipments. This study showed that ocean transportation costs were important factors influencing the competitive position of the countries in the world market. A comparison of the optimum model with existing flows indicated that there would have been more than 25 million dollars of net savings associated with optimum flows. Among the exporting countries, the U.S. would have had the largest net gain, followed by Pakistan and Turkey. Of the importing countries, Taiwan, India, and Italy would have realized the largest net gain with optimum flow.

Yoon (1987) used a spatial equilibrium model to analyze the competitive position of the Southern U.S. rice industry in the international market. He found that the competitive position of the Southern U.S. rice industry was relatively low in the world rice market. In contrast, Thailand, China, and Burma would have relatively high competitive positions under the trade conditions evaluated in his analysis. Results also indicate that the U.S. cargo preference policies did little to affect the world rice trade market structure. Yoon stated that the industry should continue to encourage the creation of more rice export and domestic policies that reduce production and processing costs, in order to enhance the competitive position of the U.S. rice industry.

Zhang (1990a) showed that U.S. transportation costs for rice was primarily influenced by three factors: geographical distance, ship size, and ship flag. Specifically, as distance increased, shipping rates increased proportionally. Likewise, larger ships have lower unit cost per ton than smaller ships. Also, of three flags used in the models, shipping cost for U.S. flag ships was substantially higher than that for other ships. Liberian-flag ships were selected to be most frequently used for the shipments.

Hagen et al.(1991) suggested that ocean freight rates were quite volatile, and would have a very significant negative impact on California cotton export competitiveness.

In fact, they reported that 10 percent of increased ocean freight rates had an average effect of a 6.9 percent decrease in cotton sales. The median percent reported was 2.0. They also found that cotton exporters believe their industry would best be served with the deregulation of ocean freight rates, and the elimination of shipping surchargers.

Finally, Goodwin (1992) emphasized the importance of transportation costs when he evaluated the law of one price (LOP)[4], for prices in five international wheat markets. Under this law, efficient arbitrage and trade activities should ensure that individual wheat prices in spatially separated markets are linked through a common long-run equilibrium. His results indicated that the LOP failed as a long-run equilibrium relationship when transportation costs were ignored. However, when wheat prices were adjusted for freight rates, the LOP was fully supported.

Organization of Following Chapters

The rest of the dissertation is organized into the four following chapters. The second chapter presents background information related to the world rice situation in terms of consumption, production and trade, as well as the analysis of different characteristics of rice terms of shipping.

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[4] The law of one price (LOP), an important component of international trade models, asserts that efficient trade and arbitrage activities will ensure that prices in spatially separated markets, once adjusted for exchange rates and transportation costs, will be equalized.

Chapter three develops the theoretical framework concerning the development of spatial equilibrium analysis for international trade. The reactive programming model is presented, along with its major assumptions, and its underlying implications. This chapter also presents data requirements and a detailed explanation of the development of information used to run the model.

Chapter four analyzes the results generated by the spatial equilibrium model to satisfy objectives 3 and 4. In a first scenario, the optimum volumes of trade, world trade prices, and international flow patterns are compared with the actual trade data of 1990. This chapter also relates to the sensitivity analysis of the optimum model, in which three additional scenarios are evaluated: (i) the effects of the cargo preference policies, (ii) the effects of individual changes in ocean freight rates of four major rice exporting countries, and (iii) the effects of simultaneous changes in all ocean freight rates.

Summary, conclusions, limitations, and suggested areas for further research are presented in the fifth chapter.

CHAPTER II

BACKGROUND INFORMATION

The purpose of this chapter is to provide background information for the analysis of transportation costs. The information includes the situation of the rice international market, in terms of consumption, production, imports, and exports, with special emphasis on the U.S. rice industry. Types of vessels, types of flag, terms of shipment, and U.S. cargo preference policies are also provided in order to better examine transportation costs of rice in world markets.

U.S. Rice Consumption, Production, and Trade

Rice is one of the major food grains in the world. Over a third of the world's population, predominantly in Asia, depends on rice as a primary dietary staple. Per capita annual consumption of rice in Asia is around 100 kilograms (Kg.), compared with three to four Kg. per person in the Western world (Ito et al., 1989; Huang et al., 1991). Even though the per capita consumption of rice has been decreasing in recent years throughout some countries in Asia, rice has been increasing in importance in terms of its total consumption (Table 1). It has been estimated that by the year 2000, rice will be the chief source of energy for

Table 1. World Consumption of Milled Rice for Selected Countries and Regions, Selected Periods

Country	1965-69	1970-74	1975-79	1980-84	1985-90
	................(1,000,000 M.T.)...................				
China	63.53	74.44	86.54	104.71	122.39
India	36.53	42.50	46.56	54.16	63.76
Indonesia	11.46	14.85	18.01	23.53	27.45
Bangladesh	11.30	11.21	12.91	14.42	16.11
Japan	11.36	11.58	10.32	10.38	9.80
Thailand	6.03	7.73	7.79	8.10	8.47
Burma	4.18	4.67	5.52	8.53	6.93
South Korea	3.90	4.51	5.62	5.44	5.61
Pakistan	1.58	1.85	2.07	2.19	2.11
U.S.	1.20	1.36	1.55	2.02	2.51
E.C.12	1.08	1.17	1.36	1.38	1.52
World	186.07	218.39	245.95	292.32	325.63
	.... (%)......................				
China	34.1	34.1	35.2	35.8	37.6
India	19.6	19.5	18.9	18.5	19.6
Indonesia	6.2	6.8	7.3	8.0	8.4
Bangladesh	6.1	5.1	5.2	4.9	4.9
Japan	6.1	5.3	4.2	3.6	3.0
Thailand	3.2	3.5	3.2	2.8	2.6
Burma	2.2	2.1	2.2	2.9	2.1
South Korea	2.1	2.1	2.3	1.9	1.7
Pakistan	0.9	0.8	0.8	0.8	0.6
U.S.	0.6	0.6	0.6	0.7	0.8
E.C.12	0.5	0.5	0.6	0.5	0.5

Source: Zhang, 1990b; U.S.D.A., 1991.

about 40 percent of the World's people, thereby surpassing wheat (Chang and Luh, 1991).

Rice is also an important crop, second only to wheat, in terms of total cereal production. In 1989, rice and wheat together occupied over one-quarter of the arable land in the world (Wisner and Wang, 1990). In recent years Thailand, Bangladesh, China, India, and Indonesia have been the largest world rice producers, accounting for about 75 percent of total world production. Brazil and the U.S. are the largest non-Asian rice-producing areas, and account for 2.1, and 1.4 percent, respectively, of the total world rice production (Table 2).

