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I am submitting herewith a dissertation written by Richard Sakian Gunting entitled "An Empirical Estimation of the Demand Functions for U. S. Rice." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Agricultural Economics.

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AN EMPIRICAL ESTIMATION OF THE DEMAND FUNCTIONS FOR U.S. RICE

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ABSTRACT

This study was concerned primarily with the distribution of U.S. rice and its by-products domestically and abroad. A simultaneous equation demand model was developed and estimated using the three-stage least squares (3SLS) technique, while a multiple regression supply model was formulated and estimated employing ordinary least squares (OLS) technique. Annual time-series data, obtained from secondary sources and covering the period (1950-78), were utilized in the estimations of both these models. The price and income elasticities or flexibilities were determined from the supply and demand results which were evaluated at the mean values of the selected periods (1950-71, 1950-78 and 1972-78). The reduced form coefficients were also derived from the 3SLS estimates of the demand model in order to examine the impacts of a given change in a predetermined variable on each of the endogenous prices and quantities of U.S. rice.

The results of the demand model indicated that corn was a substitute for milled rice used for food while barley was a substitute for brewer rice. Wheat bran was also found to compete with rice millfeed. The farm price of rice was affected by the quantity of rough rice milled; the quantity of milled rice used for food influenced the retail price of rice; and the quantity of rice millfeed was found to affect the price of the rice bran. The U.S. export price of rice influenced the quantities of U.S. rice exports demanded in Asia and Africa, but not in Europe and the Western Hemisphere. Except for the Western Hemisphere, the regional per capita incomes were important shifters of the regional demand for U.S. rice exports. The U.S. rice exports faced a considerable competition from rice exports of other rice exporting countries.

The demand for U.S. rice exports in Asia and Africa were found to be inelastic compared to the domestic demand for U.S. rice when they are evaluated at the mean values of the period (1972-78). Thus, the total revenue from U.S. rice exports in Asia and Africa could be increased by increasing the U.S. export price of rice; and the total revenue from the sale of U.S. rice domestically could be raised by reducing the domestic prices of U.S. rice.

According to the impact multiplier analysis, any policy geared to stabilize the farm price of rice and income by regulating the U.S. rice production seemed to be ineffective. Any changes in the U.S. export price of rice and the volume of U.S. rice exports, resulting from a change in a domestic factor, did not seem to influence the international rice trade. On the contrary, any changes in the volume of world rice exports were indicated to affect the quantities and the prices of U.S. rice. Also, a given change in the world per capita income was found to increase the demand for world rice exports as well as the demand for U.S. rice exports in Asia. Finally, the price of U.S. rice was indicated to be positively related with the world price of rice.

The U.S. rice supply was influenced by the last year's ratio of the farm price of rice to the support price of rice, the previous year's U.S. rice acreage harvested and the lagged government rough rice ending stocks. The elasticity of U.S. rice acreage harvested with respect to the previous year's ratio of the farm price of rice and the support price of rice was found to be inelastic.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Rice is a grain cereal plant, known botanically as Oryza sativa, widely cultivated for its edible seed. In terms of the worldwide acreage planted and total production, it is second to wheat in the cereal category of plant foods of man. For instance, in 1977 the world total wheat production was approximately 382 million metric tons while the world total rough rice production was about 367 million metric tons.

Rice is mainly grown in Asia which accounts for about 90 percent of the world total rice production. The Western Hemisphere produces roughly 6 percent of the world rice production while the balance is shared by Africa, Europe and Oceania. Some of the major rice producing countries in Asia include China, India, Indonesia, Japan, Thailand, Bangladesh, Khmer Republic, Pakistan and Burma. The U.S. is the largest producer of rice in the Western Hemisphere, while the leading rice producing country in Europe is Italy and the largest producer in Oceania is Australia. Egypt and Malagasy are the major rice producers in Africa.

Rice is the staple food grain of about one-half of the world's population. Its consumption is mostly concentrated in Asia and to a lesser extent, but with increasing importance, in Africa, Europe and the Western Hemisphere. Unlike wheat, rice is primarily consumed where it is grown. Only about 4 percent of the world total rice production enters the international trade. The chief exporters of rice are the U.S., Thailand, Pakistan, Burma, China, Brazil, Italy and Australia. There seems to have been considerable competition in the export market between the U.S. and Thailand in the past two decades. However, the U.S. had led the world in rice exports since 1978.

Due to the climatic conditions, rice is largely grown in the southern parts of the U.S. such as Arkansas, Texas, Louisiana, Mississippi, California and Missouri. U.S. rice acreage harvested reached almost the three million acre mark with the rough rice production of about 85 million cwt. in 1978. In that same year, the U.S. accounted for roughly 30 percent of the total rough rice produced in the Western Hemisphere but only 1.6 percent of the world total rough rice production.

While U.S. rice production is a relatively small part of the world rice production, the U.S. exports the majority of that production, and these exports are a significant portion of world rice trade (approximately 26 percent in 1978). For example, in 1978 approximately 63 percent of the U.S. total milled rice disappearance was exported. The balance was used domestically for direct food, processed food and beer brewing. At least in the past two decades, the rate of increase in the U.S. rice exports has been generally faster than the increase in domestic utilization. This clearly suggests the importance of exports in the U.S. rice market economy.

It is evident that the U.S. plays an important role as a supplier of rice in the international market, particularly in the event of worldwide shortage in rice supply such as occurred in 1971 and 1972. During this period, the sudden reduction in the world rice supply, due to unfavorable weather conditions, resulted in a worldwide rice shortage which pressured the world price of rice to rise above the U.S. support price. This increased the demand for U.S. rice exports. At this time the U.S. rice export payments, which were started in December, 1958, were discontinued. This sudden increase in the quantity demanded for U.S. rice exports caused the U.S. rough rice ending stocks to drop significantly to their lowest points in recent history. However, increases in the worldwide rice production in 1974, in response to the higher prices as well as the return of better weather conditions, drove the world price level down again to a level slightly above that of 1971.

The U.S. rice market economy is comprised of several domestic and export market outlets which are interdependent by virtue of necessary flows of rice from the farm level to these market outlets. Therefore, it is very important to consider the demand functions associated with each of these market outlets simultaneously in the formulation of a demand model for the U.S. rice market economy.

A. OBJECTIVES

The general purpose of this study is to determine the effects of certain economic variables on the production and marketing of U.S. rice. The most important of these variables are deduced from microeconomic theory with the observed flow of rice from farm production to consumption as the background. The principle objectives are:

1. To estimate the farm-level supply function of rough rice.
2. To estimate the demand function for U.S. rice in the various market outlets.
3. To analyze key exogenous variables that affect utilization levels and prices of U.S. rice.

B. REVIEW OF LITERATURE

Although rice first attracted much attention as a commercial crop in North Carolina in 1730 [7, p. 1], economic studies for U.S. rice are limited relative to major U.S. crops. In order to establish a frame of reference for this study, some past studies will be reviewed. The first 10 studies examined are somewhat less relevant to the analytical aspect of this study. However, they are useful in the conceptualization of the problem. The last two publications reviewed have major contributions in the conceptualization of the problem as well as the analytical framework for this research.

Timmer [24, pp. 191-196] suggested a linear programming (LP) framework in analyzing the generation of rice policies in Asia. This framework was designed to facilitate cross-country comparisons of rice policy formulation as well as the delineation of objectives, policies and constraints that were specific to each country or general for a set of countries under consideration.

In 1975, Timmer [23, pp. 197-231] published an article concerning the political economy of Indonesia. The author discussed the agronomic and economic setting of Indonesian rice culture with special attention to the history of rice policy. Modern Indonesian rice policies were discussed with the goal of understanding the types of overriding objectives, important constraints affecting policy choices and factors that drive the system. The article was concluded with an evaluation of modern Indonesian rice policy together with a prognosis that tentatively rejected the historical determinism that constantly concealed any discussion of Indonesian rice policy.

Siamwalla [21, pp. 233-249] examined the political and economic aspects of price determination for rice in Thailand. The study covered the period since 1851, but special attention was given to the period between 1955 and 1973. The author contended that the Thai government had never tried to influence prices by regulating production nor considered restricting domestic consumption. Thus, changes in volume of rice for domestic uses and prices were mainly affected by changes in the volume of rice exports. Given these circumstances, the author concluded that Thai domestic prices and export policies were inextricably linked.

An elaborate study in rice by Goldman [4, pp. 251-293] focused on the early development of Malaysian rice policy and the economic analysis of the self-sufficiency process. The author evaluated the efficiency of Malaysian rice policy with respect to foreign exchange, stabilization of domestic rice prices and redistribution of income. His findings indicated that a simultaneous rice policy of self-sufficiency and income distribution might have a small positive gain but a direct conflict between these policy objectives could emerge as well.

Realizing unstable production and a volatile rice market, Goldman [5, pp. 99-143] attempted to identify and measure the main factors affecting temporal rice price formation in Indonesia. The respective econometric models for wet-dry season rice output and seasonal prices were formulated with reference to a theoretical framework of intertemporal price theory. Using ordinary least squares (OLS) technique in the estimation, the results obtained indicated that the dry season crop was the key factor influencing the seasonal rice price instability, *ceteris paribus*.

In 1974, Timmer [22, pp. 145-167] examined the size of marketing margins between the rural stalk paddy price and the retail price of medium quality milled rice for the capital cities of eight provinces in Indonesia. Several alternative models reflecting certain set of assumptions were formulated and estimated using OLS technique. From the interpretations of results obtained, the author concluded that rural stalk paddy and retail prices were strongly interdependent for some part of the year. Thus, market connectedness was found important for understanding of Indonesian rice marketing and price formation.

Mangahas, Recto and Ruttan [14, pp. 685-702] determined the market surplus[1] of rice and corn for the Philippines as a whole and for nine major regions by means of the difference of actual output and consumption by subsistence crop producers. Simple regression and distributed lag models were used in the estimations of output response. From the results obtained, various elasticities were calculated. It was found that the short-run supply elasticities, calculated from an estimated hectarge response function, ranged from 0.10 to 0.30, while the market surplus elasticities ranged from 0.20 to above 1.00. Both market-surplus and supply elasticities for rice were generally found to be higher than that of corn. The authors further concluded that the prices of rice and corn could probably allocate resources fairly effectively, but there was little evidence to indicate rice and corn outputs were influenced by changes in prices. It was also found that price changes in the retail

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[1] Supply of rice and corn was not defined as the total amount produced, but rather the residual of current output after a significant portion of it has been deducted for home consumption.

levels of the marketing systems had contributed insignificant effects on farm prices which implied a small change in the marketing margins of both commodities.

In a somewhat similar study, Chin [1, pp. 583-586] determined the market surplus of paddy rice in Taiwan, a case in which the barter components were considered important. Specifying all variables in terms of natural logs, five equations consisting of total rice output, quantity sold, quantity bartered for household consumption items, quantity bartered for farm expenses and quantity consumed directly by farm households were formulated and estimated by means of OLS technique. Short-run and long-run elasticities were derived from the estimated equations. Different positive output elasticities for quantity sold, quantity bartered for farm expenses and quantity bartered for household consumption items were obtained. Chin concluded that disaggregating market-surplus was justified. Also, the total market-surplus elasticities were found to be lower than elasticities of quantity sold, indicating the negligence of the barter components of total market-surplus could result in serious overestimation of price and output responses.

Using the LP framework suggested by Timmer [24, pp. 191-196], Mears [15, pp. 319-357] discussed some relationships of the political environment to important developments in the U.S. rice economy relative to the world and particularly to the Asian rice economy. Problems such as the economic scene, the evolution of rice policies and their impact on desired goals and efficiency were discussed. Mears pointed out from his findings that low farm prices in the 1920's and 1930's had led policy makers to include production limitations, price support for farmers and surplus disposal. Although the need for a support price and for export subsidies was minimized (due to high world prices) in 1972, concessionary exports remained at relatively high levels. The author contended that in 1975, policy makers had begun to realize the need for appropriate review and possible revision of U.S. rice policies, somewhat similar to those implemented for many other basic commodities in 1973. For example, for the U.S. government to gain support for a reduced budgetary drain, less restriction on entry into production and reduction in consumer prices are necessary. This goal had attracted support from middlemen and some farmers, but other farmers--those constrained by technical factors (expansion of planted area)--were against it. The author contemplated that, provided priorities change, high support price for farmers with allotments and pressure for export expansion were likely to be maintained by the government.

In 1977, O'Carroll and Traylor [16] developed an econometric model to examine the principal factors affecting annual supply of and demand for U.S. rice. On the supply side, acreage planted and yield per acre were estimated individually. Then the production response was derived by the products of the estimated acreage planted and yield per acre. On the marketing side, domestic demand and exports were estimated. All components of supply and demand were estimated using OLS. The authors claimed to have used simultaneous equation methods of estimation but failed to obtain meaningful results. The estimated market relationships were then used in a simulation model to evaluate different rice reserve and target price strategies to determine the extent to which rice stocks in the U.S. can be used to provide price and income stabilization without depleting the U.S. reserves.

Using an econometric model, Grant and Leath [6] analyzed certain economic and institutional factors affecting supply, demand and prices of U.S. rice. They derived the production response for each major rice producing state (Mississippi, Arkansas, Texas, Louisiana, California and Missouri) utilizing the products of estimated acreage harvested and yield per acre.[1] The sum of the rice production from each state gave the U.S. total rice production. Treating annual U.S. rice supply as given for the marketing year, they developed a simultaneous equation model to estimate different equations reflecting different uses of U.S. rice such as feed, food, beer brewing, commercial exports, government exports, commercial ending stocks, government ending stocks, rice hulls and seed. U.S. rice prices such as farm price, brewer price, retail price, price for rice bran, U.S. export price and Thai export price of rice were also estimated in the system.

Results on the supply side indicated that acreage harvested was influenced by lag variables including farm price, private carryover and while yield per acre was affected by technological change and local climate in each state. Accordingly, U.S. rice production was influenced by factors affecting acreage harvested and yield.

On the demand side, population and income were found to influence food rice consumption but retail price of rice had an insignificant effect. Income affected the demand for brewer rice also. Rice millfeed was influenced by the total quantity of rice milled and the general

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[1] Acreage harvested and yield equation in the supply side were all estimated using OLS technique.

price level in the feed market. Variables such as U.S. and Thai export prices, government exports and U.S. rice production were found to influence U.S. commercial exports. It was also found that the commercial export price elasticity was less elastic than that of government export. The authors noted that the degree of substitution of the government and commercial exports was relatively small due to different types of markets involved, the quality of production demanded and credit terms.

CHAPTER II

THEORETICAL FRAMEWORK

A. ECONOMIC MODEL

The U.S. rice supply and utilization system involves the physical flows of rice from the farm to the consumption levels as well as certain economic factors that affect and accordingly alter the rate at which these flow processes occur. On the basis that the rice production and distribution system are at least reasonably competitive, the physical flows of U.S. rice can be schematically shown along with the economic pressures which cause these flows. These are presented in Figure 1.

In Figure 1, the solid lines represent the physical flows of rice from the farm levels to the various market outlets and the broken lines show the effects of certain economic variables on these flows. A broken line with a single arrow indicates only one direction of effect, while that with double arrows represents a simultaneous effect of the variables in question. The circles indicate all the quantities of rice and the squares denote all the prices of rice at various stages of the market system. Other economic variables influencing both production and the distribution of rice are contained in the rectangles. The valves indicate the points of impacts of a certain set of relevant variables on a particular physical flow of rice and the asterisk (*) denotes the endogenous prices and quantities of rice.

The upper section of Figure 1 indicates some selected factors affecting the production of U.S. rice through acreage harvested and

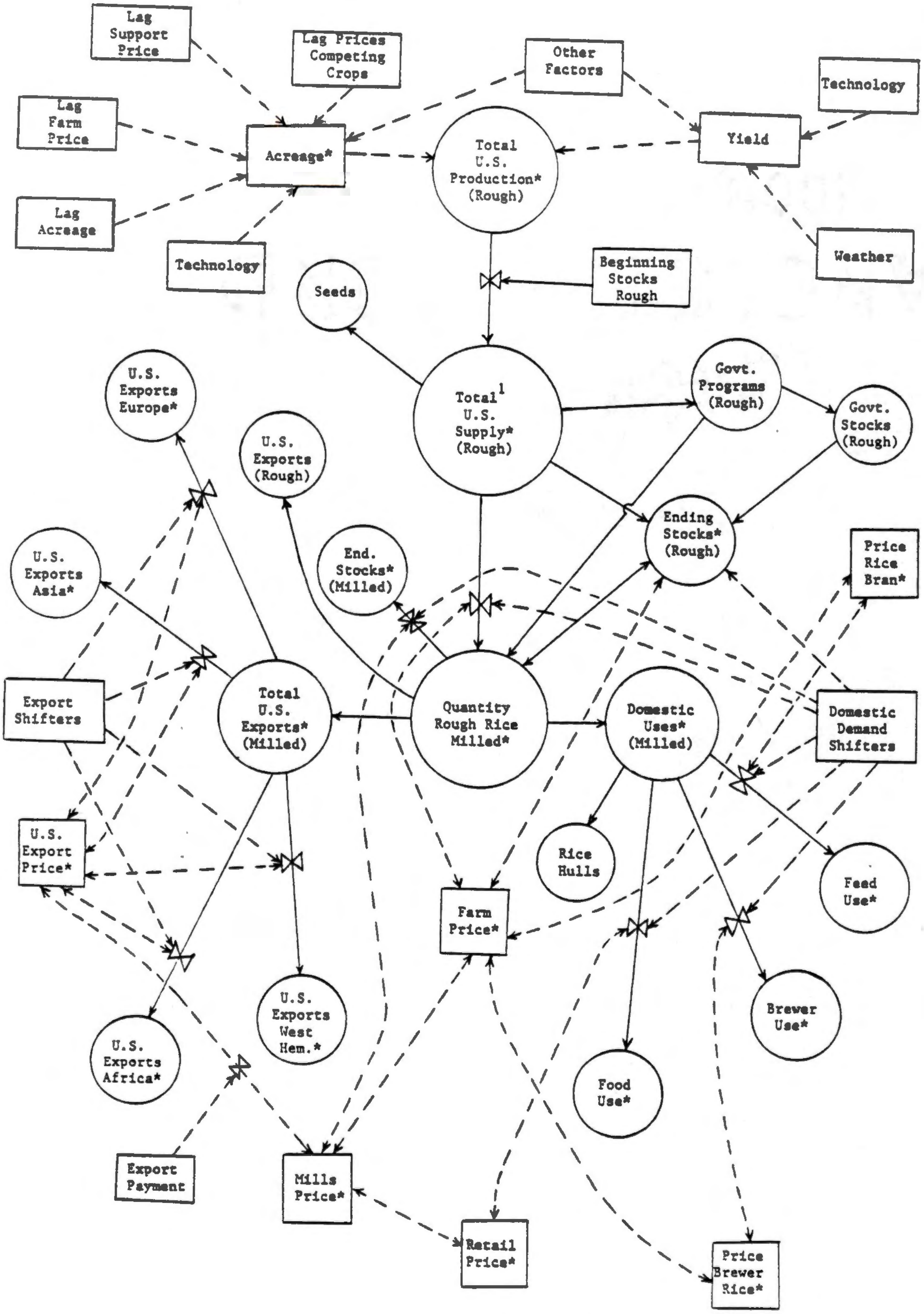

Figure 1. Production and Market Structure of U.S. Rice Economy

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[1] The U.S. total rough rice supply excludes (the extremely) small quanity of rice imports.

yield per acre. Yield per acre is influenced mainly by weather conditions and technology, while acreage harvested is affected by such lag variables as the farm price of rice, farm support price of rice, farm prices of competing crops and current technology. The rough rice supply is arrived at by adding rough rice beginning stocks to the current rough rice production.

During the marketing period, the current annual U.S. rough rice supply disappears into various government and commercial market outlets, leaving some surplus as ending stocks at the farm level. Some of these rice utilization systems and certain factors influencing them are depicted in the lower section of Figure 1.

The first rice transaction at the farm level involves the U.S. rice mills and government programs. The annual volume of rough rice flowing from producers to U.S. mills is expected to be determined by the farm price of rice received by farmers and some economic variables acting as shifters of the derived demand function. The other portion of rough rice moving into U.S. mills is from the government sectors which is assumed to be exogenously determined in this study.

The end product of rice mills, the total milled rice, is then distributed for exports, domestic uses and ending stocks. The by-products of rice milling are made up of hulls and brans. It is assumed that the domestic uses of milled rice and by-products such as for food, beer brewing and rice millfeed are influenced by the comparable prices of rice and certain set of demand function shifters, for example, income population and prices of substitutes and/or complementary goods.

U.S. milled rice exports are disaggregated into four components according to regional destinations.[1] These will enable a more accurate representation of U.S. rice exports with the assumption that a certain set of economic variables affecting each component reflect regional variations. Because of the lack of separate data for the U.S. commercial and government rice exports, they are treated in the same regional aggregate. The movement of U.S. rice exports to various regional destinations are hypothesized to be determined by the U.S., and the world export prices of rice and other U.S. rice export demand function shifters.

The total rough rice ending stocks comprising of both the government and private ending stocks are expected to be affected by the farm price of rice received by farmers and some stock function shifters. The private stocks are typically held for convenience and price expectation purposes because rice production is seasonal. The government stocks (through the Commodity Credit Corporation) are acquired by means of the price support loan program and direct purchase in the event of excess supply. Essentially, this portion of the total rough rice stocks is used to maintain the farm price of rice above the equilibrium level.