It is also important to note that the five largest rice producers (China, India, Indonesia, Bangladesh and Thailand) are also among the largest consumers, accounting for more than 70 percent of all rice consumption (Table 1). Other major rice-consuming countries include Vietnam, Japan, Burma, and Brazil. Because such a large percentage of rice is consumed and produced in the same countries, only a small amount of the total world rice production enters international trade. Thus, the world market in rice is characterized to be relatively small. In 1989, for example, only about 15 million tons, equivalent to less than five percent of the total rice world production, was traded, as compared to 18.6 percent for wheat and 12 per cent for coarse grain (Wisner and Wang, 1990).

Table 2. World Rough Rice Production Statistics for Selected Countries and Regions, 1965-1991

Year	1965-69	1970-74	1975-79	1980-84	1985-91
	................(1,000,000 M.T.)................				
Bangladesh	16.1	16.5	18.5	20.7	24.3
Brazil	6.6	6.3	7.7	8.8	10.1
China	96.4	119.9	135.5	161.6	175.5
India	53.6	53.6	62.5	71.9	99.9
Indonesia	15.0	20.6	24.2	33.9	42.0
Pakistan	2.6	3.5	4.4	5.0	4.8
Thailand	12.3	13.7	15.5	18.3	19.4
South Korea	4.7	5.1	5.8	7.7	7.9
Japan	17.7	15.6	16.0	13.2	13.5
Australia	0.2	0.3	0.5	0.7	0.8
U.S.	4.1	4.2	5.5	6.5	6.6
E.C.12	1.6	1.8	1.8	1.8	2.1
Others	44.7	61.4	71.5	81.5	77.6
Total	275.6	322.5	369.4	431.6	484.5
	...................(%).....................				
Bangladesh	5.8	5.1	5.0	4.8	5.0
Brazil	2.4	2.0	2.1	2.0	2.1
China	35.0	37.2	36.7	37.4	36.2
India	19.5	16.6	16.9	16.7	20.6
Indonesia	5.4	6.4	6.6	7.9	8.7
Pakistan	2.6	1.1	1.2	1.2	1.0
Thailand	0.9	4.2	4.2	4.2	4.0
South Korea	1.7	1.6	1.6	1.8	1.6
Japan	6.4	4.8	4.3	3.1	2.8
Australia	0.1	0.1	0.1	0.2	0.2
U.S.	1.5	1.3	1.5	1.5	1.4
E.C.12	0.6	0.6	0.5	0.4	0.4
Others	18.1	19.0	19.3	18.8	16.0
Total	100.0	100.0	100.0	100.0	100.0

Source: I.R.R.I., 1987; U.S.D.A., 1992.

The U.S., tenth in the world in rice production, is second, after Thailand, in world rice exports. Between 1985 and 1991 the U.S. exports averaged more than 2.3 million metric tons, equivalent to 36 percent of its total rice production, and to 18.8 percent of the total world rice exports (Table 3). For the same years, Thailand led in rice exports with almost 4.5 million M.T., which accounted for 35.6 percent of the total world rice exported. Other major rice exporters were Pakistan, China, Vietnam, and the E.C. (basically Italy and Spain).

The U.S. share of world rice exports has decreased in recent years, going from an average of 22.6 percent of the total rice exported during 1975-1979, to an average of 18.8 percent in 1985-1991. U.S. rice export destinations are relatively diversified, going to the Middle East, Africa, and other countries like Canada, Mexico, and Brazil (Table 4). For instance, the three largest importers of the U.S. rice in 1991 were Saudi Arabia (11.1 percent), Brazil (8.2 percent), and Canada (6.8 percent).

It should also be mentioned that the "small market" problem of rice world trade is compounded by the fact that 45 percent of Asian production is not irrigated and relies completely on the Asian monsoons[5] (Cramer et al., 1991).

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[5] The Asiatic monsoon is a wind system that influences the climatic region and reverses direction seasonally in India and Southern Asia. It is commonly marked by heavy rains (Webster's New International Dictionary of English, 1986).

Table 3. World Milled Rice Exports Statistics for Selected Countries and Regions, 1965-1991

Year	1965-69	1970-74	1975-79	1980-84	1985-91
	...................1,000 M.T.				
Burma	779.2	462.8	505.0	721.4	419.0
China	1544.2	2513.6	1544.8	1064.2	717.6
India	5.6	23.4	118.6	489.0	364.3
Pakistan	310.8	449.6	809.4	1090.4	1003.0
Thailand	1397.2	1332.2	2042.4	3539.8	4499.3
Vietnam	10.7	1.4	9.2	60.6	655.1
Australia	86.4	140.4	233.0	397.0	402.3
U.S.	1713.0	1722.6	2222.8	2650.6	2372.9
E.C.12	319.2	520.6	745.6	972.2	1042.3
Total	7962.0	9066.4	9812.2	12480.6	12640.7
	......................(%)				
Burma	9.8	5.1	5.1	5.8	3.3
China	19.4	27.7	15.7	8.5	5.7
India	0.0	0.1	0.2	3.9	2.9
Pakistan	3.9	5.0	8.2	8.7	7.9
Thailand	17.5	14.7	20.8	28.4	35.6
Vietnam	0.1	0.0	0.1	0.5	5.2
Australia	1.0	1.5	2.4	3.2	3.2
U.S.	21.5	19.0	22.6	21.2	18.8
E.C.12	4.0	5.7	7.6	7.8	8.2

Source: I.R.R.I., 1987; U.S.D.A., 1992.

Table 4. Top Ten U.S. Rice Export Markets, Selected Years

	1991		1990		1989	
Rank	Country	% of Total Exports[1]	Country	% of Total Exports[1]	Country	% of Total Exports[1]
		(%)		(%)		(%)
1	Saudi Arabia	11.1	Iraq	12.1	Iraq	18.8
2	Brazil	8.2	Saudi Arabia	9.5	Saudi Arabia	8.7
3	Canada	6.8	Mexico	7.5	Belgium-Luxemb.	6.3
4	Haiti	6.1	Peru	6.3	Turkey	4.4
5	Turkey	5.7	Canada	5.4	Spain	4.4
6	South Africa	4.9	Turkey	5.3	Mexico	3.8
7	Switzerland	4.1	Haiti	4.3	Canada	3.5
8	Liberia	3.9	South Africa	4.1	Switzerland	3.2
9	Netherlands	3.5	Belgium-Luxemb.	4.1	Haiti	3.1
10	Mexico	3.5	Jordan	3.7	South Africa	3.1
	Sub-total	57.8		62.4		58.1

[1] Percent calculated as proportion of total value of U.S. rice exports.

Source: U.S.D.A., 1992.

The resulting variability in production contributes to substantial instability in world rice prices. Furthermore, in order to stabilize domestic prices and prevent rice shortages, rice-consuming countries have many trade restrictions and domestic policies that distort trade. Over half the world rice is transacted between government agencies rather than on a commercial basis, amounting to 7.2 million metric tons in 1989 (Childs and Lin, 1989), implying that rice markets are strongly influenced by political as well as economic factors.

Rice Transportation Vessels

Rice is exported on three general types of ships: cargo liners, tanker vessels and tramp steamers. Cargo liners are ships traveling a fixed route according to a predetermined schedule and rates. Liner owners usually sell space on a vessel by the freight-ton to a number of different shippers at predetermined rates. Two types of rate schedules are used by liners: class tariffs and commodity tariffs. Under a class tariff, products are carried at a rate determined for each specific class of service. Under a commodity tariff, each good carried is given a separate rate (Zhang, 1990a).

Cargo liner competition is usually limited by arrangements covering freight rates charged. The largest and most prominent liner companies are increasingly engaged in cargo transportation between inland locations in which ships serve only as links in an overall transport system.

Shipments of rice on liners have been significant in past years. During the 1980's, cargo liners accounted for 22.2 percent to 45 percent of U.S. rice exports (U.S. Department of Commerce, 1986). The U.S. liner fleet has maintained a relatively large share of U.S. rice export trade despite effective foreign-flag competition. This result is partly due to successful productivity improvements by major operators and to federal subsidies that have helped to maintain U.S. liner fleet's cargo share position (U.S. Congress, 1983).

Tanker vessels usually handle large tonnages of single commodities by operating one or a fleet of ships especially designed for one cargo. Size and capacity range from the ultra large crude carriers of over half a million metric tons to the small coastal tanker. Tankers can, therefore, take advantage of economies of size. However, the advantage of tankers is minimized and may even be offset by too much turnaround time in loading and discharging. Most ports importing rice have an insufficient unloading capacity to take advantage of tankers (Zhang, 1990a).

For U.S. rice exports, tankers are the least important vessels used among all the types of ships. The largest amount of rice export carried by tankers in the 1980's was four percent. The U.S. flag tanker fleet is small and is attracting little business in the severely over-tonnaged international markets. Due to the lack of opportunities in the world market, much of the U.S. subsidized fleet has taken advantage of a provision allowing tankers to enter the domestic trade (Wood and Johnson, 1989).

The last type of ship, tramp steamers, are ocean carriers employed worldwide, but not over a fixed trade route, or under a regular scheduled service. Bulk agricultural commodities, such as grains and fertilizers, are their most important cargoes. Rates are determined by negotiations between the shipper and the carrier, with a shipbroker usually serving as an intermediary. The agreement is usually called a charter party[6]. Tramp owners charter their vessel to shippers either on a voyage basis, in which case the contract is usually for one voyage and a particular commodity, or on a time basis where the contract is for a specific time period.

Tramps are indeed one of the most important transportation means for carrying rice exports from the U.S. to international markets. Tramp vessels accounted for 72 percent of rice exports from the U.S. Southern region in 1981, and 77.7 percent during 1986 (U.S. Department of Commerce, 1986).

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[6] A charter is a contracted arrangement based on the mutual commercial interests of a charterer, who requires a vessel to meet his transportation needs, and a owner who places his vessel at the disposal of the charterer.

Flag of Registry

All vessels are registered in a nation and are owned by an individual or company incorporated in the nation of registry. All vessels are under the jurisdiction of the maritime authority of the nation of registry and are bound by its laws and regulations. All shipping firms operating under a given registry face similar cost structures. Cost inequalities among vessels with different flags are basically the result of their respective maritime policies which apply equally to all companies of a given flag (Wood and Johnson, 1989).

The most common policies associated with flag of registry are policies regarding the place where shipments can be purchased, who may work on these ships, and how these ships are taxed and regulated. Most countries involved in international sea transport apply similar policies for the first two. However, differences exist among countries concerning taxation and regulation.

Some countries known as "convenience" countries, allow easy registration with minimum taxes and regulations, and they are "open" to accept easily the registration of shipowners regardless a nationality. Major countries that currently permit "open" registries are Liberia, Panama, Cyprus, Singapore, and Somalia.

Open registry has been most attractive to U.S. shipowners because U.S. maritime policies prevent the U.S.

shipping industry from being competitive in international shipping. In fact, U.S. flag ship costs are substantially higher than foreign-flag costs for both ship acquisition and operation, due to higher construction cost, as well as operational costs associated with higher wage rates of the crew, costs of storage and supplies, repairs, and insurance (Zhang, 1990a).

For instance, unlike shipowners in other maritime countries, those in the U.S. are, with a few exceptions, required to purchase their capital equipment within the U.S. This requirement raises costs tremendously. Similarly, with minor exceptions, U.S. shipowners have employed only U.S. citizens as seamen, and the wages of U.S. seamen are by far the highest in the world. Thus, the only way the U.S. fleet continues to survive is through government subsidization.

Government subsidies are basically of two forms: operating differential subsidies, and construction operational subsidies. These subsidies represent distortions of competition in international shipping markets and the cost of these subsidies to U.S. taxpayers is becoming increasingly large. In addition to direct subsidies, the U.S. government provides indirect protection for its shipping industry. For instance, through cabotage laws, foreign flagships are prohibited from carrying domestic cargoes. Through cargo preference laws, certain cargoes are mandated to move on U.S. flagships. The cargo preference laws are discussed in more detail in the next section.

The number of shipments, total tonnage, and average rate charged per M.T. for different flagships reported in a sample of the main world ports surveyed by the Chartering Annual, is presented in Table 5. Note that the rates charged for the shipping of rice generally range between U.S.$ 25 and U.S.$ 55 per M.T. for foreign flagships, and that the rates for U.S. flagships are notably higher than this range. Shipments on U.S. flagships comprised 43.9 percent of the total number of shipments in the present sample. The higher percentage of U.S. flagship found is probably due to better reporting of U.S. shipments, since Maritime Research Incorporated is physically located in the U.S., and/or the fact that cargo preference laws would have more impact on shipments of agricultural commodities than on shipments of waterborne commerce in general (Harrer, 1979). Shipments on open registry flagships, of which Cyprus, Greece, Jamaica, and Panama are the most important in terms of the number of shipments, comprised 25.3 percent of the total number of rice shipments reported.

The U.S. Cargo Preference Policies

The practice of restricting certain cargoes to U.S. flags began with the 1904 law requiring that all military cargoes be moved in U.S. bottoms. In 1948, the U.S.