The milled rice ending stocks are privately held for convenience in a much smaller quantity compared to rough rice ending stocks. Unlike rough rice, milled rice production can easily be controlled by rice millers. Therefore, it is hypothesized that the levels of the milled rice ending stocks are determined by the mill price of rice and other

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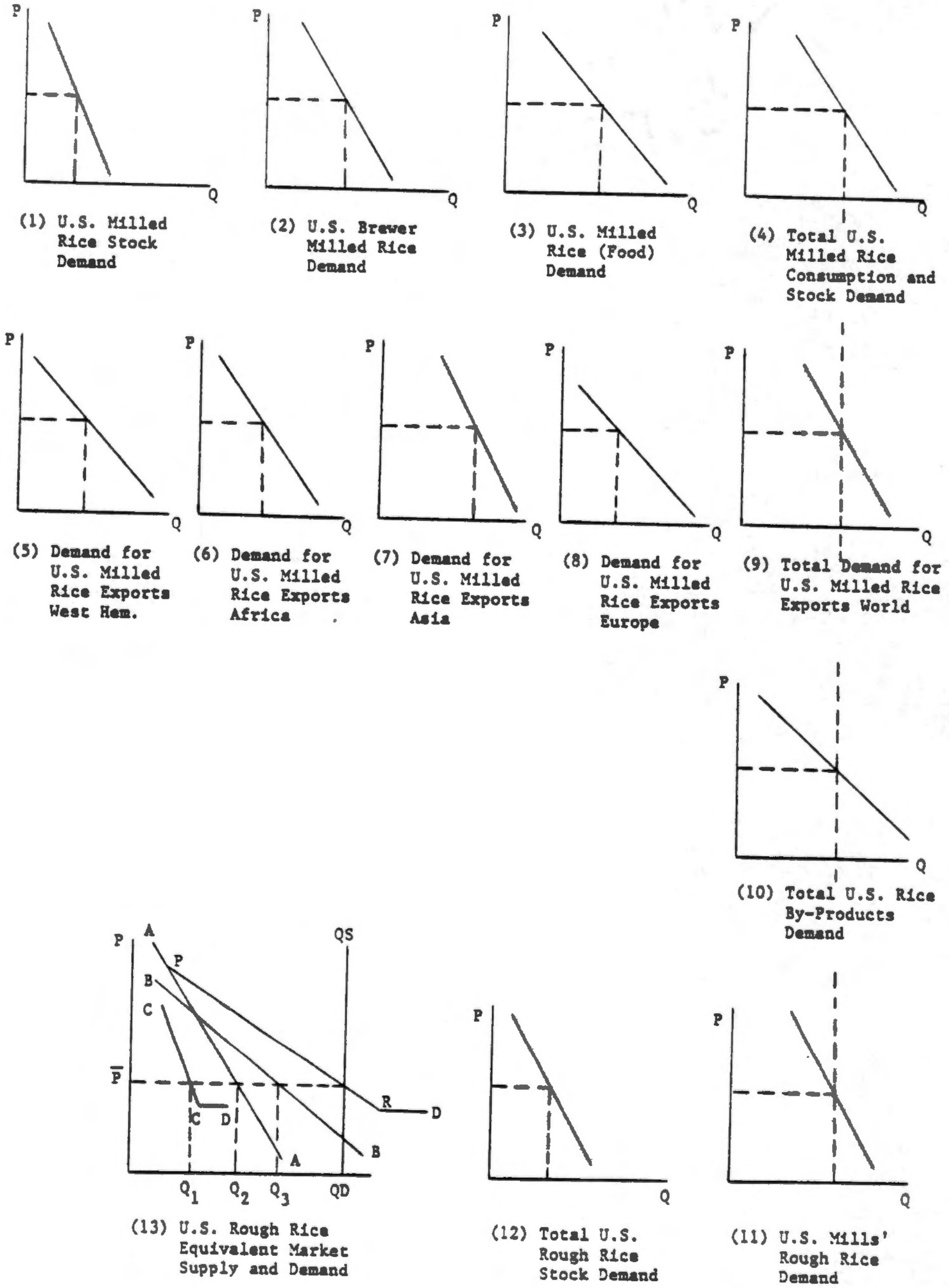
[1] These disaggregations are adopted from exports by destinations compiled by Holder and Grant [7, pp. 111-116].

stock function shifters such as the quantity of rough rice milled at U.S. rice mills and the last year's milled rice ending stocks.

In an effort to account for the total disappearance of U.S. rice, outlets for rough rice used for seeds, rough rice exports and rice hulls are also shown in Figure 1. These uses are minor relative to the other uses so their impacts in the model are assumed to be insignificant.

The major U.S. rice distribution system involving the various market outlets can also be presented in terms of a price-quantity relationships (graphs 1 through 13 in Figure 2) at a given point in time, _ceteris paribus_. In each graph, P (on the vertical axis) indicates the comparable price of rice or rice by-products and Q (on the horizontal axis) denotes the quantity of rice or rice by-products. The horizontal summation of the demand curves in graphs (1) through (3) provides the U.S. demand curve for milled rice consumption and ending stocks (4). The total foreign demand curve for U.S. milled rice exports (9) can be obtained by summing graphs (5) through (8). Adding U.S. total rice by-product demand curve (10) to (4) and (9) yields a demand for rough rice (11), the derived demand curve of the U.S. rice mills.

Treating all quantities of milled rice as rough rice equivalents and summing (11) and (12) gives the summary of the various demand functions for rough rice (13). The aggregate domestic demand curves obtained from the summation of (2), (3) and (10) and the total foreign demand curve for U.S. rice exports (9) are represented by AA and BB, respectively. The curve CCD indicates the aggregate demand curve for stocks (1) and (12). The horizontal portion, CD or RD, indicates the government nonrecourse loan programs. The aggregate demand curve for all U.S. rice in the market, APRD, is obtained by summing AA, BB and CCD horizontally.



(1) U.S. Milled Rice Stock Demand

(2) U.S. Brewer Milled Rice Demand

(3) U.S. Milled Rice (Food) Demand

(4) Total U.S. Milled Rice Consumption and Stock Demand

(5) Demand for U.S. Milled Rice Exports West Hem.

(6) Demand for U.S. Milled Rice Exports Africa

(7) Demand for U.S. Milled Rice Exports Asia

(8) Demand for U.S. Milled Rice Exports Europe

(9) Total Demand for U.S. Milled Rice Exports World

(10) Total U.S. Rice By-Products Demand

(13) U.S. Rough Rice Equivalent Market Supply and Demand

(12) Total U.S. Rough Rice Stock Demand

(11) U.S. Mills' Rough Rice Demand

Figure 2. Price-Quantity Model of U.S. Rice Market Economy

The intersection of the aggregate demand curve (APRD) and the vertical supply curve (QS) gives the annual equilibrium price of rough rice ($\overline{P}$) and the total quantity of rough rice (QD). The latter is made up of the equilibrium quantities of stocks (Q_1), domestic uses (Q_2) and exports (Q_3).

B. ECONOMETRIC MODEL

Ideally, economic theory is used in deciding which relations make up the model, which variables are to be included in each of the relations and what is the sign of some of the partial derivatives. It has very little to say about the functional form of the relations and the values of the parameters. Furthermore, these relations are assumed to be deterministic and, therefore, there is no allowance made for the existence of stochastic disturbances.

To make predictions and decisions these relations must be presented in terms of real-world numbers which can be measured by means of an appropriate empirical tool. Therefore, econometrics, which is often defined as the measurement of relationships implied by economic theory [20, p. 6], is employed to estimate the supply and demand relations in the U.S. rice economy.

With reference to the proposed economic models (Figure 1, p. 12, and Figure 2, p. 16), various behavioral equations and identities used to estimate the supply and demand functions for U.S. rice will be specified. The endogenous variables are variables to be explained by the model and are denoted by an asterisk (*). The predetermined variables, which can be subdivided into exogenous and lagged endogenous, are completely determined outside the system under consideration. The disturbance terms associated with each of the behavioral equations are indicated by U_j. Likewise the symbols λ_{jk} and β_{jk} are the parameters of the endogenous and exogenous variables, respectively, while α_j indicates the intercepts. The subscript t indicates the t^{th} year, j denotes the j^{th} equation and k symbolizes the k^{th} explanatory variable. The subscript r indicates rough rice and m for milled rice. Finally, variables which were already defined as they first appeared in the previous equation(s) are not redefined in the subsequent equation(s) to avoid repetition.

The supply model consisting of the first three equations has one behavioral and two identity equations, while the demand model comprising of equations (4) through (22) has 15 behavioral and four identity equations. The equations are as specified below.

Rice Acreage Harvested in the U.S.

$$(1)\quad AC^*_t = \alpha_1 + \beta_{1.1}(PF_{rt-1}/SP_{rt-1}) + \beta_{1.2}PS_{bt-1} + \beta_{1.3}AC_{t-1} + \beta_{1.4}EST_{rt-1} + U_1$$

where:

AC^*_t = average acreage harvested, U.S., thousand acres

PF_{rt-1} = season average farm price of rough rice received by farmers, lagged one year, dollars per cwt., deflated by last year's wholesale price index (WPI_{t-1}), 1967 = 100

SP_{rt-1} = support price of rough rice with acreage allotment, lagged one year, dollars per cwt., deflated by WPI_{t-1}, 1967 = 100

PS_{bt-1} = season average price of soybeans (beans) received by farmers, lagged one year, dollars per cwt., deflated by WPI_{t-1}, 1967 = 100

AC_{t-1} = average rice acreage harvested, U.S., lagged one year, thousand acres

EST_{rt-1} = total rough rice ending stocks at all positions, August 1, lagged one year, thousand cwt.

Typically, producers decide on how large the acreage to be planted in the current year. Although rice acreage appears to be exogenous due to government acreage allotment programs, the program administrator could not have decided on the level of rice acreage to be planted without some regard for the economic variables producers would consider in making the same decision [16, p. 14]. In practice, however, not all rice acreage planted is harvested perhaps because of an unforeseen fall in the farm price of rice, unfavorable weather conditions, <u>et cetera</u>. It is more practical to estimate rice acreage harvested instead of rice acreage planted, although the latter directly influences the former.

The last year's ratio of the farm price of rice received by farmers to the support price of rice (PF_{rt-1}/SP_{rt-1}) is expected to have a positive effect on the acreage harvested (AC_t^*). If the farm price of rice is expected to increase, producers will increase rice acreage planted which will enable a larger rice acreage to be harvested. The previous year's farm prices of competing crops affect the acreage harvested for rice negatively because increases in the prices of these crops will encourage U.S. rice producers to shift some portions of their rice acreage to these crops. To capture at least some of the effects of these crops, the lagged farm price of soybean (PS_{bt-1})[1] is specified in equation (1). The sign of the coefficient $\beta_{1.2}$ is negative. The rice acreage harvested in the current year is expected to increase if the lagged rice acreage harvested (AC_{t-1}) had increased. At least within the time period covered in this study, acreage harvested for rice had shown a positive trend (Appendix A). Therefore, the sign of the parameter $\beta_{1.3}$ is positive. An increase in the previous year's total rough rice ending stocks (EST_{rt-1}) will prssure producers to reduce rice production in the current year and consequently the acreage planted for rice. Therefore, the coefficient $\beta_{1.4}$ is negative.

U.S. Rice Production (Identity)

$$(2) \quad QP^*_{rt} = AC^*_t \times YPA_{rt}$$

where:

QP^*_{rt} = total quantity of U.S. rough rice production, thousand cwt.

YPA_{rt} = average yield per acre harvested, U.S., pounds

The quantity of rough rice producted (QP^*_{rt}) is definitially the acreage harvested (AC^*_t) times the yield per acre (YPA_{rt}).

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[1] Soybeans may not be representative of all competing crops to rice, because this crop is not grown by all rice farmers especially in different regions and states. Since there is no price index for all substitute crops reflecting all rice producing areas, the farm price of soybeans is used only as a proxy variable.

U.S. Rice Supply (Identity)

(3) $QS^*_{rt} = QP^*_{rt} + EST_{rt-1}$

where:

QS^*_{rt} = total quantity of U.S. rough rice supply, thousand cwt.

The total quantity of U.S. rough rice supply (QS^*_{rt}) is equal to the sum of the current quantity of rough rice production (QP^*_{rt}) and the last year's total rough rice ending stocks (EST_{rt-1}).

Derived Demand for Rough Rice of U.S. Rice Mills[1]

(4) $$PF^*_{rt} = \alpha_4 + \lambda_{4.1}QM^*_{rt} + \lambda_{4.2}PT^*_{mt} + \lambda_{4.3}PW^*_{mt} + \lambda_{4.4}PR^*_{mt} + \beta_{4.5}T_t + U_4$$

where:

PF^*_{rt} = season average farm price of rough rice received by farmers, U.S., dollars per cwt., deflated by WPI_t, 1967 = 100

QM^*_{rt} = total quantity of rough rice milled by U.S. rice mills, thousand cwt.

PT^*_{mt} = season average Thai export price of milled rice, white rice 100 percent second grade, f.o.b. mill, Bangkok, dollars per cwt., deflated by WPI_t, 1967 = 100

PW^*_{mt} = season average U.S. mill price of No. 2 long-grain rice, f.o.b. mill, Houston, Texas, dollars per cwt., deflated by WPI_t, 1967 = 100

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[1] Corresponds to graph (11) in Figure 2, p. 16.

PR^*_{mt} = season average retail price of rice, U.S. long-grain, dollars per cwt., deflated by consumer price index (CPI_t), 1967 = 100

T_t = time variable

The U.S. mills utilize rough rice as the input to produce the intermediate product, milled rice, which will be distributed to different domestic and export market outlets. This type of demand is derived.

Based on the law of demand, the quantity of rough rice milled (QM^*_{rt}) and the farm price of rough rice (PF^*_{rt}) are inversely related. Any increases in the Thai export price of rice (PT^*_{mt}), the U.S. mill price of rice (PW^*_{mt}) and the U.S. retial price of rice (PR^*_{mt}) are hypothesized to raise the farm price of rough rice. The time variable (T_t) is used to capture any trend in the farm price of rice. If the farm price of rice has generally been increasing over the years, then the coefficient ($\beta_{4.5}$) is positive.

U.S. Total Rough Rice Ending Stocks[1]

$$(5) \quad EST^*_{rt} = \alpha_5 + \lambda_{5.1} PF^*_{rt} + \lambda_{5.2} PT^*_{mt} + \beta_{5.3} QS_{rt} + \beta_{5.4} D1S + U_5$$

where:

EST^*_{rt} = total rough rice ending stocks, U.S., at all positions, i.e., private plus government, August 1, thousand cwt.

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[1] In accord with graph (12) in Figure 2, p. 16.

QS_{rt} = total quantity of rough rice supplied, U.S., thousand cwt.

D1S = 1 if in 1972-75 total rough rice ending stocks, otherwise = 0

The relation between the total rough rice ending stocks (EST^*_{rt}) and the farm price of rough rice (PF^*_{rt}) is inverse. An increase in the Thai export price of rice (PT^*_{mt}) is expected to reduce the level of the total rough rice ending stocks because of the competitive position of the U.S. rice exports with rice exports from other countries. The quantity of rough rice supplied in the U.S. (QS_{rt}) affects the level of total rough rice ending stocks directly. This is due to excess rice production which leads to the accumulation of rough rice stocks, especially when the U.S. rice markets have failed to absorb the previous year's rough rice stocks. The dummy variable (D1S) is specified in equation (5) to account for the short-run decreases in the levels of U.S. rough rice ending stocks because of the sudden increases in the demand for U.S. rice during the worldwide rice shortage from 1972 to 1975. The coefficient $\beta_{5.4}$ is expected to be negative.

U.S. Demand for Milled Rice Used as Food[1]

$$(6)\quad PR^*_{mt} = \alpha_6 + \lambda_{6.1}QF^*_{mt} + \lambda_{6.2}PW^*_{mt} + \beta_{6.3}PFC_t + \beta_{6.4}DPI_t + \beta_{6.5}T_t + U_6$$

where:

QF^*_{mt} = quantity of milled rice used for food, U.S., thousand cwt.

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[1] In conformity with graph (3) in Figure 2, p. 16.

PFC_t = season average farm price of corn received by farmers,[1] dollars per bushel, deflated by WPI_t, 1967 = 100

DPI_t = per capita disposable personal income, U.S., thousand dollars, deflated by CPI_t, 1967 = 100

T_t = time variable to capture the effect of any changes in tastes and preferences for rice in the U.S.

According to the law of demand, the quantity of milled rice used for food (QF^*_{mt}) is hypothesized to have a negative effect on the retail price of rice (PR^*_{mt}). The mill price of rice (PW^*_{mt}) and the retail price of rice move in the same direction because of the need to maintain a certain minimum marketing margin. A rise in the mill price of rice is expected to shift the demand for rice used for food to the right which in effect increases the retail price of rice. Corn is considered to be the substitute for rice used for food. An increase in the farm prices of corn (PFC_t) is expected to raise the retail price of rice. Any rise in the U.S. per capita disposable personal income (DPI_t) increases the retail price of rice because of a shift in the demand curve for rice to the right. The time (T_t), the proxy for changes in tastes and preferences, can affect the retail price of rice in either direction. If tastes and preferences for rice increase, implying increases in the demand for rice used for food, the coefficient $\beta_{6.5}$ is positive.

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[1] Obtained by weighting state prices by quantity sold. Includes allowance for unredeemed loans and purchases by the government valued at the average loan and purchase rate, by states, where applicable.

U.S. Derived Demand for Brewer Rice[1]

$$(7) \quad PB^*_{mt} = \alpha_7 + \lambda_{7.1}QB^*_{mt} + \lambda_{7.2}PF^*_{rt} + \beta_{7.3}PFB_t + \beta_{7.4}PFC_t + \beta_{7.5}DPI_t + \beta_{7.6}T_t + U_7$$

where:

PB^*_{mt} = season average mill price of brewer rice, f.o.b. mill, California, dollars per cwt., deflated by WPI_t, 1967 = 100

QB^*_{mt} = quantity of brewer rice,[2] U.S., thousand cwt.

PFB_t = season average farm price of barley received by farmers, dollars per bushel, deflated by WPI_t, 1967 = 100

T_t = time variable to account for any changes in tastes and preferences

The quantity of brewer rice (QB^*_{mt}) is hypothesized to affect the mill price of brewer rice (PB^*_{mt}) inversely. An increase in the farm price of rice (PF^*_{rt}) usually implies an increase in the mill price of brewer rice. Therefore, the parameter $\lambda_{7.2}$ is expected to have a positive sign. The farm price of barley (PFB_t) influences the price of brewer rice directly because barley and rice are substitute ingredients in brewing certain brands of beer (for example, Budweiser, Natural Light and others). Since corn is the basic ingredient for most beer brewing, and rice is used only for flavoring, these two commodities are comple-

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[1] This is consistent with graph (2) in Figure 2, p. 16.

[2] Brewer rice is mainly made up of broken grains. Beer processors also purchase significant quantities of whole-grain rice, which is granulated prior to use. The use of whole-grain is favored when its price (relative to broken grain) is low.

ments. Thus, any increase in the farm price of corn (PFC_t) shifts the derived demand for brewer rice down which reduces the price of brewer rice. The per capita disposable personal income (DPI_t), as suggested by economic theory, influences the price of brewer rice directly. To account for the effects of any change in tastes and preferences, the time (T_t) is included. The argument for its direction of impact on the price of brewer rice is similar to that in equation (6).

U.S. Milled Rice Ending Stocks[1]

$$(8)\quad EST^*_{mt} = \alpha_8 + \lambda_{8.1}PW^*_{mt} + \lambda_{8.2}QM^*_{rt} + \beta_{8.3}EST_{mt-1} + U_8$$

where:

EST^*_{mt} = quantity of milled rice ending stocks, U.S., at all positions, August 1, thousand cwt.

EST_{mt-1} = quantity of milled rice ending stocks, at all positions, August 1, lagged one year, thousand cwt.

Because most of the milled rice ending stocks (EST^*_{mt}) are at the wholesale level, the mill price of rice (PW^*_{mt}) seems to be the most relevant price affecting them. The mill price of rice is expected to have a negative effect on the quantity of milled rice ending stocks, following similar argument in equation (5). The quantity of milled rice ending stocks depends on the quantity of rough rice milled (QM^*_{rt}) at U.S. rice mills. The relation between these two variables is expected to be positive. As the lagged quantity of milled rice ending stocks (EST_{mt-1})

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[1] Tallies with graph (1) in Figure 2, p. 16.

increases, wholesalers of rice would be pressured to reduce current milled rice stocks, especially if storage facilities are limited. Also milled rice is more perishable relative to rough rice. The sign of the parameter $\beta_{8.3}$ is negative.

Foreign Demand for U.S. Rice Exports on a Regional Basis[1]

$$(9)\quad QXR^*_{mtj} = \alpha_j + \lambda_{j.1}PX^*_{mt} + \lambda_{j.2}PT^*_{mt} + \beta_{j.3}QP_{rtj} + \beta_{j.4}PDP_{tj} + \beta_{j.5}ER_{tj} + \beta_{j.6}OFI_t + \beta_{j.7}PXW_t + U_j$$

where:

j = 9, 10, 11 and 12 indicate the sequential number of equations for Asia, Africa, Europe and the Western Hemisphere

QXR^*_{mtj} = quantity of U.S. milled rice exported to the j^{th} region, thousand cwt.

PX^*_{mt} = $PW^*_{mt} - GXS_t$ = U.S. season average export price of rice,[2] based on U.S. No. 2 long-grain rice, f.o.b. mill, Houston, dollars per cwt., deflated by WPI_t, 1967 = 100

GXS_t = season average export payment for long-grain rice, dollars per cwt.

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[1] Corresponds to graphs (7), (6), (8) and (5) in Figure 2, p. 16.

[2] The U.S. export price of rice is not reported on a continuing basis [7, p. 22]. However, it can be obtained by subtracting the export payment from any of the U.S. f.o.b. mill prices of rice. The U.S. f.o.b. mill prices of rice (most of the time) are greater than the prevailing world export price of rice.

QP_{rtj} = total rough rice production in the j^th region, thousand cwt.

PDP_{tj} = per capita gross domestic product index in the j^th region, 1967 = 100

ER_{tj} = exchange rates, selected currency in the j^th region per U.S. dollar or *vice versa*

OFI_t = ocean freight index for dry cargo[1] which includes grains, 1967 = 100

PXW_t = U.S. average export price of No. 2 hard winter wheat, ordinary protein, f.o.b. vessel, Gulf ports, dollars per metric ton, deflated by WPI_t, 1967 = 100

U_j = disturbance term associated with the j^th regional equation

Equation (9) is the general presentation of the regional demand functions for U.S. rice exports in Asia, Africa, Europe and the Western Hemisphere. So, each of the j^{th} regional equation is specified with the comparable regional variables which are accordingly denoted by the subscript j. However, data for the U.S. export price of rice (PX^*_{mt}), the Thai export price of rice (PT^*_{mt}), the ocean freight index (OFI_t) and the U.S. export price of wheat (PXW_t) are not available on a regional basis; they are used as proxy variables (without the subscript j) in each of the j^{th} regional equation.

The quantity of U.S. rice exported to the j^{th} region is indirectly influenced by the U.S. export price of rice (PX^*_{mt}). The Thai export

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[1] In 1950-64, tramp voyage rates were based on 23 routes, arranged in five bulk commodity groups with approximate weight aimed to give worldwide coverage. The 1965-78 new index was based on 28 routes.

price of rice (PT^*_{mt}) is specified in each of the j^{th} equation to account for any outside influence on the demand for U.S. rice exports due to competition of rice imports from the other rice exporting countries. The coefficient ($\lambda_{j.2}$) is expected to be positive.

In the recent years technological improvement played a major role in increasing rice production in some countries that import U.S. rice, particularly in developing countries. The total rough rice production in the j^{th} region (PQ_{rtj}) is used as the proxy for technological improvement, which affects the quantity of U.S. rice exports demanded in that region negatively.

The per capita income for region j is hypothesized to increase the comparable demand for U.S. rice exports. Data for this variable are not available, thus, the regional per capita gross domestic product index (PDP_{tj})[1] is used as the proxy variable. The parameter ($\beta_{j.4}$) is expected to be positive.

Exchange rates play an important role in the international trade [19, pp. 970-971]. To make transactions possible, one of the trading countries must change currencies. For example, the importing country is concerned with the price of rice in terms of its own currency. Thus, the most representative exchange rate[2] from some selected exchange rates

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[1] The data for per capita gross domestic product index for Africa were not available prior to 1960; therefore, the per capita gross domestic product index for East and Southeast Asia is used as its proxy variable.

[2] Since the U.S. rice exports are distributed to various importing countries in the particular region, it was impossible to consider the exchange rates between the currency of the individual country and the U.S. dollars. Instead, the proxy exchange rate for region j was selected on the basis of highest R^2 when each exchange rate was regressed against the others in the j^{th} region.

in the j^{th} region is included as an explanatory variable in the j^{th} equation. Theoretically, when the U.S. devalues the dollar in terms of the given foreign currency whose value is assumed to be constant here, the quantity of U.S. rice exports demanded in that particular country is expected to increase because the price of U.S. rice is relatively cheaper than before the devaluation of the dollar.

The ocean shipping costs have been fluctuating irregularly in the recent past. They are expected to have an impact on the cost of rice imports. Data on shipping costs are incomplete on a regional basis, so the ocean freight index (OFI_t) is used as the proxy variable in each of the j^{th} regional demand equation for U.S. rice exports. When the ocean freight index increases, the U.S. rice imports of region j decrease.

While rice remains an important food grain for most rice importing countries, consumption of other food grains is also becoming more apparent, at least in the recent past. Several food grains could be considered as substitutes for rice but their export quantity or price index are not available. Since wheat is probably one of the most important substitutes for rice, the U.S. export price of hard winter wheat (PXW_t) is selected and specified in each of the j^{th} regional demand function for U.S. rice exports. Based on economic theory, the partial derivative of the quantity of U.S. rice exports demanded in the j^{th} region with respect to the export price of wheat is positive.

Trade barriers such as tariffs or quotas were also considered to be important in influencing the demand for U.S. rice exports. However, lack of published data on these variables, especially on the part of importing countries, prohibited their inclusions.

Total Quantity of U.S. Milled Rice Exports (Identity)

$$(13)\quad QXT^*_{mt} = QXAO^*_{mt} + QXAF^*_{mt} + QXE^*_{mt} + QXWH^*_{mt}$$

where:

QXT^*_{mt} = total quantity of U.S. milled rice exports to countries all over the world, thousand cwt.

$QXAO^*_{mt}$ = quantity of U.S. milled rice exports to Asia and Oceania, thousand cwt.

$QXAF^*_{mt}$ = quantity of U.S. milled rice exports to Africa, thousand cwt.

QXE^*_{mt} = quantity of U.S. milled rice exports to Europe, thousand cwt.

$QXWH^*_{mt}$ = quantity of U.S. milled rice exports to Western Hemisphere, thousand cwt.

The total quantity of U.S. milled rice exports (QXT^*_{mt}) is obtained from the sum of the quantities of U.S. rice exports to each region of Asia,[1] Africa, Europe and the Western Hemisphere.

Thai Export Price of Rice

$$(14)\quad PT^*_{mt} = \alpha_{14} + \beta_{14.1}QX_{mt} + \beta_{14.2}PDPW_t + \beta_{14.3}PT_{mt-1} + \beta_{14.4}T_t + U_{14}$$

where:

QX_{mt} = quantity of world milled rice exports (excluding U.S.), thousand cwt.

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[1] U.S. rice exports to Asia includes the U.S. rice exports to Oceania.

$PDPW_t$ = per capita gross domestic product index of the world, 1967 = 100

PT_{mt-1} = last year's season average Thai export price of milled rice, white rice 100 percent second grade, f.o.b. mill, Bangkok, dollar per cwt., deflated by WPI_{t-1}, 1967 = 100

T_t = time variable to capture the effect of any changes in tastes and preferences for rice worldwide

An inverse relation is expected to exist between the Thai export price of rice (PT^*_{mt}) and the quantity of world rice export (QX_{mt}). The per capita gross domestic product index ($PDPW_t$) is used as the proxy variable for the per capita income of the world. If this exogenous variable increases, the Thai export price of rice is expected to move in the same direction. The underlying reason is that any rise in the per capita world income will shift the Thai export price of rice function to the right. This, in effect, increases the Thai export price of rice. With the assumption that the previous and current year Thai export prices of rice move in the same (positive) direction of a trend, the sign associated with the coefficient $\beta_{14.3}$ is positive or _vice versa_ if the trend is moving downwards. The time (T_t) is included to capture any variations in the Thai export price of rice due to tastes and preferences. It is difficult to state the expected sign of the parameter $\beta_{14.4}$, _a priori_.

U.S. Demand for Rice Millfeed[1]

$$(15)\quad PRBM^*_t = \alpha_{15} + \lambda_{15.1}QUF^*_t + \beta_{15.2}FGPI_t + \beta_{15.3}PWB_t + \beta_{15.4}LSPI_t + \beta_{15.5}T_t + U_{15}$$

where:

$PRBM^*_t$ = season average price of rice bran, bulk, f.o.b. mill, Texas, dollars per cwt., deflated by WPI_t, 1967 = 100

QUF^*_t = quantity of rice millfeed used for animal feed, thousand cwt.

$FGPI_t$ = index of feed prices received by farmers for corn, oats, barley and sorghum, 1967 = 100

PWB_t = season average price of wheat bran, bulk, Kansas City, dollars per ton, deflated by WPI_t, 1967 = 100

$LSPI_t$ = livestock production index, meat animals: cattle and calves, sheep and lambs and hogs, 1967 = 100

T_t = time variable to account for any trend in the price of rice bran

In accordance with the law of demand, an inverse relation between the price of rice bran ($PRBM^*_t$) and the quantity of rice millfeed (QUF^*_t) is expected. To account for the effect of substitute feed grains on the demand for rice millfeed, the index of feed prices ($FGPI_t$) is used as a shifter. Its direction of influence on the price of rice bran is hypothesized to be positive. A closer substitute for rice bran could be wheat bran, which is also a by-product of wheat mills. Hence, an increase in the season average price of wheat bran (PWB_t) is expected to influence the price of rice bran in the same direction. To a certain extent the

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[1] Corresponds to graph (10) in Figure 2, p. 16.

trend of livestock production determines the demand for feed. For this reason, the livestock production index ($LSPI_t$) is included to explain some of the variations in the price of rice bran. An increase in the trend of the livestock production index is expected to indicate an increase in the demand for rice millfeed which in turn signals an increase in its price. The time (T_t) is also included to account for any possible trend in the price of rice bran. If the use of rice millfeed as feed increases over time, the price of rice bran is anticipated to increase.

Quantity of Milled Rice Used for Food in the U.S.

$$(16) \quad QF^*_{mt} = \alpha_{16} + \lambda_{16.1}PR^*_{mt} + \lambda_{16.2}QM^*_{rt} + \beta_{16.3}T_t + U_{16}$$

where:

T_t = time variable to capture any trend in the utilization of milled rice as food in the U.S.

Any rise in the retail price of rice (PR^*_{mt}) is expected to influence the quantity of milled rice used for food (QF^*_{mt}) to fall. The quantity of rough rice milled (QM^*_{rt}) at U.S. rice mills determines the quantity of milled rice produced directly, and consequently the quantity of milled rice used for food. The sign of the parameter $\lambda_{16.2}$ is positive. Time (T_t) is included to determine any possible trend in the quantity of milled rice used for food in the U.S. The sign associated with the coefficient $\beta_{16.3}$ is difficult to determine at *a priori*.

Quantity of Brewer Rice Used in the U.S.

$$(17)\quad QB^*_{mt} = \alpha_{17} + \lambda_{17.1}PF^*_{rt} + \lambda_{17.2}QM^*_{rt} + \beta_{17.3}PFC_t + \beta_{17.4}T_t + U_{17}$$

where:

T_t = time variable to capture any trend in the usage of brewer rice in the U.S.

It is hypothesized that any increase in the farm price of rice (PF^*_{rt}) is usually transmitted into the mill price of brewer rice (PB^*_{mt}) which in effect reduces the quantity of brewer rice utilization (QB^*_{mt}). The sign of the parameter $\lambda_{17.1}$ is negative. Similar to the quantity of milled rice used for food, the quantity of brewer rice is also influenced directly by the quantity of rough rice milled (QM^*_{rt}) at U.S. rice mills. Corn and rice are complementary ingredients in beer brewing. Therefore, any increase in the farm price of corn (PFC_t) affects the quantity of brewer rice in the opposite direction. The time (T_t) is included in order to account for any trend in the utilization of brewer rice by the beer industry in the U.S. The argument for the sign associated with $\beta_{17.4}$ is similar to that of equation (16).

Quantity of Rice Millfeed Used in the U.S.

$$(18)\quad QUF^*_t = \alpha_{18} + \lambda_{18.1}QM^*_{rt} + \beta_{18.2}PWB_t + \beta_{18.3}T_t + U_{18}$$

where:

T_t = time variable to account for any trend in the utilization of rice millfeed in the U.S.

The quantity of rice milling by-products is directly related to the quantity of rough rice milled (QM^*_{rt}). It is evident that the quantity of rice millfeed utilized (QUF^*_t) will increase if the quantity of rough rice milled rises. Wheat bran is a substitute for rice bran used as an ingredient for feed. Therefore, the price of wheat bran (PWB_t) and the quantity of rice millfeed are expected to have a positive relation. The time (T_t) is expected to trace any trend in the quantity of rice millfeed utilization in the U.S. It is difficult to determine the sign of the parameter $\beta_{18.3}$ at *a priori*.

U.S. Mill Price of Rice

$$(19) \quad PW^*_{mt} = \alpha_{19} + \lambda_{19.1}PF^*_{rt} + \lambda_{19.2}PT^*_{mt} + \beta_{19.3}PW_{mt-1} + U_{19}$$

where:

PW_{mt-1} = U.S. season average mill price of No. 2 long-grain rice, f.o.b. mill, Houston, Texas, lagged one year, dollars per cwt., deflated by WPI_{t-1}, 1967 = 100

The farm price of rice (PF^*_{rt}) and the mill price of rice (PW^*_{mt}) are expected to move in the same direction because an increase in the farm price of rice is usually transmitted to the mill price of rice. The coefficient ($\lambda_{19.2}$) associated with the Thai export price of rice (PT^*_{mt}) is positive due to the competition between the U.S. rice exports and the rice exports from the other rice exporting countries. Finally, the last year's mill price of rice (PW_{mt-1}) is expected to explain some of the variations in the current mill price of rice. The direction of effect depends on the trends of the two variables; i.e., if the two prices are moving upwards, the sign of the coefficient $\beta_{19.3}$ is positive.

U.S. Export Price of Rice (Identity)

$$(20) \quad PX^*_{mt} = PW^*_{mt} - GXS_t$$

The U.S. export price of rice (PX^*_{mt}) is simply the difference between the selected mill price of rice (PW^*_{mt}) and the U.S. government rice export payment (GXS_t). The mill price of No. 2 long-grain rice quoted at Houston, Texas, is selected in this study [6, p. 6].

Quantity of Rough Rice Milled at U.S. Rice Mills (Identity)

$$(21) \quad QM^*_{rt} = QF^*_{mt} + QB^*_{mt} + QXT^*_{mt} + QUF^*_t + EST^*_{mt} + QH_t$$

where:

QH_t = rice hulls, thousand cwt.

The quantity of rough rice milled by U.S. rice millers (QM^*_{rt}) is obtained by summing all of the quantities of milled rice used for consumption (QF^*_{mt}, QB^*_{mt} and QXT^*_{mt}), milled rice ending stocks (EST^*_{mt}) and the rice by-products ($QUF^*_t + QH_t$).

General U.S. Rice Market Equilibrium (Identity)

$$(22) \quad QS_{rt} = QD^*_{rt}$$

where:

$QD^*_{rt} = QM^*_{rt} + EST^*_{rt}$, the total quantity of U.S. rough rice in the markets

This identity corresponds to graph (13) in Figure 2, p. 16, where the demand and the annual vertical supply curves intersect at QD which determines the general initial equilibrium price of rice ($\bar{P}$).

The identities included in these proposed econometric models are not technically required in the estimations of the behavioral equations. However, their inclusions are necessary in providing sufficient information in an effort to make these models complete.

C. METHOD OF STATISTICAL ESTIMATION

Method of Estimation for the Supply Model

Like all other crops, rice production is the acreage harvested times yield per acre. While acreage harvested is hypothesized to be influenced by the variables as specified in equation (1), yield is mainly determined by technology and weather conditions. But weather conditions are stochastic in nature, which also vary in different rice growing areas, and technology is rather difficult to quantify. For these reasons, yield is treated as exogenous and the acreage harvested is dealt as endogenous variable, which is to be estimated.

Since the explanatory variables specified in the acreage harvested function are all exogenous, ordinary least squares (OLS) technique will be used in its estimation. This technique should provide a consistent and an asymptotically efficient estimate of the regression parameters, the case where the stochastic lagged endogenous variable (AC_{t-1}) and the error term (U_{1t}) are contemporaneously uncorrelated [12, pp. 301-302].

Method of Estimation for the Demand Model

Because rice production is seasonal, the supply curve of U.S. rice is said to be nearly vertical. Although the farm level equilibrium price and quantity of rice are determined at the intersection of the demand and the vertical supply curves as presented in equation (22) and graph (13) in Figure 2, p. 16, variations of the price and quantity of rice are mostly influenced by the shifts in the demand curve.

The demand model for the U.S. rice market economy consists of various simultaneously interdependent structural relations representing prices, domestic uses, exports and rice stocks. Some of the variables on the right-hand side of these structural equations are typically endogenous and correlated with the disturbance terms; therefore, the OLS estimates of the parameters would be inconsistent. But each of the set of simultaneous stochastic equations involved in the model is overidentified by the order conditions [11, pp. 244-252]. With an overidentified model, there are several techniques available that can be used to obtain improved estimates of the parameters of these structural equations. Two-stage least squares (2SLS) which is a single-equation method and three-stage least squares (3SLS) which is a multiple equation method could be used in this type of analysis.

The 2SLS, developed independently by Bassman (1957) and Thiel (1957), provides consistent estimates of the regression parameters. Other advantages [11, p. 228] in using this technique includes: 1) it is intuitively appealing because it is easy to understand and requires relatively modest computational demands; and 2) it is a "limited-information" procedure.[1]

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[1] A given equation that is contained in a simultaneous equation framework may be estimated by the 2SLS technique with only "vague" knowledge of the other equations.

While 2SLS technique may provide consistent estimates of the coefficients, in general, these estimates are not asymptotically efficient [12, p. 573] because of the disregard of the interactions of the disturbance terms across the interdependent structural equations in the system. Deficiency of this type can be overcome by using 3SLS technique which gives both consistent and asymptotically efficient estimates of the parameters. However, this technique is more sensitive to specification errors. Both the 2SLS and 3SLS will be used in the estimation of the demand model. The most satisfactory results obtained from either of these statistical techniques will be reported.

D. DATA

The annual time-series data covering the period from 1950 through 1978 are used in this study. These data were obtained from various secondary sources [7, 9, 17 and 26-31]. To adjust for inflation, the nominal price and income variables were deflated using the "most appropriate" price indices based on the 1967 dollars.

CHAPTER III

STATISTICAL RESULTS

The statistical results of the econometric models previously developed are presented in this chapter. The acreage harvested function, equation (1), in the supply model was estimated by means of the OLS technique, while the demand model was estimated using the 2SLS and 3SLS techniques. Since the 3SLS seems to perform better than 2SLS, the results obtained from the 3SLS are reported while the results acquired from the 2SLS are presented in Appendix B.

The individual coefficient as estimated in the supply and demand model is evaluated on the basis of 1) its expected sign as suggested by economic theory, 2) its magnitude in comparison with the arithmetic mean (Table I) of the variable in question and 3) its significance as indicated by the "*t*-ratio" in parentheses. The use of the *t*-ratio in evaluating the estimated coefficients in the supply model is proper. However, the use of the *t*-ratio is not quite appropriate in testing the significance of the structural coefficients in the simultaneous equation demand model. The application of a consistent simultaneous equation estimation technique results in an asymptotically normal *t*-distribution; but in small samples the desired confidence interval is usually referred to the tabulated *t*-distribution, it is clear that the use of the *t*-ratio obtained from a consistent estimation technique is not exactly valid [12, p. 584].

TABLE I

ARITHMETIC MEANS AND STANDARD DEVIATIONS OF THE VARIABLES USED IN THE SUPPLY AND DEMAND MODELS

Variables	Unit	Arithmetic Mean	Standard Deviation
Endogenous			
AC^*_t	1,000 acres	1,981.690	405.208
QP^*_{rt}	1,000 cwt.	75,768.690	26,541.080
EST^*_{rt}	"	9,073.138	8,246.061
EST^*_{mt}	"	2,111.897	994.603
$QXAO^*_{mt}$	"	18,440.966	9,873.701
$QXAF^*_{mt}$	"	3,578.483	3,103.337
QXE^*_{mt}	"	3,667.241	2,719.440
$QXWH^*_{mt}$	"	3,313.138	1,306.314
QXT^*_{mt}	"	28,999.828	13,618.775
QF^*_{mt}	"	16,291.310	3,036.024
QB^*_{mt}	"	4,392.586	1,451.039
QUF^*_t	"	7,642.483	2,439.010
QM^*_{rt}	"	70,351.103	23,322.728
QD^*_{rt}	"	79,424.241	27,997.085
PF^*_{rt}	\$/cwt.	5.367	1.153
PW^*_{mt}	"	11.300	2.800
PX^*_{mt}	"	10.323	3.347
PB^*_{mt}	"	5.581	1.254
PR^*_{mt}	"	23.911	3.259
$PRBM^*_t$	"	1.920	0.341
PT^*_{mt}	"	8.643	2.919
Exogenous			
PF_{rt-1}/SP_{rt-1}		1.139	0.251
AC_{t-1}	1,000 acres	1,943.000	357.231
ESG_{rt-1}	"	6,144.857	7,477.547
$QPWH_{rt}$	1,000 cwt.	9,079.517	3,077.302
QS_{rt}	"	89,568.966	30,110.026

TABLE I (continued)

Variables	Unit	Arithmetic Mean	Standard Deviation
Exogenous			
QX_{mt}	1,000 cwt.	125,656.276	24,172.218
DPI_t	1,000 $	2.420	0.502
ERG_t	Marks/$	3.652	0.741
$ERPH_t$	Pesos/$	4.095	2.130
$FGPI_t$	%	127.035	48.995
OFI_t	"	123.586	38.650
$PDPA_t$	"	94.138	33.982
$PDPE_t$	"	94.414	26.782
$PDPLA_t$	"	100.310	23.707
$PDPW_t$	"	92.345	23.556
PFB_t	$/bu.	1.109	0.247
PFC_t	"	1.329	0.294
PXW_t	"	1.946	0.381
PT_{mt-1}	$/cwt.	8.783	2.953
PW_{mt-1}	"	11.448	2.773
GXS_t	"	0.966	1.158
PWB_t	$/ton	42.674	8.814

Because of their asymptotic property, the *t*-ratios employed in testing the significance of the structural coefficients in the demand model are referred to as the "approximate" *t*-ratios. For the purpose of this study, a given estimator, as indicated by its corresponding "approximate" *t*-ratio in the demand model or *t*-ratio in the supply model, is considered statistically significant at the 10 percent level. But a word of caution is in order. It should not be concluded that a particular variable is economically unimportant just because it has failed a significant test against the null hypothesis that its corresponding coefficient is zero [33, p. 56].

Despite the theoretical reasons, some of the explanatory variables specified in the previous supply and demand models were dropped in the process of the statistical estimations. The criteria for dropping a variable may be due to a combination of statistical problems such as: 1) wrong sign of the estimated coefficient, 2) statistically insignificant and 3) existence of high degree of multicollinearity.

The "goodness" of fit of the supply model is evaluated by means of the coefficient of multiple determination (R^2) and the standard error of the estimate (S.E.) while the performance of the demand model is validated on how close the simulated values of each endogenous variable track their actual values in the series. The selected price flexibilities, elasticities and the reduced form coefficients derived from the 3SLS estimates are also reported as they might be useful in certain policy analysis for the U.S. rice.

A. OLS RESULTS OF THE SUPPLY MODEL

The supply model is comprised of the estimated behavioral equation (1) and identities (2) and (3).

Rice Acreage Harvested in the U.S.

The OLS results[1] obtained for the rice acreage harvested function are:

$$(1)\quad \widehat{AC}^*_t = -72.745 + \underset{(2.913)^s}{507.406}(PF_{rt-1}/SP_{rt-1}) + \underset{(6.686)^s}{0.815}AC_{t-1} - \underset{(2.702)^s}{0.016}ESG_{rt-1}$$

$R^2 = 0.754$ D.W. $= 2.036$ S.E. $= 214.308$

The signs of the estimated coefficients are as expected and the coefficients of the explanatory variables included are statistically significant. The last year's farm price of soybean (PS_{bt-1}) was dropped from the final estimation because its estimated coefficient was positive (contrary to prior expectation) and it was also statistically insignificant.

An increase in the previous year's ratio of the farm price of rice to the support price of rice (PF_{rt-1}/SP_{rt-1}) by one unit seems to motivate the U.S. rice producers to increase the current acreage harvested (AC^*_t) by 507,406 acres. In reality, however, the yearly observed change in this price ratio is about 0.1 unit which results in

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[1] The asterisk (*) denotes the endogenous variable, and "s" indicates that the coefficient is significantly different from zero at the 10 percent level.

an increase of only 50,740.6 acres in the current acreage harvested. A 1,000-acre rise in the last year's acreage harvested (AC_{t-1}) is indicated to increase the current acreage harvested by 815 acres.

The previous year's total quantity of rough rice ending stocks (EST_{rt-1}), i.e., government plus private rice stocks at all positions, was initially specified in equation (1), but it was dropped in the final estimation because its coefficient was found statistically insignificant with the wrong sign. However, the portion of the last year's rough rice ending stocks held by the U.S. government (ESG_{rt-1}), when specified, is found to influence the current acreage harvested significantly. An increase in this explanatory variable by 1,000 cwt. decreases the current acreage harvested by 16 acres.

The results of the estimated equation are somewhat satisfactory as indicated by the coefficient of multiple determination ($R^2 = 0.754$).[1] This indicates that the explanatory variables included in the model are at least able to explain about 75 percent of the variations in the dependent variable (AC_t^*). Moreover, the estimated standard error (S.E. = 214.308) is small relative to the mean $\overline{AC} = 1,981.690$ (Table I, p. 42), indicating a fair degree of accuracy of the regression model as a whole in predicting the values of the acreage harvested, given the observed values of the independent variables.

The Durbin-Watson Statistics (D.W. = 2.036) is usually presented to indicate the degree of autoregression. Since the lagged of the dependent variable is among the explanatory variables, the test of this

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[1] The F-ratio associated with the R^2 is 24.470, which is significant at the 0.05 level.

statistic is not applicable [12, p. 295]. If the sample size used in this study were large enough (say n > 30), the h statistics[1] for testing serial correlation could be applied [10, pp. 312 and 313].

U.S. Rice Production (Identity)

$$(2)\quad \widehat{QP}^*_{rt} = \widehat{AC}^*_{t} \times YPA_{rt}$$

The estimated quantity of rough rice production (QP^*_{rt}) is obtained from the products of the estimated values of acreage harvested (AC^*_t) and the yield per acre (YPA_{rt}).[2]

U.S. Rice Supply (Identity)

$$(3)\quad \widehat{QS}^*_{rt} = \widehat{QP}^*_{rt} + EST_{rt-1}$$

Since the previous year's total rough rice ending stocks (EST_{rt-1}) is given, the variations in the U.S. rough rice production (QP^*_{rt}) exactly reflect the variations in the U.S. rough rice supply (QS^*_{rt}).