Table 5. Number of Shipments, Total Tonnage, and Mean Rate Charged per M.T., for Rice Cargoes on the Major Flagships of the World, 1990-1991

Flag of Registry	Percent of Shipments	Total Tonn. Shipped	Average Rate Charged
	(%)	(M.T.)	($/M.T.)
U.S.	43.9	324,868	83.9
Cyprus	9.3	68,499	36.8
Greece	8.9	66,185	44.5
Jamaica	3.4	25,470	25.4
Panama	3.7	27,720	62.7
Liberia	2.2	15,400	54.8
Mauritius	5.0	36,948	51.4
Steamer	10.1	74,900	43.5
Others	13.5	99,891	50.7
Total	100.0	739,881	

Source: Source: Maritime Research Inc., Chartering Annual 1990 and Chartering Annual 1991.

Congress passed the first cargo preference provision for aid cargoes. This practice continued on an ad hoc or annual basis until 1954, when Public Law 664 made it permanent. This Law required that 50 percent of all United States Government-sponsored shipments be moved on U.S. flagships (Harrer, 1979).

The U.S. Food Security Act of 1985 changed the cargo preferences law in the sense that it mandated a gradual increase in the share of particular exports, mostly food aid, that must be shipped on U.S. flag vessels (Tweeten, 1992). The cargo preference requirements do not apply to certain commercial agricultural export programs such as export credit, credit guarantees, blended credit, and export enhancement programs (Glaser, 1986). In 1986 and 1987, the law required that 60 percent and 70 percent food aid exports be shipped on U.S. flag vessels, respectively. And, in 1988 and thereafter, at least 75 percent of such exports must have been shipped on U.S. flag vessels. The U.S. Food and Agricultural Act of 1990 confirmed the 75 percent U.S. flag shipping requirement (U.S. Congress, 1990).

Cargo preference laws are applied in most of the countries[7], and have served as a type of quota in that they restrict foreign competition in rice and other commodities

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[7] Either unilaterally or multilaterally, more than 60 percent of countries reporting assistance to their merchant fleet (U.S. Department of Transportation, 1988) had cargo preferences policies in support of their own flag vessels.

markets, reduce the supply of shipping services, and thus maintain rates at levels high enough to allow flag operators to stay in business. The importance of these cargo preference policies is significant for the U.S. maritime industry. It has been documented, for example, that revenue from the carriage of preference cargoes totaled more than one billion dollars for all U.S. operators during 1980. Liner operators received 16 percent of all revenues under the programs (U.S. Congress, 1983)

Size of Shipment

The average shipment size of rice for the three main origin regions, for years 1990-1991, is presented in Table 6. Notice that there are marked differences in terms of average shipment size between the rice shipments originated in the main rice exporting areas (Thailand, Pakistan, and the U.S.), and other shipments. There is also a difference between the average shipment size of U.S. flag and Non-U.S. flag vessels originating in the United States. The average shipment size of U.S. flag vessels was 10,479.6 metric tons of rice, whereas it was just 6,863.8 metric tons for Non-U.S. flag vessels.

Similarly, it can be seen in Table 6 that the average rate per M.T.(adjusted by distance), charged by vessels whose origin point is located in the U.S. is notably higher than those charged by vessels that depart from

Table 6. Mean Shipment Size of Rice for Major Origin Area, 1990-1991

Origin Area	Average Shipment Size	Average Rate Shipments	Number of Shipments
	(M.T.)	($/M.T./d)[1]	(No.)
Thailand	9738.0	0.97	10
Pakistan	9528.8	0.85	8
U.S.	8671.7	2.65	62
U.S. Flag	10479.6	3.39	31
Non-U.S. Flag	6863.8	1.92	31
Others	5367.0	1.80	10
Average	8499.2	1.49	

[1] ($/M.T./d) means dollars per M.T. adjusted by distance (100 maritime miles).

Source: Maritime Research Inc., Chartering Annual 1990 and Chartering Annual 1991.

Thailand, Pakistan, and other places. The freight rates charged for rice cargoes from Pakistan and Thailand are particularly low.

The differences between the mean rate of U.S. flag vessels and Non-U.S. flag vessels are also important (3.39 versus 1.92 dollars per M.T. per 100 miles), and help to explain the higher ocean freight rates when U.S. cargo preference policies are applied.

Terms of Shipping

One of the most important specifications in a ship charter is the term of shipping. It is concerned with the responsibilities for loading and unloading a ship's cargo. These responsibilities, in general, are covered under four types of terms: free-in-and-out, free discharge, gross terms, and berth terms. When free-in-and-out terms are specified in a ship charter, the charterer[8] is responsible for the loading and the unloading of the cargo. If free discharge is specified, the charterer pays for the unloading of the ship, and the owner of the ship is responsible for the loading, whereas in the gross terms case, the shipowner is responsible for both, the loading and the unloading of the ship. Berth terms means that the contract of carriage

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[8] The charterer is a person or company who hires a ship from a shipowner for a period of time or who reserves the entire cargo space of a ship for the carriage of goods from a port or ports of loading to a port or ports of discharge.

is subject to the customs and conditions of the ports of loading and discharging (U.S.D.A., 1988).

Loading and unloading costs are usually included in the shipping rate charged per unit of weight, so these rates will vary according to the terms under which a cargo is shipped. Then, a higher rate per M.T. should be charged when the owner is responsible for loading and unloading costs and a corresponding lower rate should be charged when the charterer is responsible for taking care of all or part of these costs.

Table 7 reports the number of shipments, average rate charged per metric ton, and average size of shipment by type of shipment terms. Note that most rice was shipped under free-in-and out terms, and free discharge terms. Some cargoes were sent under berth terms arrangements. Four shipments, out of the total sample of 89 observations, were sent under liner terms, which is a specific case of gross term agreement, in which loading and unloading expenses are paid by the shipowner (U.S.D.A., 1988).

It appears that, in general, shippers from the U.S. prefer to be responsible just for the unloading of the rice cargo, leaving the responsibility of loading to the shipowners. For Non-U.S. shippers the trend is the opposite; they would rather assume the responsibility for loading and unloading a ship than incur an increase in shipping rates by letting shipowners assume all or part of

Table 7. Number of Shipments, Mean Rate, and Mean Size of Shipments by Terms of Shipment, 1990-1991

Terms of Shipment	Percent of Total Shipments	U.S. Shipments with ...	Average Shipment Size	Average Rate
	(%)	(%)	(M.T.)	($/M.T./d)[1]
Free-in-and-out	36.7	21.0	9592.1	0.92
Free discharge	43.3	100.0[2]	6894.2	3.11
Berth terms	15.6	100.0[2]	10238.2	2.26
Liner terms	4.5	25.0	5192.5	2.46

[1] ($/M.T./d) means dollars per M.T., adjusted by distance (100 maritime miles).

[2] 56.4 percent of shipments with free discharge terms used U.S. flag. This percentage was 42.8 for the case of berth terms agreement.