B. 3SLS RESULTS OF THE DEMAND MODEL

The behavioral equations of the demand model as estimated by means of 3SLS and the identity equations are presented in equations (4)

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[1] The h statistics, developed by Durbin, is computed as: $h = r(n/1 - nS_{\hat{\beta}})^{\frac{1}{2}}$ where $r \approx 1 - \frac{1}{2}d$, the (approximate) estimated first-order autocorrelation coefficient of the residuals; d = the conventional Durbin-Watson Statistics; $S_{\hat{\beta}}$ the estimated variance of the coefficient of the lagged dependent variable; and n = the sample size. Treating the h statistics as a standard normal deviate, reject the hypothesis of zero autocorrelation at the 5 percent level if $h > 1.645$.

[2] Because of the problems involved in quantifying technology and weather conditions on the national basis, the yield variable is assumed to be exogenous in the supply model. Moreover, it is not an economic variable.

through (22). The identity equations were not entered in the system estimation; however, their inclusion in this section is necessary in order to make the demand model complete.

Derived Demand for Rough Rice of U.S. Rice Mills

$$(4)\quad \widehat{PF}^*_{rt} = -257.111 - \underset{(6.517)^s}{0.00006QM^*_{rt}} + \underset{(10.201)^s}{0.311PT^*_{mt}}$$

$$+ \underset{(4.105)^s}{0.101PR^*_{mt}} + \underset{(5.259)^s}{0.133T_t}$$

With regard to the movement along the estimated mills' derived demand curve for rice, it is indicated that the 1,000 cwt. rise in the quantity of rough rice milled (QM^*_{rt}) is associated with 0.006 cent per cwt. fall in the farm price of rice (PF^*_{rt}). In order to reflect its yearly average change, a five million cwt. rise in the quantity of rough rice milled is associated with a 30 cents per cwt. decrease in the farm price of rice.

Increasing the Thai export price of rice (PT^*_{mt}) by one dollar per cwt. leads to a rise of 31.1 cents per cwt. in the U.S. farm price of rice, while increasing the U.S. retail price of rice (PR^*_{mt}) by one dollar per cwt. results in an increase of 10.1 cents per cwt. in the U.S. farm price of rice. The coefficient of time (T_t) indicates that the farm price of rice increases by 13.3 cents per cwt. each year.

U.S. Total Rough Rice Ending Stocks

$$(5)\quad \widehat{EST}^*_{rt} = -8{,}227.880 + \underset{(1.250)}{1{,}793.505PF^*_{rt}} - \underset{(2.116)^s}{1{,}103.930PT^*_{mt}}$$

$$+ \underset{(5.802)^s}{0.207QS_{rt}} - \underset{(3.720)^s}{9{,}542.780D1S}$$

With the exception of the farm price of rice (PF^*_{rt}), all of the coefficients of the explanatory variables included are statistically significant. The estimated coefficient for the farm price of rice does not have the expected sign.

If the Thai export price of rice (PT^*_{mt}) increases by a dollar per cwt., the total rough rice ending stocks (EST^*_{rt}) is indicated to fall by 1,103,930 cwt. Perhaps this relation is reasonable because the increase in the Thai export price of rice, which is the proxy for the world price of rice, makes the U.S. mill price of rice (PW^*_{mt}) to be more competitive. This situation is evident in 1972 to 1974 during which the world price of rice soared because of a shortage in rice supply worldwide.

An increase in the quantity of U.S. rice supplied (QS_{rt}) by 1,000 cwt. causes the total rough rice ending stocks to rise by 207 cwt. Thus, an effort to control the level of U.S. rice production and consequently the U.S. rice cupply directly determine the levels of the total rough rice ending stocks available.

The negative coefficient of the dummy variable (D1S) indicates a downward shift in the demand for total rough rice ending stocks which reduces the level of rough rice ending stocks by 9,542,780 cwt. This is expected because the U.S. acted as the sole supplier of rice to most rice importing countries in 1972 to 1974 when worldwide production was low due to unfavorable climatic conditions. The U.S. total rough rice ending stocks dropped to their lowest points in those same periods.

U.S. Demand for Rice Used as Food

$$(6)\quad \widehat{PR}^*_{mt} = -1{,}805.660 - \underset{(1.877)^s}{0.0008QF^*_{mt}} + \underset{(2.085)^s}{0.401PW^*_{mt}}$$

$$+ \underset{(3.781)^s}{7.563PFC_t} - \underset{(2.525)^s}{8.738DPI_t} + \underset{(3.578)^s}{0.942T_t}$$

All of the coefficients in equation (6) are indicated to be statistically significant. The sign of the estimated coefficient for the U.S. per capita disposable income (DPI_t) is contrary to the prior expectation. But it is theoretically possible to have a negative sign associated with income in a demand function which is indicative of the fact that rice could be considered as an inferior good when it is used for direct food in the U.S. By definition, the negatively sloped demand curve still holds as long as rice is not classified as a Giffen good [2, pp. 58-62].

An increase in the quantity of milled rice used for food (QF^*_{mt}) by 1,000 cwt. is associated with 0.08 cent per cwt. fall in the retail price of rice (PR^*_{mt}). In other words, one million cwt. of milled rice used for food is demanded if the retail price of rice declines by 80 cents per cwt. A dollar per cwt. rise in the mill price of rice (PW^*_{mt}) results in an increase of 40.1 cents per cwt. in the retail price of rice. As indicated by the positive sign of the estimated coefficient for the farm price of corn (PFC_t), corn appears to be a substitute for rice used for processed food. A dollar rise per bushel of corn results in a 7.563 dollars per cwt. increase in the retail price of rice. Expressing it closer to its yearly average change, a 25 cents per bushel rise in the farm price of corn results in an increase of 1.890 dollars per cwt. in the retail price of rice. An increase in time (T_t) results in a rise in the retail price of rice by 94.2 cents per cwt. per year.

U.S. Derived Demand for Brewer Rice

$$\text{(7)}\quad \widehat{PB}^*_{mt} = 440.638 - \underset{(0.728)}{0.0001QB^*_{mt}} + \underset{(2.259)^s}{0.337PF^*_{rt}}$$

$$+ \underset{(2.433)^s}{2.261PFB_t} - \underset{(1.132)}{1.16PFC_t} + \underset{(1.778)^s}{2.192DPI_t} - \underset{(3.376)^s}{0.226T_t}$$

The signs of the estimated coefficients for all of the explanatory variables in equation (7) are in agreement with prior expectations; however, the coefficients of the quantity of brewer rice (QB^*_{mt}) and the farm price of corn (PFC_t) are not statistically significant. The relation between the quantity of brewer rice and the price of brewer rice (PB^*_{mt}) supports the theory that the derived demand curve for brewer rice is negatively sloped. The negative relation between the farm price of corn (PFC_t) and the price of brewer rice also confirms the prior hypothesis that corn and rice are complementary inputs, at least in beer brewing.

From equation (7) it is indicated that a dollar per cwt. increase in the farm price of rice (PF^*_{rt}) results in a rise of 33.7 cents per cwt. in the price of brewer rice. Barley is indicated to be a substitute for brewer rice in beer brewing. Increasing the farm price of barley (PFB_t) by a dollar per bushel increases the derived demand for brewer rice which causes the price of brewer rice to rise by 2.261 dollars per cwt. Unlike the estimated demand function for rice used for food in equation (6), per capita disposable income (DPI_t) shifts the derived demand for brewer rice to the right. Based on this relation, it suggests the fact that brewer rice is not inferior among the ingredients used in beer brewing. A given positive change in the per capita disposable income by 1,000 dollars leads to an increase in the price of brewer rice by 2.192 dollars per cwt. Over the years (T_t) the price of brewer rice fell by 22.6 cents per cwt. per year.

U.S. Milled Rice Ending Stocks

$$(8)\quad \widehat{EST}^*_{mt} = 1{,}102.994 - \underset{(2.758)^s}{98.548PW^*_{mt}} + \underset{(6.531)^s}{0.030QM^*_{mt}}$$

The milled rice ending stocks (EST^*_{mt}) seem to be strongly influenced by mill price of rice (PW^*_{mt}) and the quantity of rough rice milled (QM^*_{rt}). The previous year's milled rice ending stocks (EST_{mt-1}) was excluded from the final estimated equation due to statistical problems. Not only was this lagged variable highly correlated with the quantity of rough rice milled and the mill price of rice, but also its estimated coefficient had the wrong sign.

Unlike the relation between the total rough rice ending stocks (EST^*_{rt}) and the farm price of rice (PF^*_{rt}) in equation (5), the relation between the milled rice ending stocks and the mill price of rice is as expected. An increase in the mill price of rice by a dollar per cwt. causes the milled rice ending stocks to decrease by 98,548 cwt.

As is apparent from the results, the quantity of milled rice ending stocks rises by 30 cwt. for every 1,000 cwt. increase in the quantity of rough rice milled. Such a small increment is not surprising since milled rice is relatively more perishable than rough rice. Besides, rough rice is milled most of the time after the contracts for milled rice are made between millers and rice distributors such as rice exporters, importers and U.S. retail distributors.

Demand for U.S. Rice Exports in Asia

$$(9)\quad \widehat{QXAO}^*_{mt} = -7{,}764.470 - \underset{(2.566)^s}{1{,}372.140PX^*_{mt}} + \underset{(2.445)^s}{1{,}580.665PT^*_{mt}}$$

$$+ \underset{(3.897)^s}{332.409PDPA_t} - \underset{(1.330)}{1{,}576.370ERPH_t}$$

$$+ \underset{(0.360)}{961.815PXW_t}$$

Demand for U.S. Rice Exports in Africa

$$(10)\quad \widehat{QXAF}^*_{mt} = 610.691 - \underset{(1.756)^s}{389.926PX^*_{mt}} + \underset{(0.441)}{110.259PT^*_{mt}}$$

$$+ \underset{(6.183)^s}{68.810PDPA_t} + \underset{(0.500)}{3.9760FI_t} - \underset{(0.484)}{477.378PXW_t}$$

Demand for U.S. Rice Exports in Europe

$$(11)\quad \widehat{QXE}^*_t = 1{,}909.853 - \underset{(1.045)}{193.477PX^*_{mt}} + \underset{(0.158)}{32.689PT^*_{mt}}$$

$$+ \underset{(3.804)^s}{73.377PDPE_t} - \underset{(1.070)}{689.067ERG_t}$$

$$- \underset{(1.005)}{7.6950FI_t} + \underset{(0.007)}{6.056PXW_t}$$

Demand for U.S. Rice Exports in the Western Hemisphere

$$(12)\quad \widehat{QXWH}^*_t = 2{,}829.279 + \underset{(2.691)^s}{446.675PX^*_{mt}} - \underset{(2.784)^s}{477.929PT^*_{mt}}$$

$$- \underset{(1.892)^s}{0.395QPWH_{rt}} + \underset{(1.522)}{42.170PDPLA_t}$$

$$- \underset{(3.231)^s}{21.920FI_t} + \underset{(1.525)}{1{,}064.969PXW_t}$$

Some statistical problems were encountered in the initial estimations of the previously specified U.S. rice export demand equations (9) through (12). Consequently, several of the regional variables were excluded in the final estimations of these structural equations in order to reduce the degree of multicollinearity.

The U.S. export price of rice (PX^*_{mt}) is included in all of the four regional export demand equations. Its coefficients are statistically significant in equations (9), (10) and (12). However, its effect on the quantity of U.S. rice exports demanded in the Western Hemisphere ($QXWH^*_{mt}$), in equation (12), is positive which is contrary to prior expectation. Therefore, a given increase in the U.S. export price of rice by a dollar per cwt. results in a decrease of 1,372,140 cwt. in the quantity of U.S. rice exports demanded in Asia ($QXAO^*_{mt}$) and a reduction of 389,926 cwt. in the quantity of U.S. rice exports demanded in Africa ($QXAF^*_{mt}$), but an increase of 446,675 cwt. in the quantity of U.S. rice exports demanded in the Western Hemisphere.

Except for equation (12), the estimated coefficients associated with the Thai export price of rice (PT^*_{mt}) in equations (9), (10) and (11) have the expected positive sign. But the coefficients of this variable are statistically insignificant in equations (10) and (11). A rise in this explanatory variable by a dollar per cwt. results in an increase in the quantity of U.S. rice exports demanded in Asia by 1,580,665 cwt. in equation (9), but a decrease in the quantity of U.S. rice exports demanded in the Western Hemisphere by 477,929 cwt. in equation (12). It is apparent from the first three U.S. rice export demand equations that an increase in the world price for rice, as represented by the Thai export price of rice, makes the U.S. mill price of rice (PW^*_{mt}) more competitive and results in an increase in the volume of U.S. rice exports demanded in these regions. However, it is difficult to make any economic implication on the impact of world rice price on the volume of U.S. rice exports demanded in the Western Hemisphere because of the negative coefficient associated with it.

The direction of effect of the regional per capita gross domestic product index of Asia and Africa ($PDPA_t$),[1] Europe ($PDPE_t$) and the Western Hemisphere ($PDPLA_t$), the proxy for the regional per capita income, is as hypothesized. In all but equation (12) the coefficients of these regional income indices are found statistically significant. An increase in the per capita gross domestic product index of Asia by 1 percent results in an increase in the quantity of U.S. rice exports demanded in Asia by 332,409 cwt. and a rise of 68,810 cwt. in the quantity of U.S. rice exports demanded in Africa. Similarly, a 1 percent rise in the per capita gross domestic product index of Europe leads to an increase of 73,377 cwt. in the quantity of U.S. rice exports demanded in Europe. As indicated by the corresponding "approximate" _t_-ratios, the quantity of U.S. rice exports demanded in Africa is the most responsive while that of the Western Hemisphere is the least responsive to a given change in the per capita income. The responsiveness of the quantities of U.S. rice exports demanded in Asia and Europe to a given change in per capita income is about the same.

Although the exchange rates, Philippines Pesos per U.S. dollar ($ERPH_t$) and German Deutsche Marks per U.S. dollar (ERG_t), were included

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[1] As has been stated earlier, the per capita gross domestic product index for Asia is used as the proxy for per capita income in Africa.

in the final estimations in equations (9) and (11), respectively, their coefficients are not statistically significant. Their negative influence on the quantities of U.S. rice exports demanded in Asia and Europe, however, are as expected. For instance, a given increase in the number of Philippines Pesos per U.S. dollar shifts the demand for U.S. rice exports, equation (9), to the left which in effect reduces the quantity of U.S. rice exports demanded in Asia. This implies that a given quantity of U.S. rice is relatively more expensive in Asia because the value of one Philippines Peso is less relative to the U.S. dollar. Similar interpretation can be applied for a given positive change in the German Deutsche Marks per U.S. dollar in equation (11). The selected exchange rate for Africa, U.S. dollars per Nigerian Nira ($ERNG_t$), was dropped from equation (10) because its coefficient was found statistically insignificant and highly correlated with some of the explanatory variables in that equation. Somewhat similar statistical problems prevented the inclusion of the selected exchange rate for the Western Hemisphere, U.S. dollars per Peruvian Sole ($ERPI_t$), in the final estimation of equation (12).

The ocean freight index (OFI_t) was excluded in the final estimation of equation (9) because it was highly correlated with some of the explanatory variables and the sign associated with its estimated coefficient was not as expected. Although it is included in equations (10) through (12), it is found to influence only the quantity of U.S. rice exports demanded in the Western Hemisphere. Therefore, increasing the ocean freight index by 1 percent results in a decrease in the quantity of U.S. rice exports demanded in this region by 21,920 cwt. Qualitatively, a given increase in this variable seems to indicate a shift in the demand for U.S. rice exports in Africa to the right but a shift in the demand for U.S. rice exports in Europe to the left. It is difficult to make any quantitative statement about its marginal effects on the quantities of U.S. rice exports demanded in Africa and Europe because its coefficients are statistically insignificant. The ocean freight rates seem to be statistically unimportant in explaining the variations in the volume of U.S. rice exports demanded in Asia, Africa and Europe.

The U.S. export price of wheat (PXW_t) seems to be statistically unimportant in explaining the variations in the quantities of U.S. rice exports demanded in all the regions. It has a negative estimated coefficient in equation (10). This means (in a qualitative sense) that a given positive change in the U.S. export price of wheat tends to shift the demand for U.S. rice exports (9), (11) and (12) to the right but (10) to the left. The shifts to the right would increase the quantities of U.S. rice exports demanded in Asia, Europe and the Western Hemisphere while the shift to the left would cause the quantity of U.S. rice exports demanded in Africa to decrease. In other words, U.S. wheat exports have the tendency to compete with U.S. rice exports demanded in Asia, Europe and the Western Hemisphere, but they seem to complement the portion of U.S. rice exports demanded in Africa.

The quantities of rough rice production in Asia ($QPAO_{rt}$), Africa ($QPAF_{rt}$) and Europe (QPE_{rt}) were dropped in the final estimation of equations (9), (10) and (11), respectively, because they were found highly correlated with some of the explanatory variables, particularly the regional per capita gross domestic product index, in each of the above behavioral equations. However, a given increase in the quantity of rough rice production in the Western Hemisphere ($QPWH_{rt}$) by 1,000 cwt.

causes the demand for U.S. rice exports (12) to shift to the left which reduces the quantity of U.S. rice exports demanded in this region by 395 cwt. This means about 0.4 percent of U.S. rice exported to the Western Hemisphere is reduced for every 1 percent increase in the quantity of rough rice production in this region. This partially explains why the quantity of U.S. rice exports demanded in this region has declined over the years, particularly the portions of U.S. rice exports demanded by the countries in Latin America.

Total Quantity of U.S. Rice Exports (Identity)

$$(13) \quad \widehat{QXT}^*_{mt} = \widehat{QXAO}^*_{mt} + \widehat{QXAF}^*_{mt} + \widehat{QXE}^*_{mt} + \widehat{QXWH}^*_{mt}$$

As presented in the identity equation (13), the estimated total U.S. rice exports demanded in countries all over the world is derived from the summation of the predicted values of U.S. rice exports demanded in each of the four regions. It is apparent from the results obtained that the regional variables and even the variables common to all of the demand equations for U.S. rice exports indicated different directions and magnitudes of effects on the levels of U.S. rice exports demanded in each region. Therefore, the above disaggregations of the total U.S. rice exports are justified in order to capture regional differences.

Thai Export Price of Rice

$$(14) \quad \widehat{PT}^*_{mt} = 8.602 - \underset{(2.600)^s}{0.0001QX_{mt}} + \underset{(2.131)^s}{0.060PDPW_t}$$

$$+ \underset{(2.289)^s}{0.400PT_{mt-1}}$$

The signs of the estimated parameters are consistent with the prior expectations. The time (T_t), used to capture the effects of any changes in tastes and preferences for rice, was dropped in the final estimation of this equation because it was found to be highly correlated with the quantity of world rice exports (QX_{mt}) and the world per capita gross domestic product index ($PDPW_t$).

An increase in the quantity demanded for world rice exports by 1,000 cwt. is associated with 0.01 cent per cwt. decrease in the Thai export price of rice (PT^*_{mt}). That is, 10 million cwt. (an approximate observed yearly change) of the world rice exports is demanded if the Thai export price of rice declines by a dollar per cwt.

The per capita world income which is represented by the world per capita gross domestic product index ($PDPW_t$) seems to be important in determining the world demand for rice exports. A given increase in this variable by 1 percent results in a rise in the Thai export price of rice by six cents per cwt.

Increasing the previous year's Thai export price of rice (PT_{mt-1}) by a dollar per cwt. results in an increase of 40 cents per cwt. in the current Thai export price of rice. From this relation it can be inferred that the current pricing of the world rice has some historical reference to its past year's price.

<u>U.S. Demand for Rice Millfeed</u>

$$(15)\quad \widehat{PRBM^*_t} = 1.067 - \underset{(5.889)^s}{0.0001QUF^*_t} + \underset{(1.593)}{0.001FGPI_t} + \underset{(8.182)^s}{0.031PWB_t}$$

The signs of the estimated coefficients are in conformity with prior expectations. The previously specified variables, the livestock production index of meat animals ($LSPI_t$) and time (T_t) were excluded in the final estimation of equation (15) for statistical reasons. Both of these variables were found to be highly related to the other explanatory variables in that equation. Moreover, the coefficient of the livestocks production index of meat animals was not statistically significant.

As the results indicate, an increase in the quantity of rice millfeed used (QUF^*_t) by 1,000 cwt. is essentially associated with a fall in the price of rice bran ($PRBM^*_t$) by 0.01 cent per cwt. In other words, the quantity of rice millfeed demanded rises by one million cwt. if the price of rice bran falls by 10 cents per cwt.

Because of the positive relation between the price of wheat bran (PWB_t) and the price of rice bran, wheat bran is confirmed to be one of the substitutes for rice bran in certain feed mixes. If the price of wheat bran increases by a dollar per ton, the price of rice bran rises by 3.1 cents per cwt.

Quantity of Milled Rice Used for Food in the U.S.

$$(16)\quad \widehat{QF}^*_{mt} = -371{,}215 - \underset{(2.041)^s}{67.278PR^*_{mt}} + \underset{(2.755)^s}{0.057QM^*_{rt}} + \underset{(3.482)^s}{196.086T_t}$$

Increasing the retail price of rice (PR^*_{mt}) by a dollar per cwt. results in a decrease in the quantity of milled rice used for food by 67,278 cwt. The availability of milled rice used for food is directly determined by the volume of rough rice milled by U.S. rice millers (QM^*_{rt}). Therefore, increasing this explanatory variable by 1,000 cwt. leads to an increase in the quantity of milled rice used for food by 57 cwt. The estimated coefficient associated with the time variable (T_t) indicates an increase of 196,086 cwt. in the quantity of milled rice used for food each year.

Quantity of Brewer Rice Used in the U.S.

$$(17)\quad \widehat{QB}^{*}_{mt} = -184{,}227 - \underset{(2.790)^{s}}{375.510PF^{*}_{rt}} + \underset{(1.834)^{s}}{0.027QM^{*}_{rt}}$$

$$+ \underset{(3.810)^{s}}{2{,}036.714PFC_{t}} + \underset{(2.235)^{s}}{94.718T_{t}}$$

The direction of effect of the farm price of corn (PFC_t) on the quantity of brewer rice (QB^*_{mt}) is contrary to prior expectation. Because of the fact that the farm price of rice (PF^*_{rt}) is directly related to the mill price of brewer rice (PB^*_{mt}), an increase in the farm price of rice by a dollar per cwt. leads to a decrease in the quantity of brewer rice by 375,510 cwt. Increasing the quantity of rough rice milled (QM^*_{rt}) by 1,000 cwt. results in an increase of 27 cwt. in the quantity of brewer rice used in the U.S. Based on the estimated coefficient associated with time (T_t), the quantity of brewer rice is indicated to increase by 94,718 cwt. per year.

Quantity of Rice Millfeed Used in the U.S.

$$(18)\quad \widehat{QUF}^{*}_{t} = 6{,}180.888 + \underset{(15.157)^{s}}{0.104QM^{*}_{rt}} + \underset{(1.569)}{6.617PWB_{t}} - \underset{(0.167)}{3.119T_{t}}$$

The quantity of rice millfeed used domestically (QUF^*_t) is mainly determined by the quantity of rough rice milled (QM^*_{rt}). A rise in this explanatory variable by 1,000 cwt. results in an increase of 104 cwt. in the quantity of rice millfeed utilized in the U.S. In a qualitative sense, any increase in the price of wheat bran (PWB_t) is found to raise the quantity of rice millfeed used. Therefore, wheat bran and rice millfeed are indicated to be competitive inputs in certain feed mixes.

Based on the negative sign associated with the estimated coefficient of time (T_t), the trend in the usage of rice millfeed seems to be declining each year.

U.S. Mill Price of Rice

$$(19)\quad \widehat{PW}^*_{mt} = -0.531 + \underset{(13.417)^s}{2.040PF^*_{rt}} + \underset{(2.504)^s}{0.147PT^*_{mt}} - \underset{(1.080)}{0.034PW_{mt-1}}$$

In a statistical sense, both the U.S. farm price of rice (PF^*_{rt}) and the Thai export price of rice (PT^*_{mt}) influenced the U.S. mill price of rice (PW^*_{mt}) significantly. The signs of the parameter estimates conform with prior expectations.

A dollar rise per cwt. in the U.S. farm price of rice is associated with an increase in the U.S. mill price of rice by 2.040 dollars per cwt. The magnitude of this estimated coefficient implies a relatively large marketing margin between the farm level and the U.S. rice mills.

As expected, U.S. rice exports compete with world rice exports because of the positive estimated coefficient associated with the Thai export price of rice. In other words, when the Thai report price of rice increases and reaches a certain level, the U.S. rice exports become more attractive in the international rice markets because the U.S. mill price of rice is relatively low. But when the quantity demanded for U.S. rice exports has risen high enough, the U.S. mill price of rice from which the U.S. export price of rice is derived, identity equation (20), will be forced to rise which in effect reverses the direction of change in the quantity of U.S. rice exports demanded.

The previous year's U.S. mill price of rice (PW_{mt-1}) does not seem to affect the current U.S. mill price of rice. It could then be inferred that there is no close relation between the lagged (one year) and the current U.S. mill price of rice.

U.S. Export Price of Rice (Identity)

$$(20)\quad \widehat{PX}^*_{mt} = \widehat{PW}^*_{mt} - GXS_t$$

The estimated value of the U.S. export price of rice (PX^*_{mt}) is obtained by subtracting the U.S. government rice export payments (GXS_t) from the predicted U.S. mill price of rice (PW^*_{mt}). The influence of the U.S. mill price of rice on the U.S. export price of rice has already been mentioned in the discussion of equation (19).

Quantity of Rough Rice Milled at U.S. Mills (Identity)

$$(21)\quad \widehat{QM}^*_{rt} = \widehat{QF}^*_{mt} + \widehat{QB}^*_{mt} + \widehat{QXT}^*_{mt} + \widehat{QUF}^*_{t} + \widehat{EST}^*_{mt} + QH_t$$

The estimated quantity of rough rice milled (QM^*_{rt}) is equal to the sum of the various estimated quantities of rice such as milled rice utilized for food (QF^*_{mt}), brewer rice (QB^*_{mt}), total U.S. rice exports (QXT^*_{mt}), milled rice ending stocks (EST^*_{mt}) and rice millfeed (QUF^*_t). The quantity of rice hulls (QH_t) is added to these estimated quantities to account for all leakages at and beyond U.S. rice mills.

General U.S. Rice Market Equilibrium (Identity)

$$(22)\quad QS_{rt} = \widehat{QD}^*_{rt}$$

where:

$$\widehat{QD}^*_{rt} = \widehat{QM}^*_{rt} + \widehat{EST}^*_{rt}$$

The general U.S. rice market equilibrium is attained at the point where the vertical annual supply curve intersects with the total demand curve. The estimated equilibrium quantity of rice (QD^*_{rt}) is cleared in the market at the estimated equilibrium price of rice $\overline{P}^*_{rt}$ which is consistent with graph (13) in Figure 2, p. 16.

C. VALIDATION OF THE DEMAND MODEL

Unlike the single-equation supply model, the set of statistical tests such as the R^2, F-ratio and the standard error cannot be used to evaluate the "goodness" of fit of the simultaneous equation demand model for U.S. rice. The reasons being that some of the more significant (in a statistical sense) equations may have to be balanced against the other less significant equations in the system. Also, the individual equation has a less dynamic structure relative to the model as a whole [18, p. 361]. Given these circumstances, a simulation model based on the 3SLS estimates is developed. These 3SLS results are used because of their better estimation efficiency by accounting for the cross-equation error covariances of interdependent structural equations in the system as compared with 2SLS.

Since the purpose of this section is to validate the demand model, the "ex post" simulation process based on the 1950 actual values of the endogenous variables and the 1950-78 actual values of the exogenous variables is performed in order to obtain the simulated values of the endogenous variables. Then, the performance of the model is evaluated on how closely the "ex post" simulation values of each of the endogenous variables tract their actual values in the series.

To determine how well an endogenous variable tracks its actual data series, two types of quantitative measures suggested by Pindyck and Rubinfeld [18, p. 362] are used.

1. RMS (root-mean-square) simulation error. The RMS error for the endogenous variable Y_t is defined as:

$$\left[\frac{1}{T}\sum_{t=1}^{T}(Y_t^s - Y_t^a)^2\right]^{\frac{1}{2}}$$

where:

Y_t^s = the simulated value of Y_t

Y_t^a = the actual value of Y_t

T = the number of periods in the "ex post" simulation

2. RMS percent error which is defined as:

$$\left[\frac{1}{T}\sum_{t=1}^{T}\left(\frac{Y_t^s - Y_t^a}{Y_t^a}\right)^2\right]^{\frac{1}{2}}$$

The RMS simulation error measures the deviation of the simulated variable from its actual values. But its magnitude can only be examined by comparing it with the mean value of the variable in question. The RMS percent error is basically the same as the RMS simulation error, but it is expressed in percentage terms to avoid the influence of units of measurement. Generally, the smaller is the magnitude of these measures the closer are the simulated values of a particular endogenous variable to the actual data series.

The RMS simulation error and the RMS percent error associated with each simulated endogenous variable are presented in Table II. The actual arithmetic means of these endogenous variables are as previously presented (Table I, p. 42). The actual and the simulated values of each endogenous variable are also to be shown graphically later. These graphs are not only useful in revealing the tracking ability of the simulated

TABLE II

RESULTS OF THE "EX POST" SIMULATION

Endogenous Variable	Unit	RMS Error	RMS Percent Error
PF^*_{rt}	\$/cwt.	1.961	40.015
PW^*_{mt}	"	4.199	40.375
PX^*_{mt}	"	5.166	59.450
PB^*_{mt}	"	0.950	20.679
PR^*_{mt}	"	3.281	15.055
PT^*_{mt}	"	2.466	24.969
$PRBM^*_{t}$	"	0.240	14.793
EST^*_{rt}	1,000 cwt.	6,045.120	167.082
EST^*_{mt}	"	1,214.160	49.431
$QXAO^*_{mt}$	"	7,990.530	39.457
$QXAF^*_{mt}$	"	2,485.920	187.655
QXE^*_{mt}	"	1,524.380	115.607
$QXWH^*_{mt}$	"	2,243.850	156.759
QXT^*_{mt}	"	8,639.220	28.832
QF^*_{mt}	"	1,861.260	10.632
QB^*_{mt}	"	1,403.140	29.780
QUF^*_{t}	"	2,659.930	33.186
QM^*_{rt}	"	25,045.700	34.841
QD^*_{rt}	"	21,768.700	27.211

variable on its actual values but also indicate how well the simulated values of an endogenous variable duplicates turning points in the actual data series.

The evaluation of the results in Table II is based only on the relative value of the RMS percent error since it is preferred to the RMS simulation error in the sense that it is free from the influence of the units of measurement. For the purpose of this study, the RMS percent error whose relative value is 40 percent or smaller is considered satisfactory. Note that the 40 percent upper limit is arbitrarily selected because the purpose of the demand model is mainly to test certain hypotheses and not for forecasting. Besides, there is no clear-cut rule stating as to what level of the RMS percent error is acceptable.

The RMS percent error of the farm price of rice (PF^*_{rt}) is 40.015 percent indicating that its predicted values track the historical data somewhat closely. Also, visual inspection of Figure 3 shows that the simulated farm price of rice (broken line) tracks its actual data series (solid line) in the long run (1950-78).[1] But the simulated values of the farm price of rice are generally higher than the actual values. Also, the simulated farm price of rice fails to duplicate some of the turning points of its actual data series. The short-run prediction of the farm price of rice is relatively poor.

The model does poorly in simulating the total quantity of rough rice ending stocks (EST^*_{rt}) as revealed by its high RMS percent error (167.082 percent). This indicates that the predicted values of this

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[1] Long run hereafter refers to the whole period (ex post) covered in the model estimation.

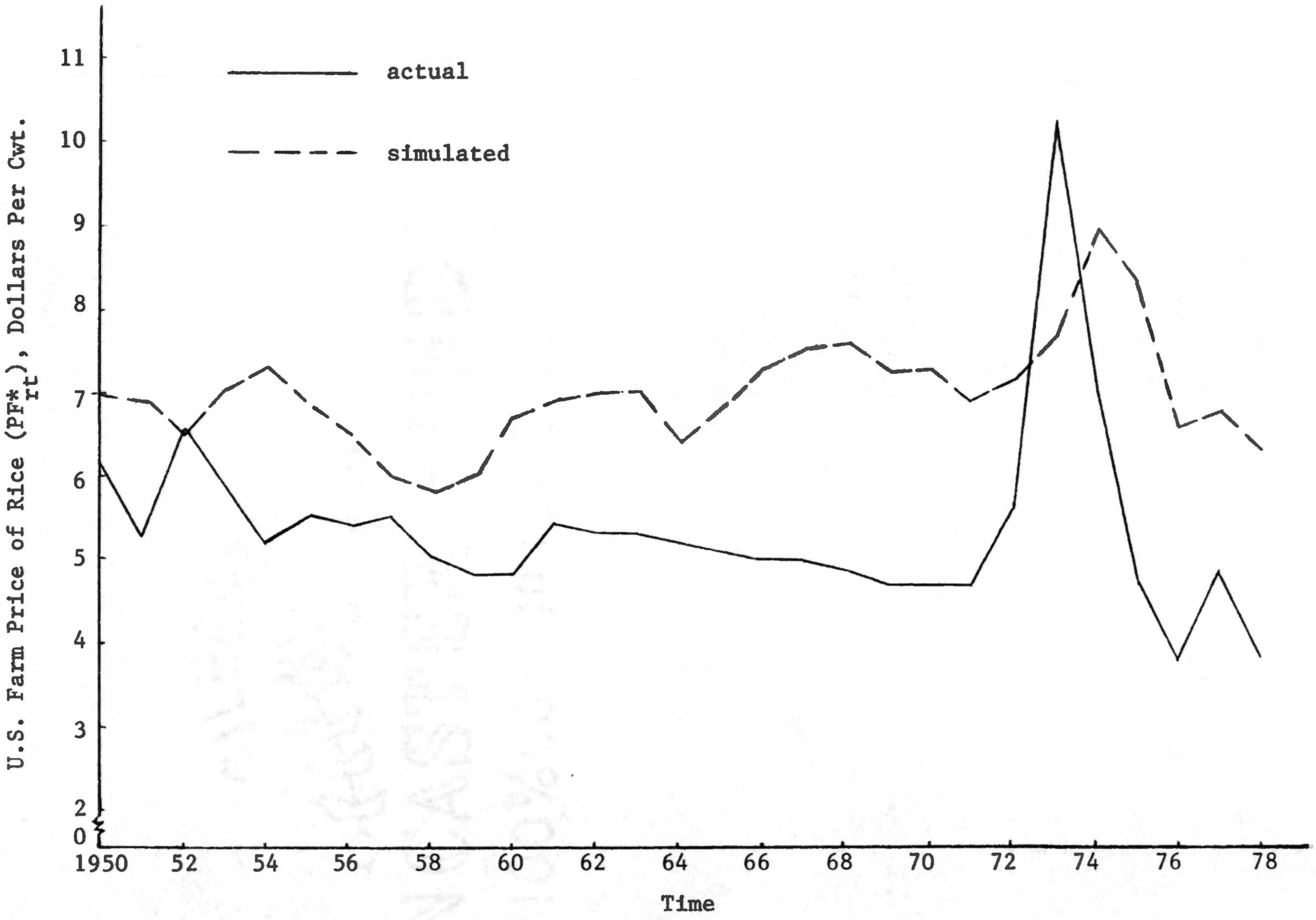

Figure 3. "Ex Post" Simulation of U.S. Farm Price of Rice

endogenous variable have drifted away from the historical data. As shown in Figure 4, the actual data series have fluctuated sharply over the periods covered in this study. There are large deviations between the simulated and the actual values of 1955-58, 1961-70 and 1972-75. Although the model is generally able to predict the trends of the total quantity of rough rice ending stocks in the long run, some of its turning points were not duplicated in the short run (for example, in 1957-59, 1951-62 and 1976-78). Such a large RMS percent error associated with the simulated values of this endogenous variable could be partly attributed by the presence of the government stocks in it which is not accounted for by the model.

The RMS percent error (15.055 percent) associated with the retail price of rice (PR^*_{mt}) indicates that the model performs very well in predicting its historical values. Figure 5 also shows that the simulated values of this variable track the actual data series in 1951-60 and 1971-78 well, but its short-run prediction in 1961-70 could be unreliable.

The simulated values of the brewer rice price (PB^*_{mt}) seem to track the historical data as indicated by the associated RMS percent error (20.679 percent) and the corresponding graph in Figure 6. However, the model fails to account for some of the sharp fluctuations in the actual data series in the short run, for example, in 1952-56. In general, the performance of the model for brewer rice price is satisfactory.

The model does fairly well in predicting the values of the milled rice ending stocks (EST^*_{mt}) relative to the total rough rice ending stocks (EST^*_{rt}) above. But the RMS percent error (49.431 percent)

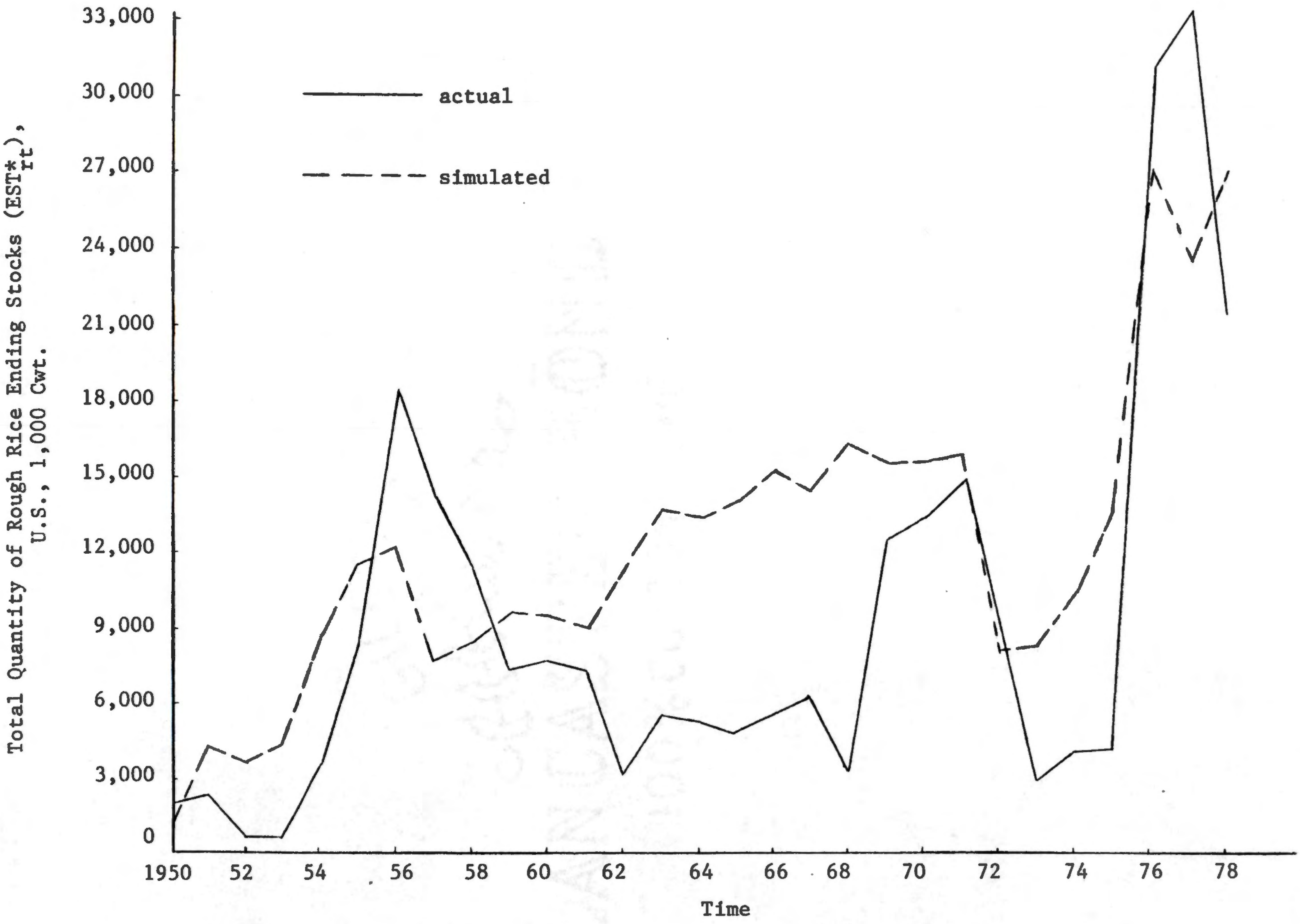

Figure 4. "Ex Post" Simulation of Total Rough Rice Ending Stocks

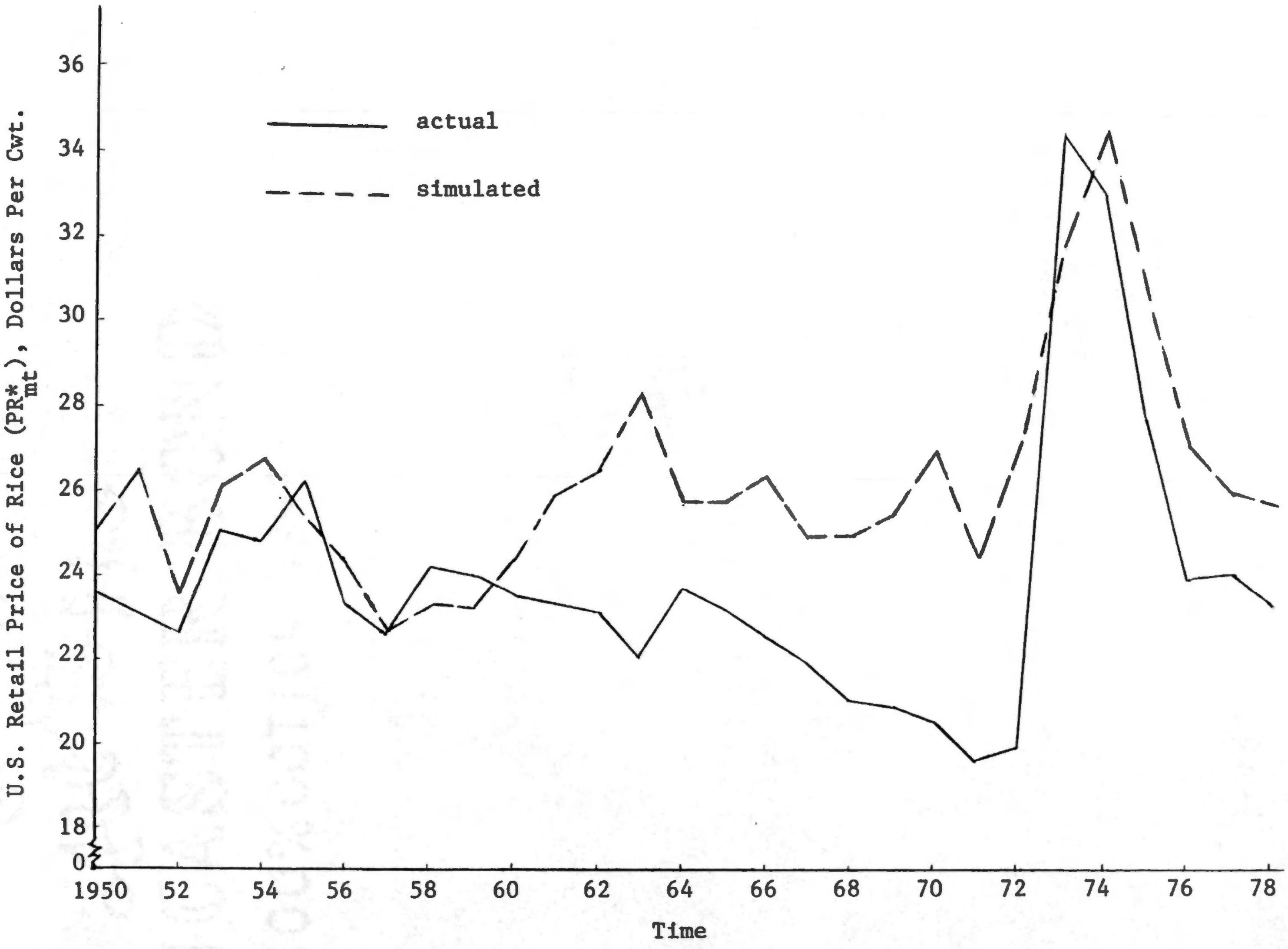

Figure 5. "Ex Post" Simulation of U.S. Retail Price of Rice

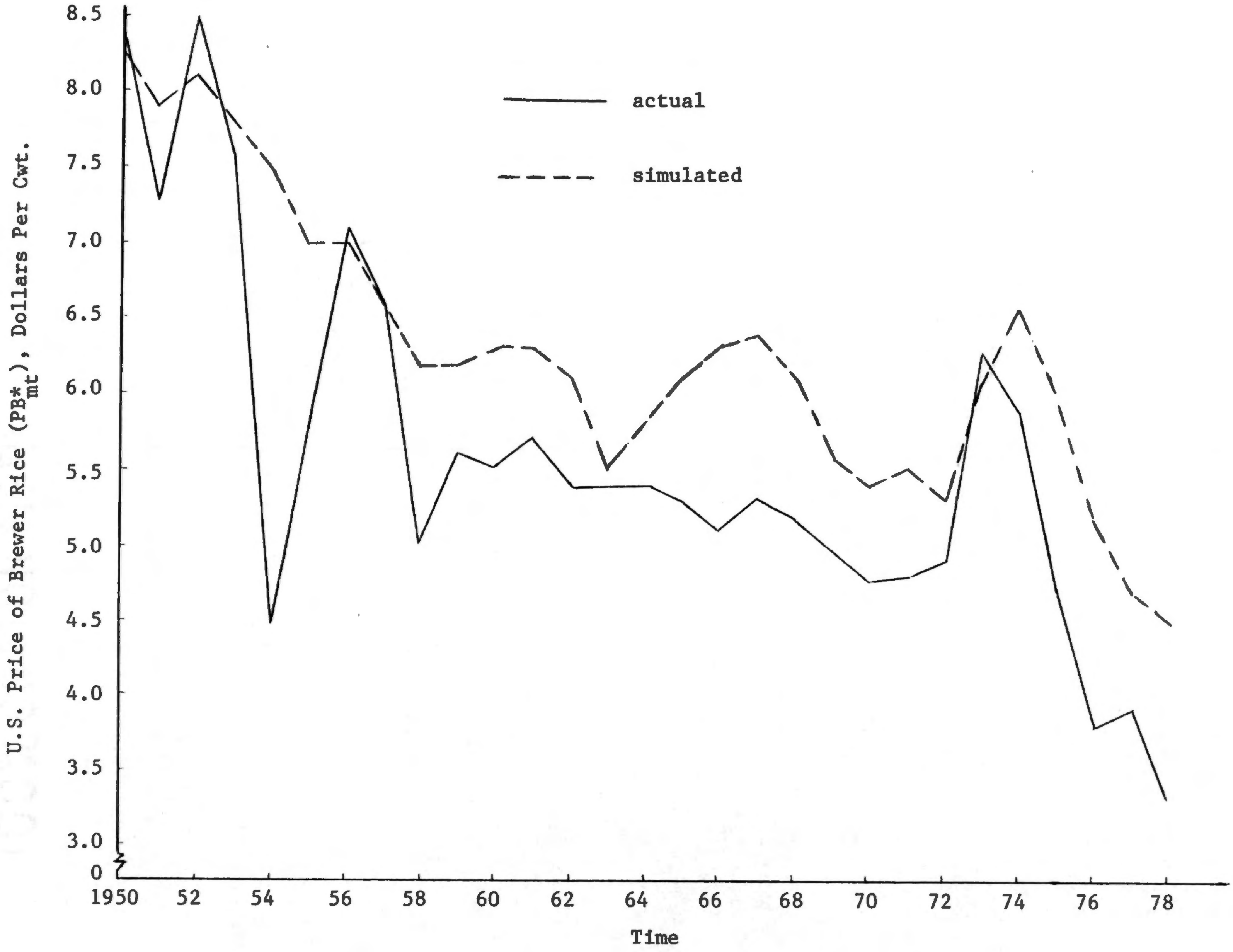

Figure 6. "Ex Post" Simulation of U.S. Price of Brewer Rice

associated with the milled rice ending stocks is still too high to be acceptable. Although they generally move in the same directions, the simulated values of the milled rice ending stocks are much lower than their historical data (Figure 7). Also, the model fails to capture some of the sudden large changes in the actual data series of this variable.