Source: Maritime Research Inc., Chartering Annual 1990 and Chartering Annual 1991.

this responsibility. U.S. flag vessels were used in 56.4 percent of U.S. rice shipments with free discharge terms, Similarly, 42.8 percent of shipments with berth terms used U.S. flag vessels to move rice cargoes from the U.S. Thus, this situation explains, at least partly, the fact that the U.S. shipments have the greatest ocean freight rates per weight and unit of distance (U.S.$ 3.11 per M.T. per 100 miles in free discharge terms, and U.S.$ 2.26 in berth terms, versus U.S.$ 0.92 per M.T. per 100 miles in free-in-and-out terms).

It is important to note in Table 7 that berth term agreements are also used for rice cargoes departing from the United States. Probably, in these cases, loading is the responsibility of the shipowner (explaining also the relatively high freight rate), and discharging is subject to the customs and conditions of the destination port.

Although not reported in this sample, a high proportion of the shipments moved under gross terms usually go to underdeveloped regions in Africa and Asia. When cargo handling facilities are poorly developed, as they are in most developing countries, rice shippers appear to be more likely to allow shipowners to assume the responsibility for loading and unloading the ship (Harrer, 1979).

Besides terms of shipping, there may be other factors which potentially contribute to the additional unit freight rates found for U.S. shipments. Flag of registry and Cargo preference policies are good examples.

Seasonality

The effects of seasonality are relatively stronger on the shipping of agricultural commodities than on other products, because most agricultural commodities traded in international markets are seasonally produced in temperate climates, primarily in the northen hemisphere. Adding to this characteristic, the fact that the suitability of the sea for shipping is influenced by the season of the year, one might expect that these factors influence the volumes of rice traded, as well as the transportation rates charged.

The number of shipments, total tonnage, and average rates charged per M.T. in each quarter of the year, by main origin, are presented in Table 8. Note that the effects of season of the year on the volume shipped from a particular origin region are different for the case of the U.S. and the Asian countries. During the winter period of January through March, a relatively small number of shipments, and volume of rice are transported from the U.S.; these values increase, however, during April-June, until those periods of the year corresponding to winter and fall in the United States. Shipments and volume of rice transported from Asia to different destinations seem to have a stable pattern

Table 8. Number of Shipments, Total Tonnage, and Mean Rate Charged for Rice Cargoes by Quarter of the Year, According to Main Origin, 1990-1991

	U.S.	Asia	Total
January-March			
- % of Shipments	8.9	35.1	16.0
- Total Tonnage	47,653	58,630	118,283
- Mean Rate ($/M.T./100 m.)	2.8	1.0	1.7
April-June			
- % of Shipments	20.3	22.5	19.8
- Total Tonnage	109,234	37,631	146,865
- Mean Rate ($/M.T./100 m.)	3.3	0.9	2.6
July-September			
- % of Shipments	36.1	27.5	32.9
- Total Tonnage	193,959	45,970	243,629
- Mean Rate ($/M.T./100 m.)	1.7	2.2	1.8
October-December			
- % of Shipments	34.7	14.9	31.3
- Total Tonnage	186,798	24,749	231,147
- Mean Rate ($/M.T./100 m.)	3.2	0.4	2.7

Source: Maritime Research Inc., Chartering Annual 1990 and Chartering Annual 1991.

throughout the year, decreasing slightly during the last months of the year (October-December).

In terms of unit freight rates, in general, there is no clear pattern during the year. On average, freight rates of the Asian countries were lower than those of the U.S., except for the months of July-September, in which the opposite occurs (2.2 dollars per M.T. per 100 miles for Asia versus 1.7 dollars per M.T. per 100 miles for the U.S.).

Summary

As a region, Asia has been a critical component of the world rice economy because its people have eaten rice as a staple food for thousands of years. Asia has also been the major rice producing region, and a major participant in the rice world trade. Major rice consuming, producing, and trading countries include China, Bangladesh, India, Indonesia, and Thailand.

Recent growth in the production and exports of rice in Asian countries has greatly affected the competitive position of U.S. rice in international markets. Transportation costs for carrying rice from the U.S. to the world markets has been one of the major factors affecting this U.S. competitive position.

U.S. fleet vessels can be viewed as two types: U.S. flag vessels and non-U.S. flag vessels. There has been a large difference in transportation rates between the two, with the U.S. flag vessels operating at much higher costs. The most important way for U.S. flag ships to continue operating and competing in the world market has been through government subsidization. For instance, U.S. cargo preference law requested that 75% of government-assisted rice exports be carried on U.S. flag vessels during 1990.

There are three major types of vessels for U.S. rice exports: liner, tanker, and tramp. Tramp vessels are the most important transportation means for carrying U.S. rice to the world market. They accounted for the largest part of U.S. rice shipments. Tankers are the least important vessels for U.S. rice exports.

There are four categories of terms of shipments in the world market: free-in-and out, free discharge, berth terms, and liner terms. The first two are the most important for transporting rice. The rice cargoes from the U.S. were mostly associated to free discharge terms, in which shippers are responsible for unloading, and shipowners are responsible for loading the rice. Most of non-U.S. shippers would rather assume the responsibility for loading and unloading a ship.

The majority of rice was shipped on U.S. flag vessels with the present sample. Other important non-U.S. flag ships included those of Cyprus, Greece, Jamaica, Panama, and Liberia. Likewise, rice transported from U.S. and Asia to different destinations seem to have a stable pattern throughout the year. Exceptions to this rule are the periods from January to March in the U.S., and from October to December in the Asian region.

CHAPTER III

METHOD AND DATA REQUIREMENTS

This chapter begins with a summary of the theoretical development of spatial equilibrium models. Then, the reactive programming model is presented in terms of its mathematical structure, and of its main operational characteristics. The second part of the chapter examines detailed information about those importing and exporting countries participating in the analysis, as well as the procedures used to estimate ocean freight rates, excess supply and demand functions, and other useful tools for the formulation and development of the mathematical programming used in this study.

Spatial Equilibrium Analysis

The theory of comparative advantage was formulated by David Ricardo to explain international trade patterns and proclaim its benefits. The construction of a general theory of location and space has been a challenge to economists since that time. In the quest for a general theory which considers the space dimension as well as other dimensions as a determinant of economic activities, one foundation stone was the general equilibrium theory, as elaborated by Walras

(1874)[9], Pareto (1909), Cassel (1923), Wicksell (1934), and their modern counterparts elaborated by Hicks (1937), Mosak (1944), Samuelson (1947), also Arrow and Debreu (1954) (cited by Takayama and Judge, 1971). However, these works were concerned with an economy in which all primary, intermediate, and final commodities were located at one point in space, and product transfers were accomplished with zero time and transport costs. General Equilibrium Models were and are amply used for comparative static evaluations of the effects of different policy issues on the behavior of the agricultural and non-agricultural sector of the economy (Norton and Hazzel, 1985; Adelman, 1986; Hertel and Tsigas, 1988; Sadoulet and de Janvry, 1992).