The RMS percent errors associated with the quantity demanded for U.S. rice exports in Asia ($QXAO^*_{mt}$), Africa ($QXAF^*_{mt}$), Europe (QXE^*_{mt}) and the Western Hemisphere ($QXWH^*_{mt}$) are 39.457, 187.655, 115.607 and 156.759 percent, respectively. Except for the quantity of U.S. rice exports demanded in Asia, the model performs poorly in simulating the historical values of the other three regional quantities of U.S. rice exports. The simulated values of the U.S. rice exports demanded in Asia do not drift away considerably from the actual values but fail to duplicate the sudden changes of the actual values in the short run, particularly in 1955-57 and 1973-75 (Figure 8). The simulated values of the U.S. rice exports demanded in Africa in 1950-55 are negative, and they deviate from the actual values in 1960-67 and 1976-78 (Figure 9). Such deviations and the negative predicted values might have caused the RMS percent error associated with it to be extremely large. In Figure 10, the simulated values of the U.S. rice exports demanded in Europe are negative in 1950-52. This plus the large deviation between the simulated values and the actual data series in 1958-78 probably explain the large RMS percent error associated with it. However, the simulated values seem to track the actual values satisfactorily in the long run. There is a marked deviation between the simulated values of the U.S. rice exports demanded in the Western Hemisphere and the actual values in 1959-78 (Figure 11). This could explain the large RMS percent error

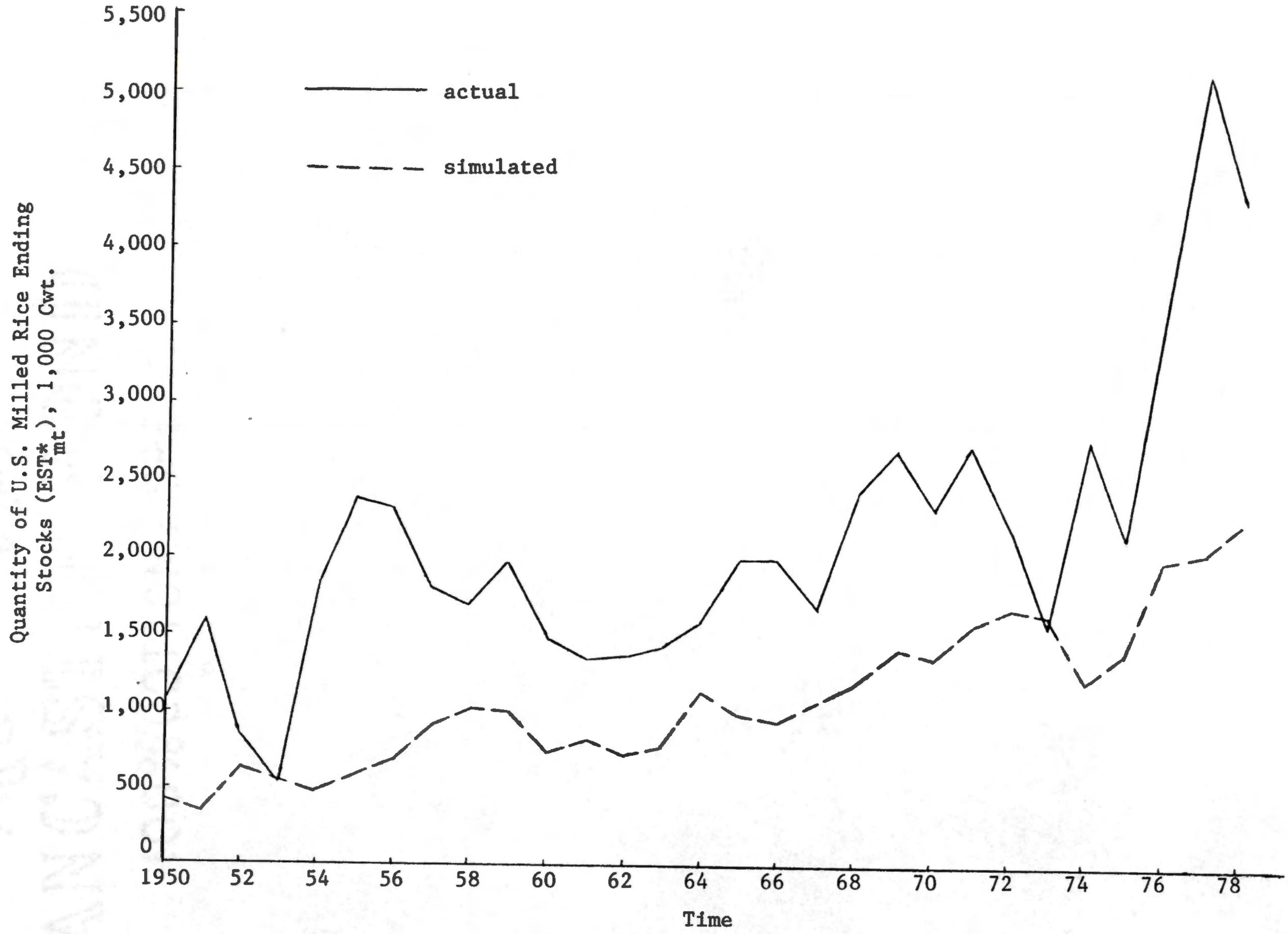

Figure 7. "Ex Post" Simulation of U.S. Milled Rice Ending Stocks

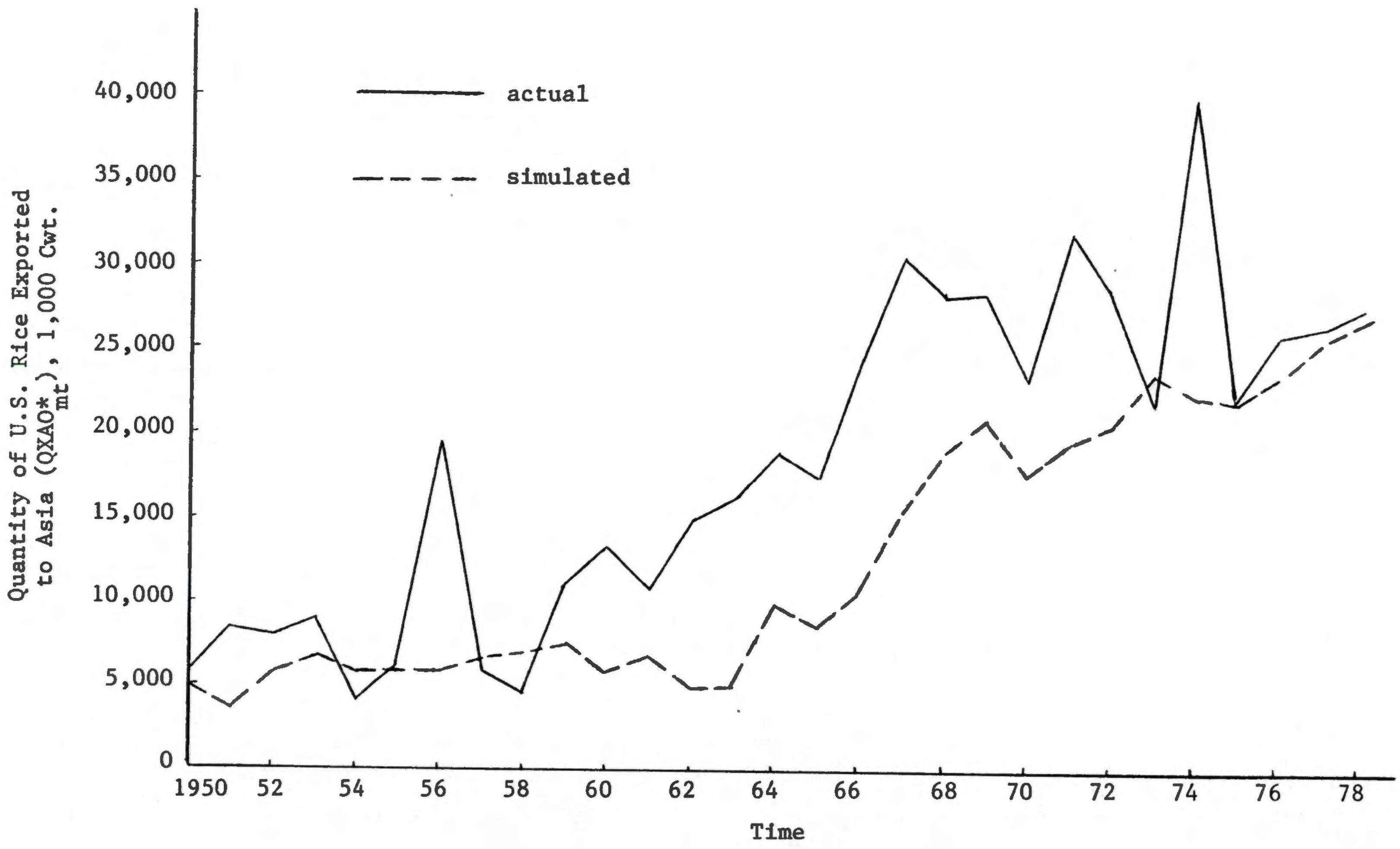

Figure 8. "Ex Post" Simulation of U.S. Rice Exported to Asia

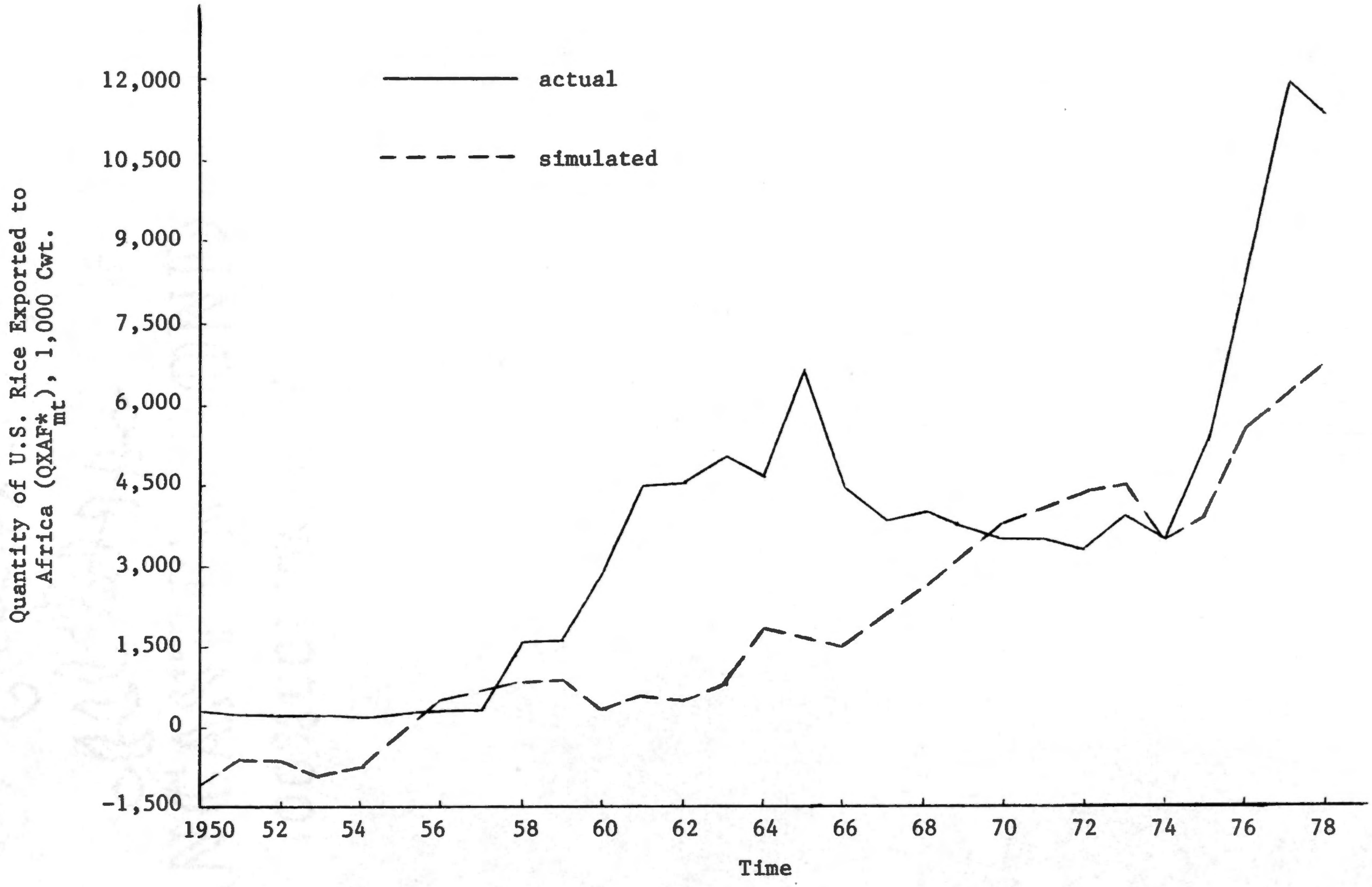

Figure 9. "Ex Post" Simulation of U.S. Rice Exported to Africa

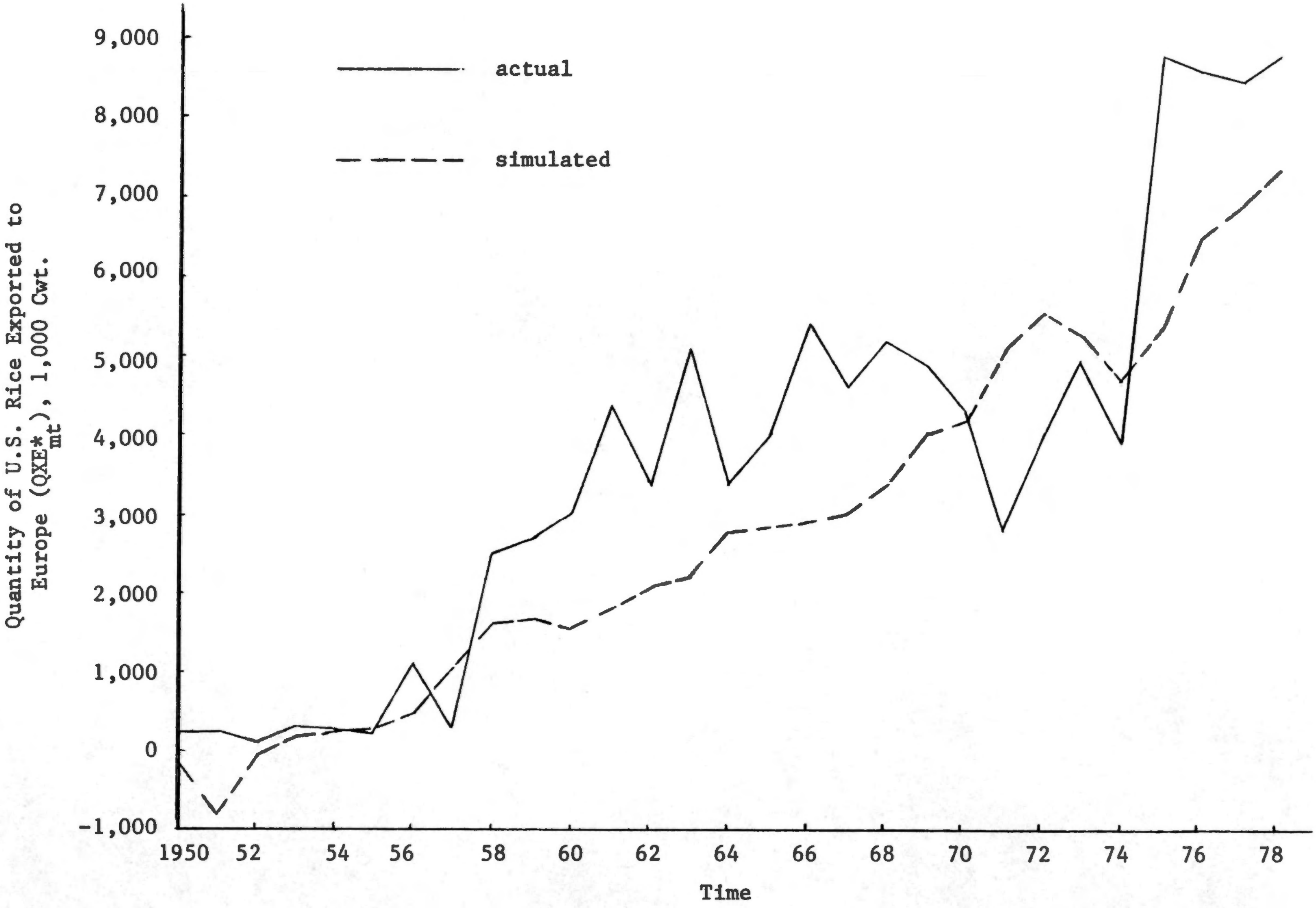

Figure 10. "Ex Post" Simulation of U.S. Rice Exported to Europe

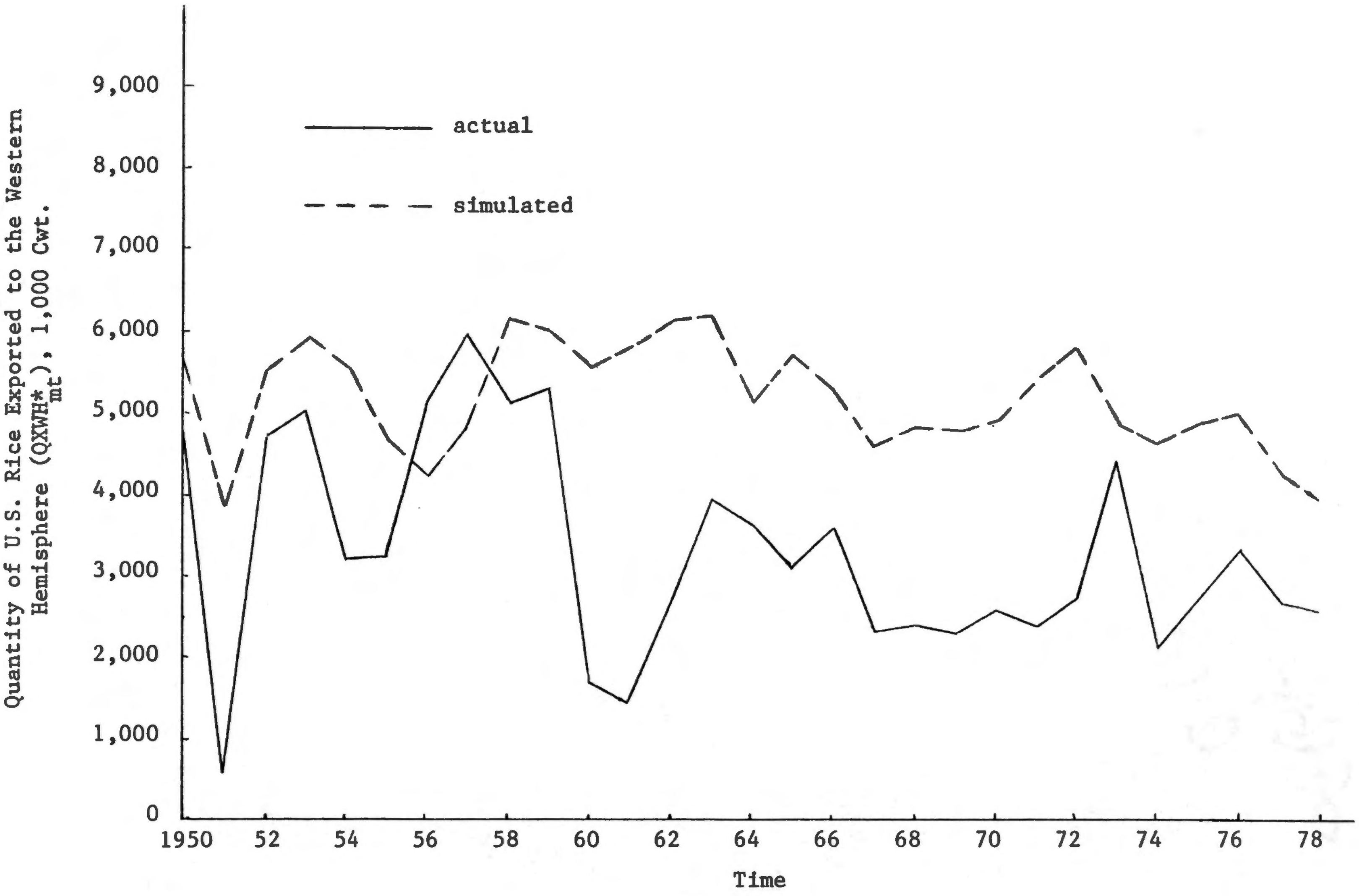

Figure 11. "Ex Post" Simulation of U.S. Rice Exported to the Western Hemisphere

associated with it. Also, several of the turning points in the historical data are not duplicated by its simulated values.

Although the model fails to simulate the actual data series of the U.S. rice exports demanded in each region, it does relatively well in predicting the total quantity demanded for U.S. rice exports (QXT^*_{mt}) whose associated RMS percent error is 28.832 percent. This is also evident in Figure 12 that its simulated values are shown to track the actual data series very well. Again the model fails to simulate some of the short-run fluctuations (turning points) in the actual data series.

Both the RMS percent error (24.969 percent) and Figure 13 indicate that the simulated Thai export price of rice (PT^*_{mt}) tracks its historical data well. With the exception of the periods (1951-53 and 1972-74), its simulated values move very closely with its actual data series. Therefore, it is evident that the performance of the model in predicting the actual values of this variable is quite satisfactory.

The RMS percent error associated with the rice bran price ($PRBM^*_t$) is 14.793 percent indicating that the simulated values of this variable do not deviate much from the actual data series. Visual inspection of Figure 14 also shows that the simulated values of this variable move very closely with the actual values almost throughout the period covered in this study. The model also does well in duplicating the short-run turning points of the historical data.

The model works relatively well in simulating the quantities of rice used domestically such as the quantities of milled rice used for food (QF^*_{mt}), brewer rice (QB^*_{mt}) and the rice millfeed (QUF^*_t) as indicated by their respective RMS percent errors, 10.632, 29.780 and 33.186 percent. Inspecting the corresponding graphs in

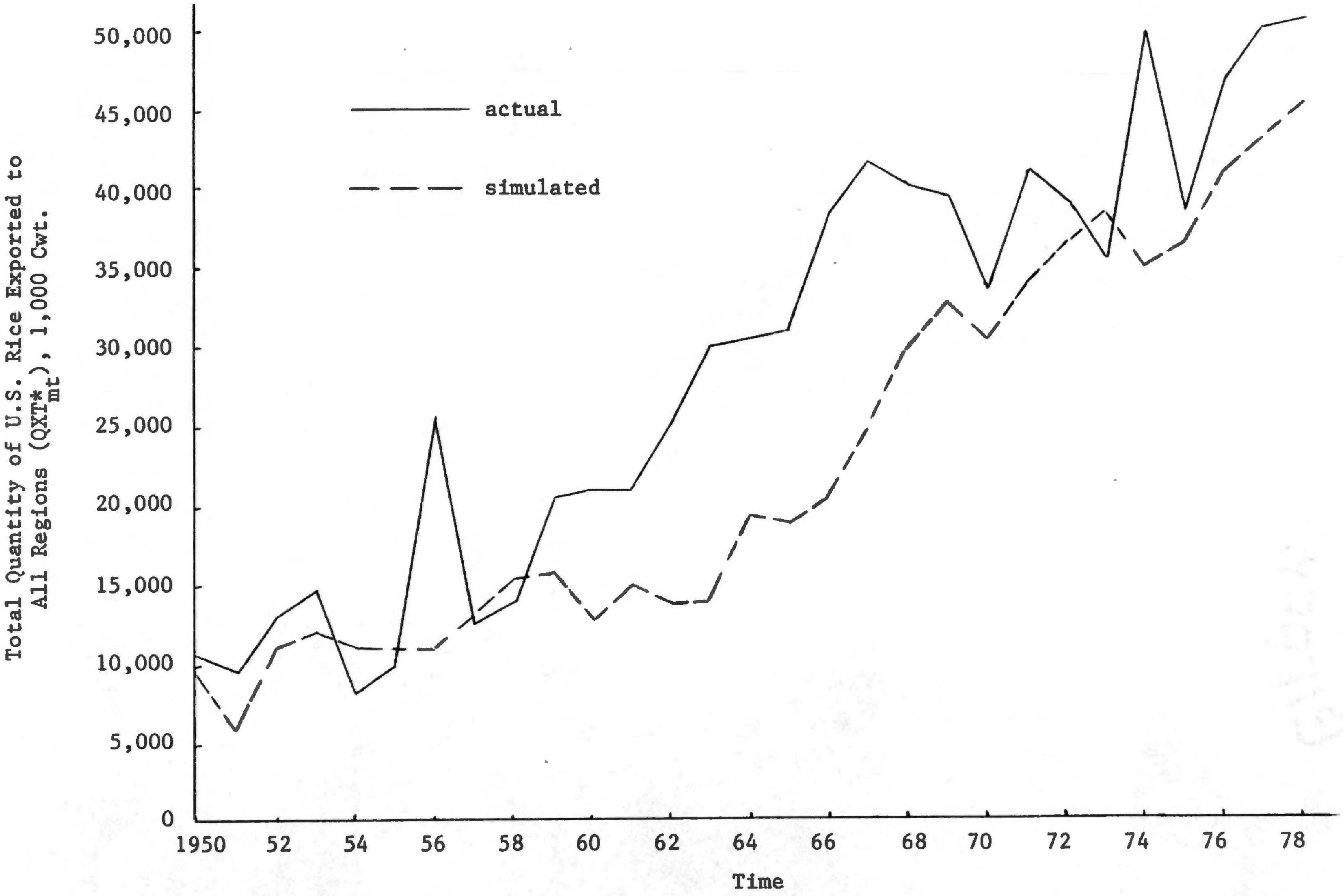

Figure 12. "Ex Post" Simulation of Total U.S. Rice Exported to All Regions

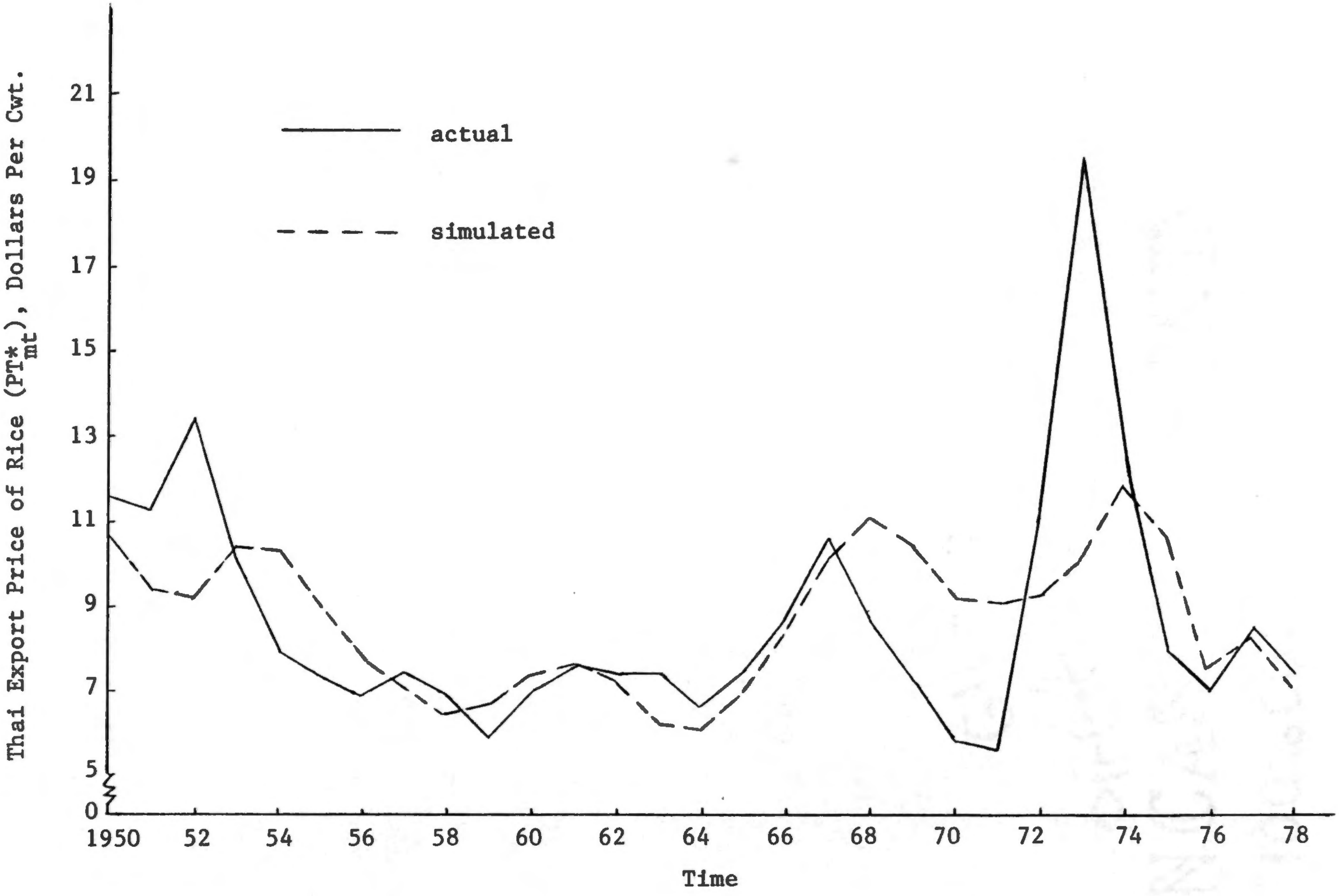

Figure 13. "Ex Post" Simulation of Thai Export Price of Rice

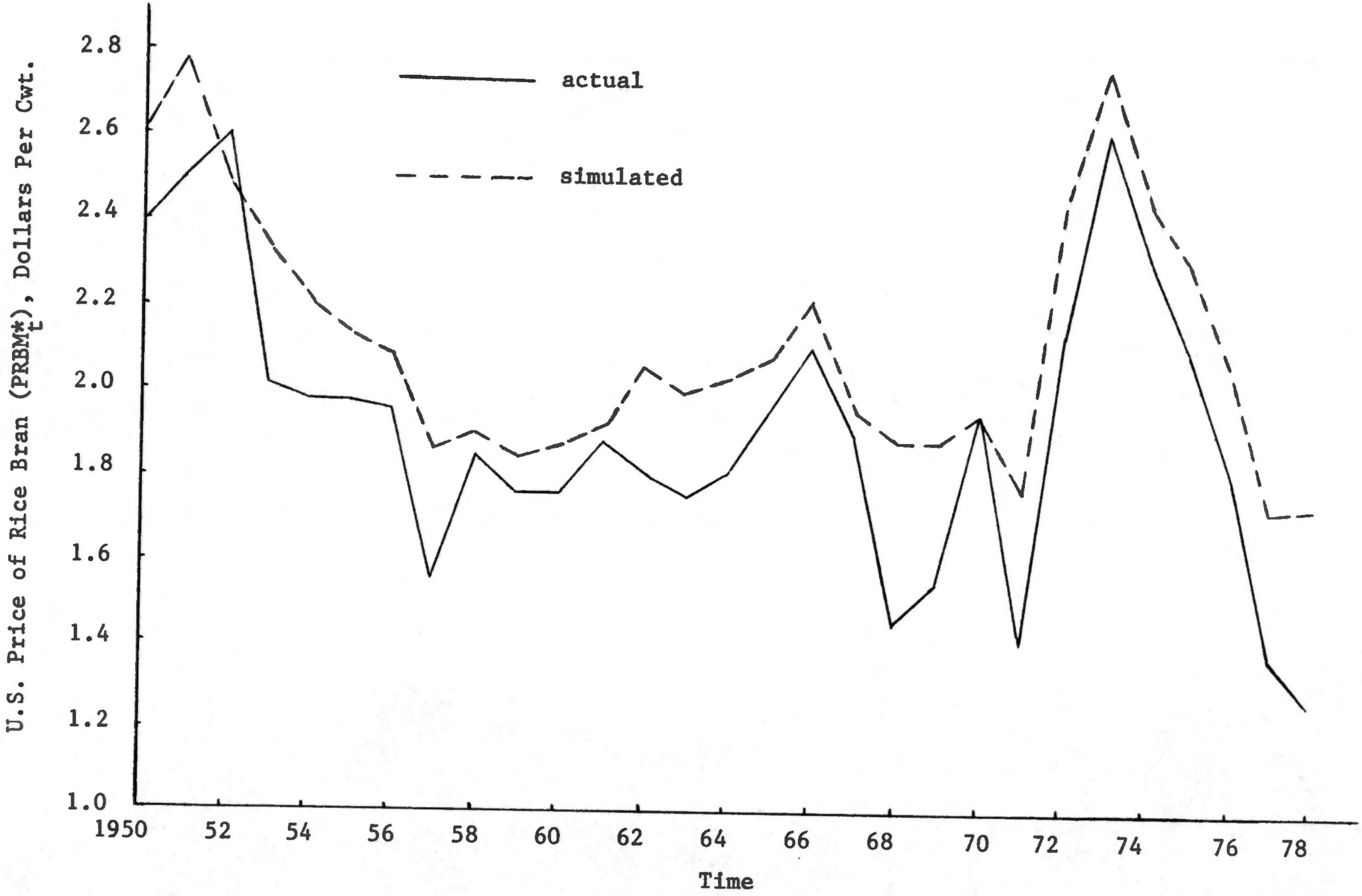

Figure 14. "Ex Post" Simulation of U.S. Price of Rice Bran

Figures 15, 16 and 17, the simulated values of these variables do in fact track their own actual data series fairly closely, at least in the long run. However, the model fails to account for the sharp down turn of the quantity of milled rice used for food in 1976-78 (Figure 15). In Figures 16 and 17, not only does the model fail to duplicate some of the short-run fluctuations occurring in their historical data but the simulated values of brewer rice and rice millfeed have larger departures from their respective actual data series.

The RMS percent error for the U.S. mill price of rice (PW^*_{mt}) is 40.375 percent and that of the U.S. export price of rice (PX^*_{mt}) is 59.450 percent. Despite the fact that the U.S. export price of rice is derived directly from the U.S. mill price of rice by means of the identity equation (20), the simulation results of the two prices are different. The model fails to predict the historical data for the U.S. export price of rice perhaps due to the uncertain nature of the government rice export payment which is highly subject to the prevailing world's rice price. In comparing the graphs for the actual and the simulated values of the U.S. mill price of rice (Figure 18) and the U.S. export price of rice (Figure 19), it is clear that the deviation associated with the U.S. export price of rice is larger than that of the U.S. mill price of rice, particularly in 1957-72.

The simulated values of the quantity of rough rice milled (QM^*_{rt}) at U.S. mills seem to track the actual data series well as indicated by the relatively low RMS percent error (34.841 percent). The graphical result in Figure 20 also shows that the simulated line of this endogenous variable is in fact moving in the same direction as the actual line. But

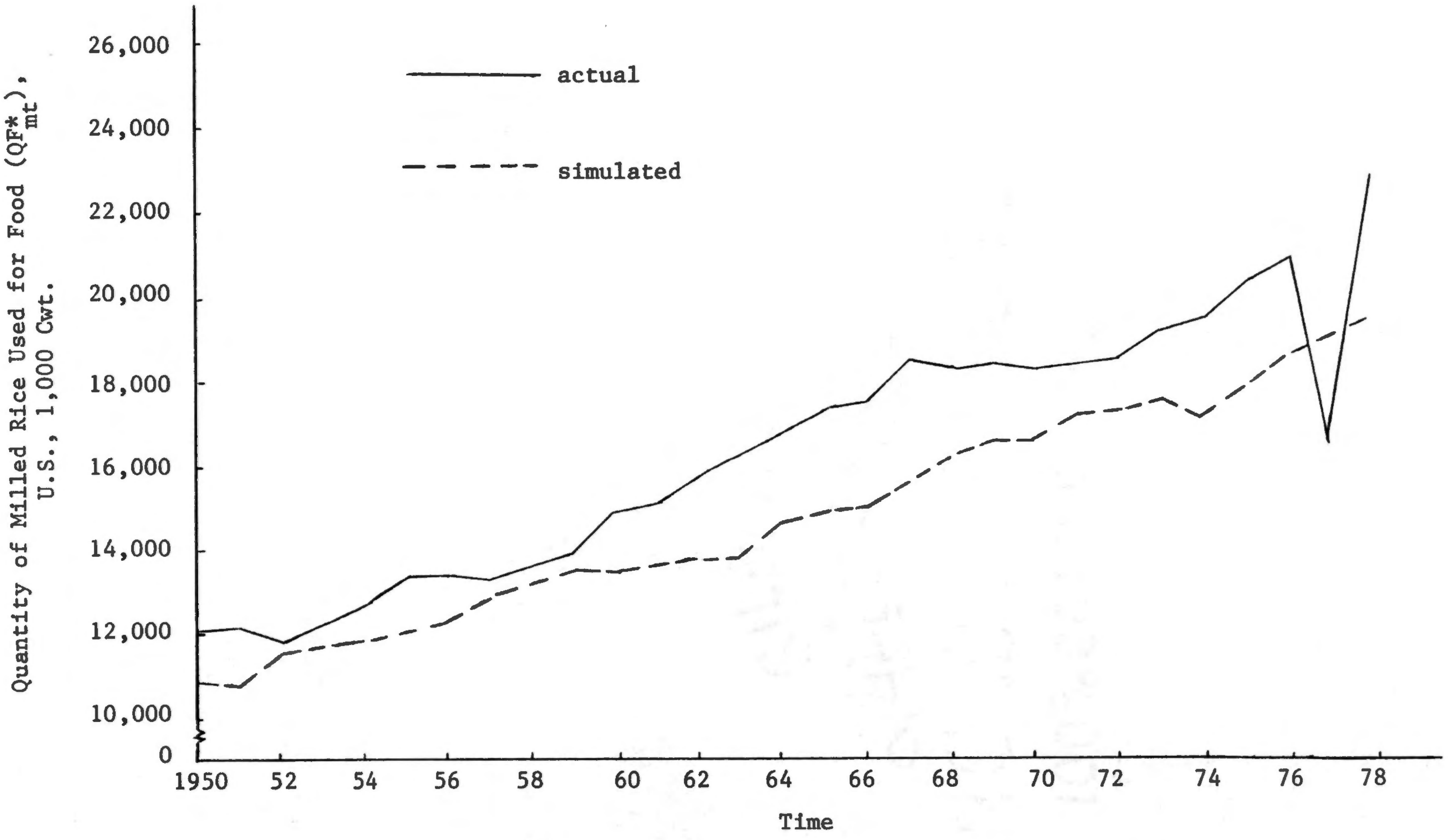

Figure 15. "Ex Post" Simulation of Milled Rice Used for Food in the U.S.

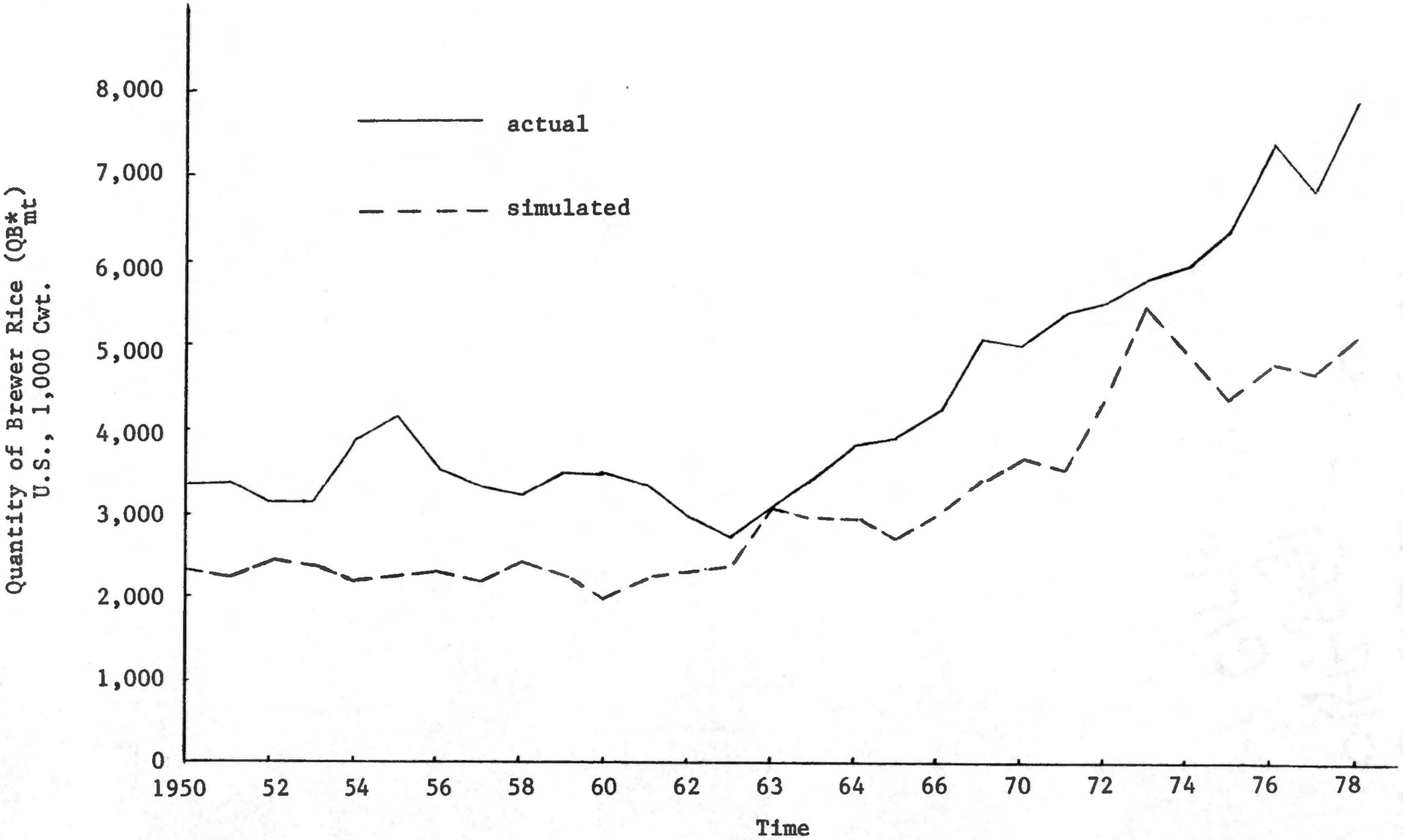

Figure 16. "Ex Post" Simulation of Brewer Rice Used in the U.S.