With the formulation of the transportation model by F.L. Hitchcock (1941)[10], economists were able to make great strides toward quantifying the locational advantages of different regions, and to obtain the least-cost flows of goods among regions based on predetermined supplies and requirements at the respective supply points and consumer centers.

It was in 1951 that Enke used a simple electric circuit

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[9] Years in parenthesis represent those years when the major publications were issued.

[10] The Russian L.V. Kantorovich formulated the first specification of the transportation problem in 1939, but his work became known in the West about a decade later (Paris, 1991).

to illustrate the equilibrium prices and quantities that resulted in a static model. The circuit was compared to the method of solution with digital computers and electronic differential analyzers. The main objective was to find a solution that could be used to determine the net price in each region, the amount of trade, the identification of exporters and importers, the aggregate trade in the community, and the general trade pattern (Enke, 1951). On this development, Samuelson (1952) showed how the general non-normative problem of partial equilibrium among spatially separated markets, as formulated by Enke, could be converted into a minimum-transport-cost problem in which standard mathematical programming could be used as a tool of analysis. The problem can be solved by trial and error of a systematic procedure consisting in varying shipments in the direction of increasing social payoffs.

Beckmann and Marschak (1955) modified the spaceless general activity analysis model of production and market allocation, to make it additive over discrete geographical areas. They described the technological relations between areas by transfer activities which express the possibility of flows of commodities from one region to another.

McKenzie (1954) used the activity analysis model elaborated by Samuelson, to present proof of the efficiency of competition and free trade in spatial equilibrium models of world production and trade, and to suggest the applicability of the activity analysis model to the theory of international trade. This model was subsequently extended by Takayama and Judge (1964), through the explicit introduction of transportation activities. In fact, Takayama and Judge used linear price dependent demand and supply functions to define an empirically oriented "quasi welfare function", extending the Samuelson (1952) and Beckmann and Marschak (1955) spatial models so that the spatial structure of prices, production, allocation, and consumption for all commodities could be determined within the model. They also proposed an algorithm which could be used to obtain directly and efficiently the competitive price and allocation solution (Takayama and Judge, 1971)

Tramel and Seale (1959, 1963) developed the Reactive Programming algorithm, which provides for the simultaneous determination of equilibrium shipping patterns between spatially separated producing areas and markets. This algorithm works either with fixed supplies at points of production and demand functions for the specified markets, or both supply and demand functions, and for making such calculations for either one or two competing products from one or more producing areas to one or more markets.

The Reactive Programming Model

In the late 1950's, Tramel and Seale (1959) introduced reactive programming, a spatial equilibrium model, useful for obtaining competitive equilibrium prices, quantities, and flows of a commodity between areas, given demand schedules, fixed or changing supplies, and transportation cost functions or constant unit transportation costs. Since its first formulation, many modifications in the algorithm have increased its efficiency as well as its ability to handle many diverse situations (Tramel and Seale, 1965; Hawks, 1970).

Reactive programming is, in fact, a spatial equilibrium computational procedure for solving a wide variety of interregional and international problems. It can be used to obtain a minimum cost spatial equilibrium solution in markets that may be characterized by linear or log-linear demand and supply relationships, fixed demand or supply quantities, two products produced and consumed, different time periods and regions of supply and demand, or various combinations of these conditions. With further modifications the program has also been used to determine spatial equilibrium in a market where a single product has two uses (Riley, 1974).

Mathematical Structure of the Model

A common "transportation problem" is a special type of linear programming problem in which fixed supplies in each of m regions are to be allocated to meet fixed demands in n markets, to minimize total transfer costs. Shipments from region i to region j are identified as Q_{ij}, the transport cost of one unit of product from origin i to destination as T_{ij}, and total transfer costs as $\Sigma_i\Sigma_jT_{ij}Q_{ij}$[11]. Shipments from each region may not exceed the quantity supplied ($\Sigma_jQ_{ij} \leq S_i$), and receipts at each market must be at least equal to the quantity demanded ($\Sigma_iQ_{ij} \geq D_j$). No negative shipments are allowed ($Q_{ij} \geq 0$).

The dual of this transportation problem can be formulated as follows:

Maximize $R = \Sigma_jD_jV_j - \Sigma_iS_iU_i$

subject to $V_j - U_i \leq T_{ij}$

$U_i, V_j > 0$

where U_i : shipping point prices

V_j : market prices

D_j : fixed demanded quantity

S_i : fixed supplied quantity

T_{ij} : transport cost of one unit of product from origin i to destination j

The objective in this dual formulation of the transportation problem is to maximize the difference between the value of market receipts and the cost of quantities supplied, that is $R = \Sigma_jD_jV_j - \Sigma_iS_iU_iR$, subject to the

[11] The primal transportation problem is specified as (Nesa and Coppins, 1981):

Minimize Transport Cost = $\Sigma_i\Sigma_jT_{ij}Q_{ij}$

Subject to: $\Sigma_jQ_{ij} \leq S_i$ (S_i is supply, $i = 1,...,m$)
$\Sigma_iQ_{ij} \geq D_j$ (D_j is demand, $j = 1,...,n$)
$Q_{ij} \geq 0$

restrictions that $V_j - U_i \leq T_{ij}$ and the aforementioned constraints for U_i and V_j.

Reactive Programming is an extension of this dual transportation model that allows substitution of supply and demand functions for the fixed supply and demand quantities respectively (King and Gunn, 1981). There is a price-dependent demand function in each market in which the price of the commodity in demanding region j is a function of the total quantity received:

$$P_j = F_j\ (\Sigma_i Q_{ij}),\ i = 1,\ldots,m$$

$$\text{where } \Sigma_i Q_{ij} = D_j$$

The unit cost of production in the ith producing region is C_i, represented by:

$$C_i = G_i\ (\Sigma_j Q_{ij}),\ j = 1,\ldots,n$$

$$\text{where } \Sigma_j Q_{ij} = S_i$$

The net price for quantities shipped from region i to market j is $R_{ij} = P_j - C_i - T_{ij}$. The weighted average net price for all shipments from i is $R_i = \Sigma_j R_{ij} Q_{ij} / \Sigma_j Q_{ij}$. Deviation of the net price for a given route, R_{ij}, from the weighted average net price for all shipments from that region, R_i, is D_{ij}, where $D_{ij} = R_{ij} - R_i$.

The reactive programming model is formulated to solve the following m x n equations:

$$R_{ij} = F_j\ (\Sigma_i Q_{ij}) - T_{ij},$$

$$i = 1,\ldots,m, \quad \text{and} \quad j = 1,\ldots,n;$$

Subject to the following restrictions:

(1) Negative shipments are not permitted, i.e.

$$Q_{ij} \geq 0$$

(2) a. Net prices for all routes used by region i must be non-negative and equal to each other.

$$Q_{ij} \neq 0 \rightarrow R_{ij} = R_i \geq 0$$

b. Net prices for all routes not used by region i must be no larger than the net price for active routes.

$$Q_{ij} = 0 \rightarrow R_{ij} \leq R_i \geq 0$$

(3) Deviations from weighted average net prices are non-positive.

$$D_{ij} = R_{ij} - R_i \leq 0$$

a. Equality holds for active routes (see 2(a) above).

b. Either condition may hold for other routes (see 2(b) above).

(4) Shipments from region i may not exceed supply.

a. $R_i > 0 \rightarrow \Sigma_j Q_{ij} = S_i$

b. $R_i = 0 \rightarrow \Sigma_j Q_{ij} \leq S_i$

Supply is fully allocated if the weighted average net price is positive, but this is not necessary if net price is zero.

Operation of the Model

The operation of the reactive programming algorithm, as summarized by King and Ho (1972), is as follows. An initial set of supply and demand quantities is selected and a linear programming subroutine is used to allocate supplies among the markets. A market price is calculated from the demand function for each of the consuming areas. By subtracting transportation costs from these market prices, net shipping point prices are obtained for the shipments in the initial allocation. A new level of output for the first shipping area is selected consistent with the net revenue received. This new quantity is then allocated among markets so as to maximize net returns, given the market prices and previous shipping patterns of all other shippers.

The same process is repeated for the second shipping area given the behavior of all other shipping areas. The iterative routine continues until it is not profitable for any shipping area either to change the level of output, or to reallocate supplies.

To expedite obtaining an equilibrium solution the linear programming subroutine is called at least every 20 iterations[12]. Individual supply points reaching equilibrium may be temporarily ignored in subsequent iterations but again reevaluated after at least each 20 iterations. In addition, a rough level of accuracy may be accepted as a computer time saving device.

Several variations of the basic program are currently available. Supplies and/or demands may be treated as fixed or entered in functional form. Upper limits may be placed on one or more supply areas.

The main objective of this study was to evaluate the

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[12] One iteration considers all supply markets.

effects of changes in ocean freight rates on the international rice market flows, considering the competitive position of each country or region. Thus, it seemed to be more appropriate to use functional forms rather than fixed supply and demand quantities. This was done to obtain flexible import and export volumes and equilibrium prices. Consequently, the reactive programming model used here utilizes functional forms of excess supplies (export volumes) and excess demands (import volumes).

Assumptions of the Study

Specific assumptions on which the present study was based are basically the following:

a. Transportation rates in exporting and importing countries or regions could be represented by those rates estimated for a single port in that country or region.

b. Even though there are many different varieties of rice traded in the international market, for our purposes all rice was assumed homogeneous.

c. Excess of supply and excess of demand functions are readily available for each exporting and importing country or region.

d. The efficiencies of all ports in the study were assumed the same and had no impact on shipping rates.

Data Requirements

The 1990 calendar year was selected as the data base for this study. The main reason was data availability.

There were three basic components of the reactive programming model in this study, for which it was necessary to collect data: (i) excess supply functions, (ii) excess demand functions, and (iii) ocean freight rates. Specific data requirements for each component is described in next subsections.

Spatial Demarcation

Since the emphasis of this study was on international trade in rice, spatial demarcation was made on a country basis. This was so done because a country represents a logical unit in international trade, and because the data on rice is generally available on national levels.

Each nation is generally represented by one or two ports in such a way that the shortest navigable route between each pair of origin-destination points could be used in order to estimate the distances between two certain ports in two different countries. For instance, Bombay was used to represent India when trade takes place between India and any western area. Calcutta represented India in its trade with any eastern area. In few cases only one port was used to represent two or more neighboring countries, due to distance data availability. For example, Buenos Aires was used to represent Argentina, but in some cases this same country was represented by Rio de Janeiro. New Orleans was the port representing the U.S. in this study.

Due to data availability concerning elasticities and/or distances, the world rice market was divided into 12 exporting countries and one exporting region, as well as 43 importing countries or regional groups. Table 9 presents the list of the countries and regions mentioned.

Estimation of Excess Supply Functions

Price-dependent excess supply functions for each exporting country may be derived directly from the data using regression analysis. However, in the present study, excess of supply functions were formulated indirectly, using secondary data.

Linear price-dependent excess of supply functions were formulated for exporting countries using data from 1990 production, consumption, stocks, and trade. Estimates of domestic elasticities, coming from other studies, were used to calculate price elasticities of excess supply, which were in turn used to generate the linear price-dependent excess supply and demand functions (Bredhal et al., 1979). There are exactly the same number of price-dependent excess supply functions as there are exporting countries and regions.

Table 9. Rice Exporting and Importing Countries or Regions, and Their Representative Ports, Used to Calculate Distances, and to Estimate Ocean Freight Rates Utilized by the Reactive Programming Model

Countries or Regions Included	Representative Points (Ports)	Countries in the Regions
Exporters		
Argentina	Buenos Aires	
Australia	Geelong	
Burma	Bassein	
China	Shangai	
India	Bombay, Calcutta	
Italy	Venice, Palermo	
Pakistan	Karachi	
Spain	Valencia	
Thailand	Bangkok	
U.S.	New Orleans	
Uruguay	Montevideo	
Vietnam	Ho Chi Minh	
Ot.S.America[1]	Guayaquil	Colombia, Ecuador, Venezuela, Chile, Guyana, Surinam, Paraguay
Importers		
Angola	Luanda	
Cameroon	Duala	
Ghana	Accra	
Guinea	Conakry	
Liberia	Monrovia	
Madagascar	Diego Suarez	
Mauritania	Dakar	
Nigeria	Lagos	
Reunion	Reunion	
Senegal	Dakar	
Sierra Leona	Conakry	
Somalia	Mogadiscio	
South Africa	Capetown	
Tanzania	Dar es Salaam	
Zaire	Luanda	
Ot.S.S. Africa[2]	Dar es Salaam Luanda	Chad, Burkina, Ivory Coast, Mali, Benin, Gambia, Morocco, and Niger

(Continued)

Table 9. (Continued)

Countries or Regions Included	Representative Points (Ports)	Countries in the Regions
Bangladesh	Chittagong	
Hong Kong	Hong kong	
Indonesia	Jakarta, Surabaya	
Malaysia	Penang	
Philippines	Manila	
Singapore	Singapore	
Sri Lanka	Colombo	
Taiwan	Kaohsiung	
Ot.S.Asia[3]	Karachi	Afganistan, Nepal
Ot.E.As./Oc.[4]	Surabaya	Brunei, Cambodia, Laos, and Papua-New Guinea
E.C.10[5]	Bordeaux	Belgium, Luxemburg, Denmark, France, West Germany, Greece, Ireland, Netherlands, Portugal, U.K.
Ot.W.Europe[6]	Marseilles	Austria, Finland, Norway, Switzerland, Swaziland, Sweden
East Europe	Rejika	Bulgaria, Czechoslovakia, Hungary, East Germany, Poland, Romania, Yugoslavia
Ex-U.S.S.R.[7]	Odessa, Vladivostok	
Brazil	Rio de Janeiro	
Canada	Victoria	
Cuba	Havana	
Mexico	Tampico	
Peru	Callao	
Ot.C.A./Carib.[8]	Kingston	Guatemala, Jamaica, Nicaragua, Salvador, Costa Rica, Honduras

(Continued)

Table 9. (Continued)

Countries or Regions Included	Representative Points (Ports)	Countries in the Regions
Iran	Abaden	
Iraq	Basrah	
Kuwait	Kuwait	
Saudi Arabia	Jeddah	
Syria	Lattakia, Beirut	
U.A. Emirates[9]	Bandar Abbas	
Ot.Md.E./N.Af.[10]	Alexandria	Libya, Oman, Qatar Algeria, Cyprus, Israel, Jordan, Lebanon, Morocco, Turkey, Yemen

[1] Other South American countries.
[2] Other Sub-Sahara African countries.
[3] Other South Asian countries.
[4] Other East Asian and Oceania countries.
[5] E.C.10 refers to those 10 Europe Community countries that do not export rice (Spain and Italy are excluded).
[6] Other West European countries.
[7] Former Union of Soviet Socialist Republics.
[8] Other Central American and Caribbean countries.
[9] United Arab Emirates.
[10] Others Middle East and North African countries.

The general procedure required to calculate excess supply elasticities for exporters is expressed mathematically as:

$$Eesj = (Esj-Edj)\frac{Qdj}{Qxj} + Esj \qquad (1)$$

where

Eesj = elasticity of excess supply in exporting country or region j

Esj = elasticity of domestic supply in exporting country or region j

Edj = elasticity of domestic demand in exporting country or region j

Qdj = level of domestic demand of exporting country or region j, for 1990

Qxj = excess supply (exports) of exporting country or region j, for 1990

Thus, to calculate the elasticities of excess supply, Eesj, for 13 exporting countries or regions, elasticities of domestic supply in each exporting country or region (Esj), elasticities of domestic demand in each exporting country or region (Edj), domestic demand of each exporting country or region (Qdj), and export volumes of each exporting country or region (Qxj) were needed.

Domestic demands (Qdj) and export volumes were taken directly from data reported by the Foreign Agricultural Service (U.S.D.A., 1991). Domestic demand and supply price elasticities were taken from U.S.D.A.'s Trade Liberalization Database (Sullivan et al., 1989; Gardiner et al., 1989), and complemented by other sources (Tyers and Anderson, 1986; Rojko et al., 1978; Liu and Roningen, 1985; Zhang, 1990b). Accordingly, the price elasticities of excess supply for each exporting country or region could be estimated by equation (1) above, as shown in Table 10.

After the elasticity of excess supply was estimated, a linear price-dependent excess of supply function was approximated, to be used with the reactive programming model, in the following way:

$$Pxj = c + d\ Qxj \qquad (2)$$

where Pxj : export price (F.O.B.) of exporting country or region in 1990, derived from total export values divided by export volumes for each exporting country or region j

Qxj : export quantities in 1990 (1000 M.T.), for each exporting country or region j

Estimates of coefficients c and d were derived from the formula of the price elasticities of supply and values of the variables Pxj and Qxj, specified in equation (2). The procedure is conveniently summarized in the following way:

$$Eesj = \frac{\Delta Qxj}{\Delta Pxj} \cdot \frac{Pxj}{Qxj} \qquad (3)$$

Thus,

$$Eesj = \frac{Pxj}{Qxj} \cdot \frac{1}{\Delta Pxj/\Delta Qxj} \qquad (4)$$

Table 10. Derivation of Price Elasticities of Excess Supply for Exporting Countries or Regions, Used to Estimate Price-dependent Excess Supply Functions

Exporting Countries or Region[1]	Elasticities of: Domestic[2] Supply (Esj)	Elasticities of: Domestic[2] Demand (Edj)	1990 Domestic Demand (Qdj)[3]	1990 Export Volume (Qxj)	Elasticity of Excess Supply (Eesj)[4]
			-----(1,000 M.T.)----		
Argentina	0.80	-0.40	156	70	3.474
Australia	0.60	-0.45	172	470	0.984
Burma	0.03	-0.06	7050	186	3.441
China	0.07	-0.05	123059	300	49.294
India	0.40	-0.50	71633	420	153.899
Italy	0.20	-0.14	340	595	0.420
Pakistan	0.03	-0.14	2250	904	0.453
Spain	0.48	-0.40	272	110	2.656
Thailand	0.33	-0.10	8600	3927	1.272
U.S.	0.40	-0.25	2709	2424	1.126
Uruguay	0.15	-0.20	85	250	0.269
Vietnam	0.20	-0.15	10460	1500	2.641
O.S.America	0.55	-0.40	2142	179	11.918

[1] See footnote of table 9 for regions' shorthand.

[2] (Sullivan et al.,1989; Gardiner et al., 1989; Tyers and Anderson, 1986; Rojko et al., 1978; Liu and Roningen, 1985; Zhang, 1990b).

[3] Domestic demand includes apparent consumption, annual stock changes, and allowances for feed, seed, and waste.

[4] $$Eesj = (Esj-Edj)\frac{Qdj}{Qxj} + Esj$$

Since,

$$\frac{\Delta Pxj}{\Delta Qxj} = d$$

Then,

$$Eesj = \frac{Pxj}{Qxj} \cdot \frac{1}{d}$$

And "d" and "c" can be estimated as

$$d = \frac{Pxj}{Qxj} \cdot \frac{1}{Eesj} \qquad (5)$$

$$\text{and} \quad c = Pxj - dQxj \qquad (6)$$

After the intercept and slope coefficients are derived, and in order to get an operationally feasible specification, the price-dependent excess supply equations for 13 exporting countries and regions were calculated from the above formulas as shown in Table 11.

Estimation of Excess Demand Functions

Similar to the derivation of elasticities of excess of supply, the elasticities of excess demand for importing countries and regions were calculated according to the following formula (Bredhal et al., 1979; Tomek and Robinson, 1990):