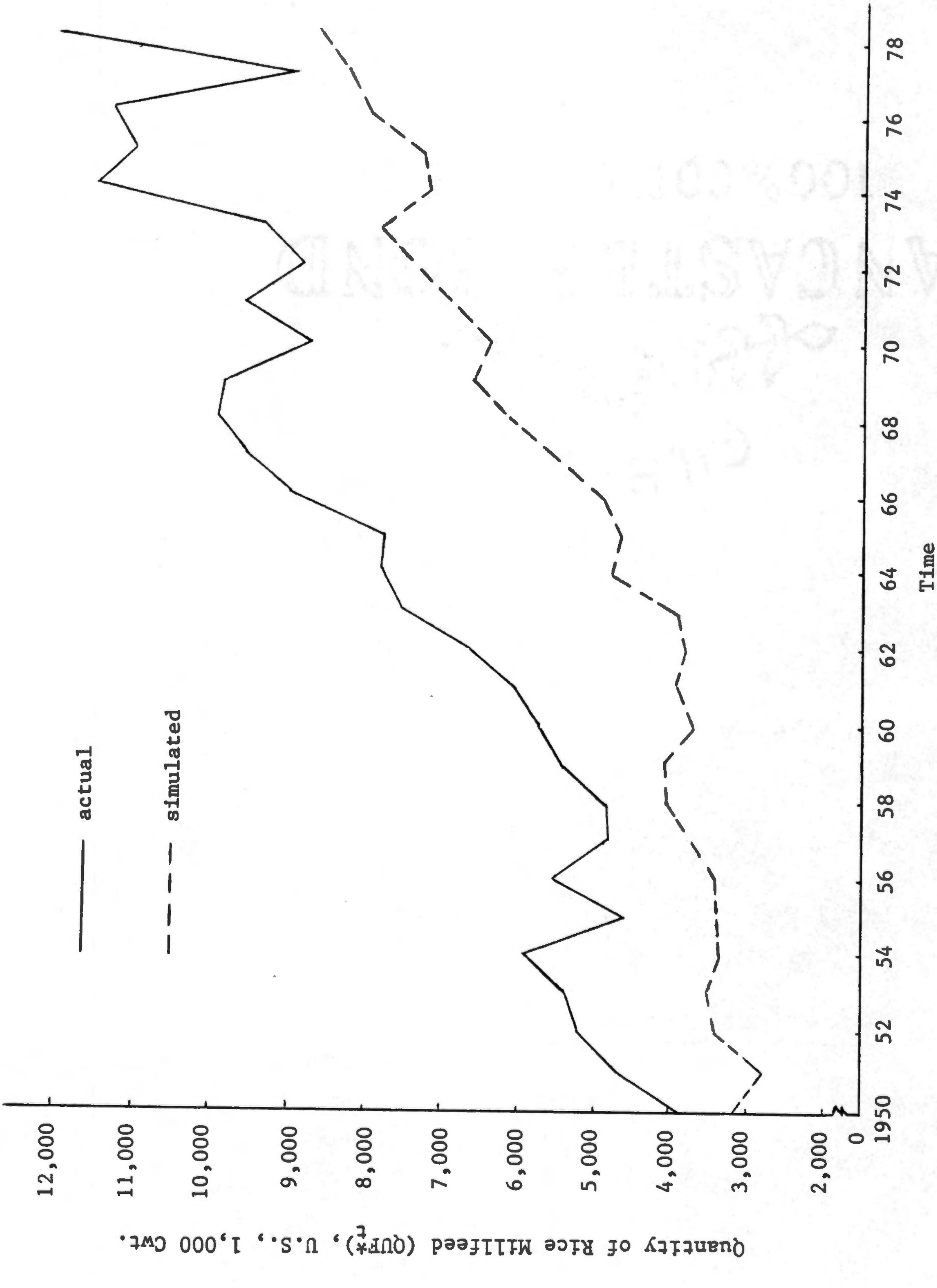

Figure 17. "Ex Post" Simulation of Rice Millfeed Used in the U.S.

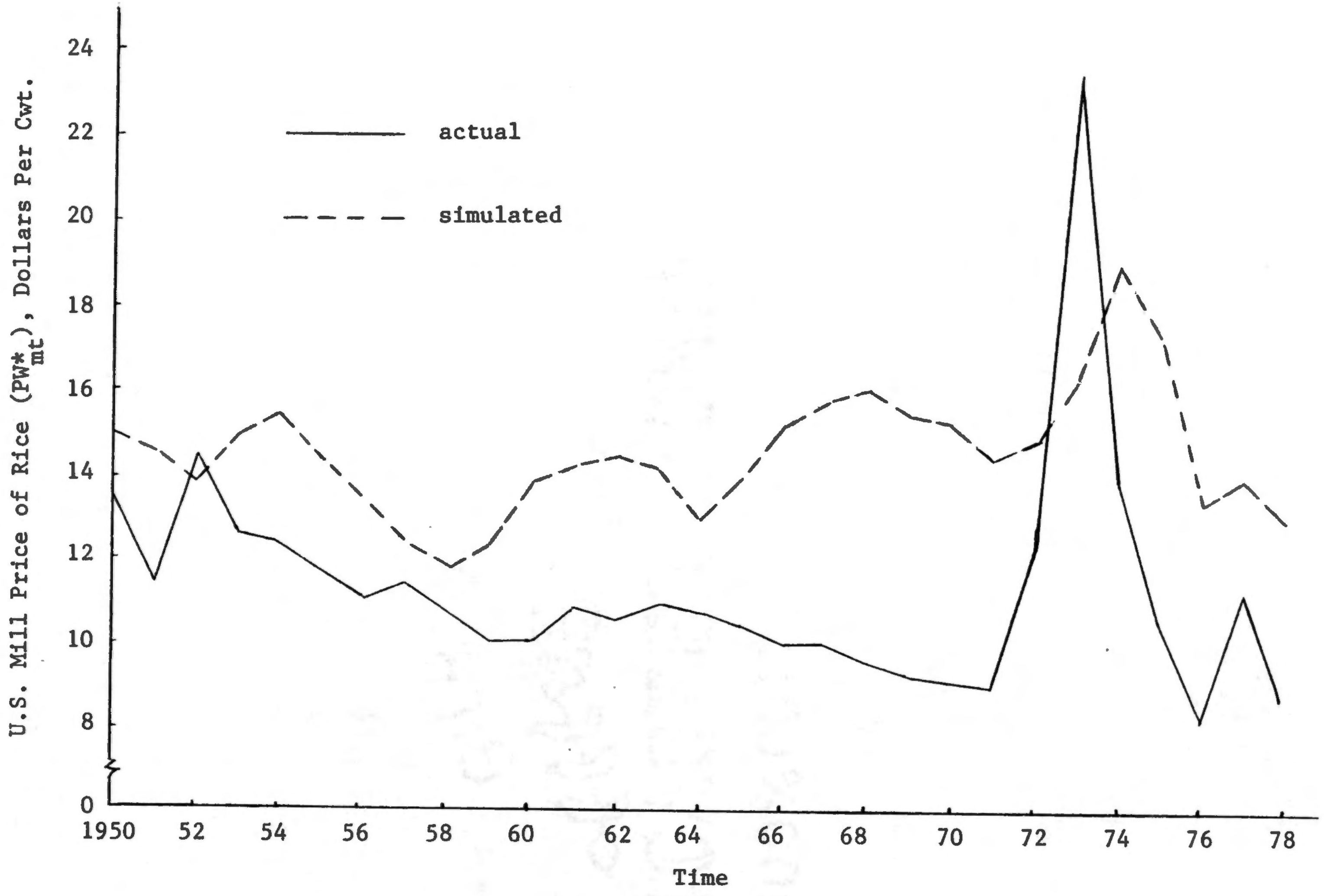

Figure 18. "Ex Post" Simulation of U.S. Mill Price of Rice

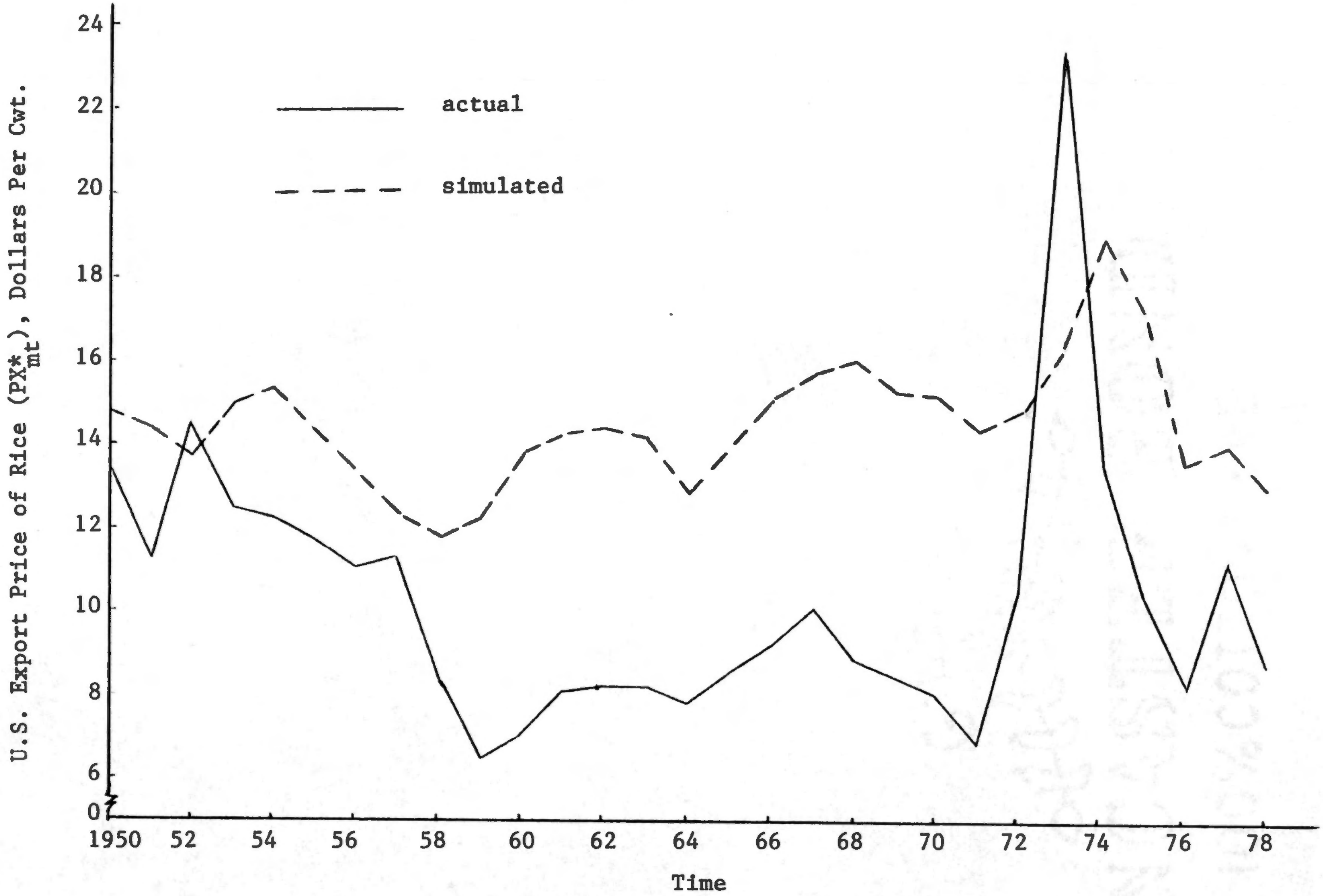

Figure 19. "Ex Post" Simulation of U.S. Export Price of Rice

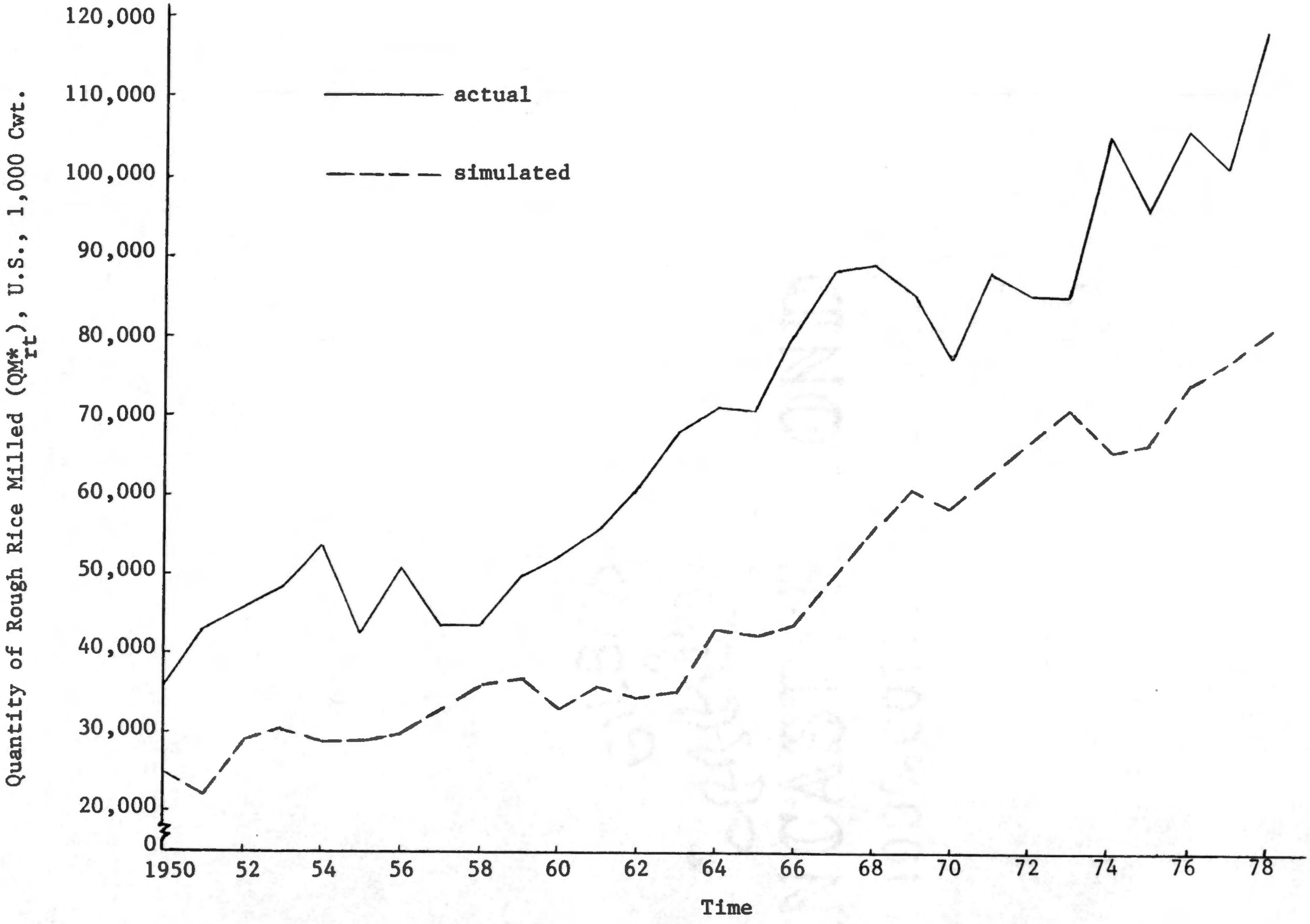

Figure 20. "Ex Post" Simulation of Rough Rice Milled at U.S. Rice Mills

the simulated line is much lower than the actual line throughout the historical period.

The RMS percent error (27.211 percent) and the graph in Figure 21 both show that the performance of the model in simulating the actual data series of the total quantity of U.S. rice in the markets (QD^*_{rt}) is quite satisfactory. The model is also able to account for most of the short-run fluctuations occurring in the historical data of this variable.

The overall results of the model simulation seem to indicate that the demand model performs relatively well in predicting most of the U.S. rice prices and the Thai export price of rice. On the quantity side, however, the model performs poorly in predicting the U.S. rice exports demanded on a regional basis and the quantities of rice ending stocks. The model "ex post" predictive power improves at the aggregate levels such as the total quantity demanded for U.S. rice exports, total quantity of rough rice milled at U.S. rice mills and the total quantity of rice in the U.S. rice markets. The "goodness" of fit of the model as a whole is reasonable since its purpose is to test some hypotheses about the relations of certain variables in the U.S. rice market economy.

D. ESTIMATED FLEXIBILITIES AND ELASTICITIES

Since the prices and quantities of rice used in the estimations of the behavioral equations in the supply and demand models were expressed in different units of measurement, it is difficult to make direct comparisons from these relations of the impact of a given change in price of rice will have on quantity of rice or vice versa. To facilitate these comparisons, the use of percentage relationships, which are independent of the size of units of measurement, is essential.

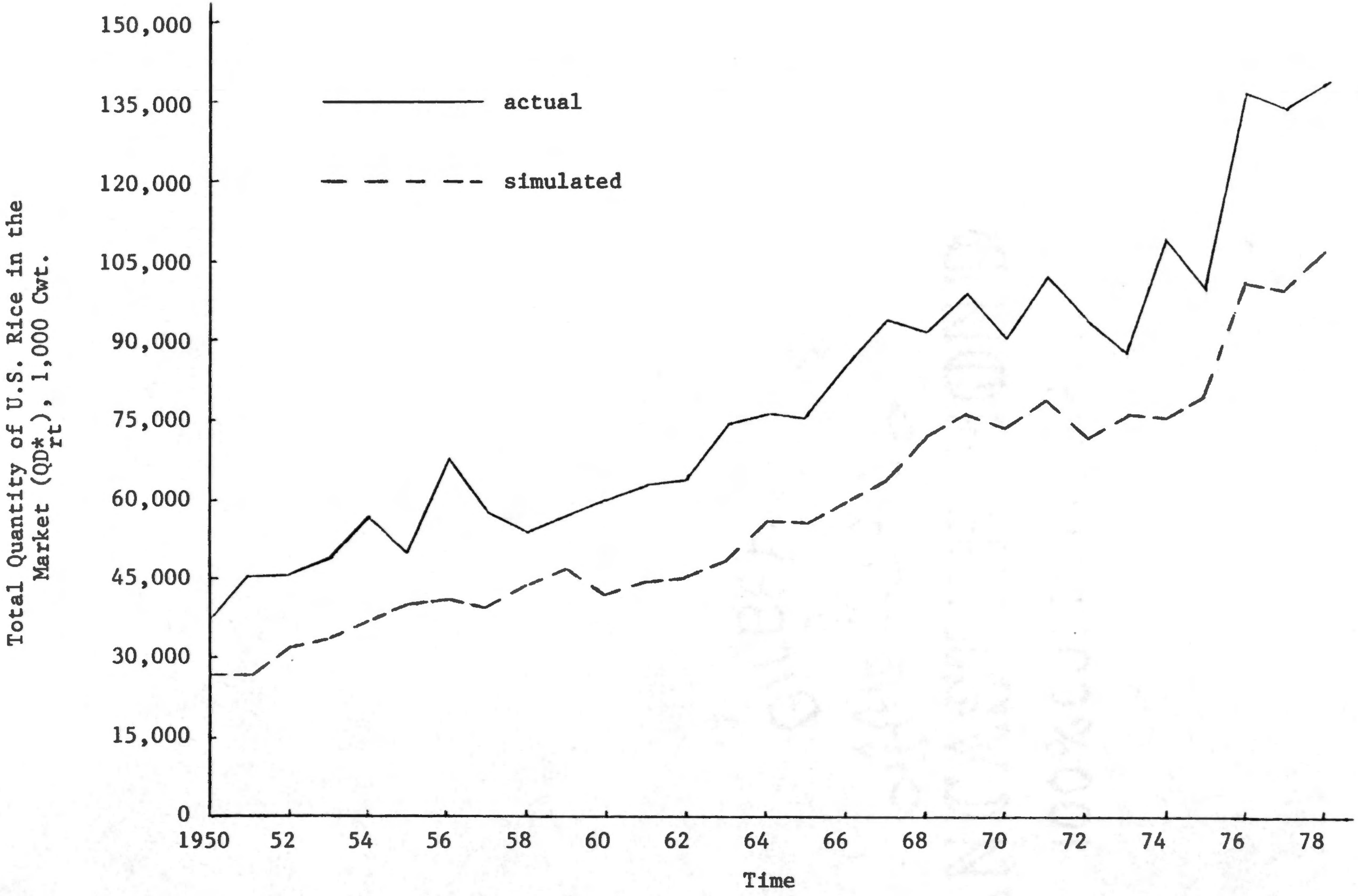

Figure 21. "Ex Post" Simulation of Total Quantity of U.S. Rice in the Market

The responsiveness of rice acreage harvested to a given change in the last year's ratio of the farm price of rice to the support price of rice will be measured in terms of the elasticity of acreage, while the responsiveness of quantity of rice demanded to a given change in the price of rice will be measured in terms of price elasticity and the responsiveness of price of rice to a given change in the quantity of rice will be measured in terms of price flexibility. The income elasticities or flexibilities are also calculated from the estimated demand equations.

Since the estimated supply and demand models are in linear form, the point elasticities and flexibilities are not constant. In addition to the point elasticities and flexibilities calculated at the average values of 1950-78, those determined at the average values of 1950-71 and 1972-78 are also presented in Table III to enable a rough approximation of their possible trends over the time period covered in this study.

When the relation between a comparable rice quantity and price is not found to be statistically significant in a particular estimated behavioral equation, the elasticity or flexibility is not calculated and presented. An attempt to use such elasticity or flexibility in policy decisions could be misleading and undesirable.

Elasticity of Rice Acreage Harvested

The respective point elasticities of rice acreage harvested ($E_{AC/PFSP}$), evaluated at the mean values of the periods (1950-71, 1950-78 and 1972-78), are 0.307, 0.308 and 0.303, respectively. As is apparent, the magnitudes of these elasticities in the three periods are about the same. That is, the U.S. rice acreage harvested increases by about 0.3 percent for a 1 percent increase in the previous year's ratio of the

TABLE III

ESTIMATED ELASTICITIES AND FLEXIBILITIES

Elasticities/ Flexibilities[a]	Equations	Estimation Method	Determined at Average Values of Selected Periods		
			1950-71	1950-78	1972-78
Elasticity of rice acreage harvested					
$E_{AC/PFSP}$	(1)	OLS	0.308	0.307	0.303
Price elasticity of demand					
$E_{ESTR/PF}$[b]	(5)	3SLS	pos.	pos.	pos.
$E_{ESTM/FW}$	(8)	"	-0.604	-0.527	-0.392
$E_{QXAO/PX}$	(9)	"	-0.856	-0.768	-0.613
$E_{QXAF/PX}$	(10)	"	-1.464	-1.125	-0.712
$E_{QXE/PX}$[d]	(11)	"	ns	ns	ns
$E_{QXWH/PX}$[b]	(12)	"	pos.	pos.	pos.
Income elasticity					
$E_{QXAO/PDPA}$	(9)	"	1.690	1.697	1.710
$E_{QXAF/PDPA}$	(10)	"	2.147	1.836	1.467
$E_{QXE/PDPE}$	(11)	"	2.278	1.889	1.412
$E_{QXWH/PDPLA}$[d]	(12)	"	ns	ns	ns
Price flexibility of demand					
$F_{PF/QM}$	(4)	"	-0.698	-0.787	-1.038
$F_{PR/QF}$	(6)	"	-0.529	-0.545	-0.589
$F_{PB/QB}$	(7)	"	ns	ns	ns
$F_{PT/QX}$	(14)	"	-1.029	-1.018	-0.989
$F_{PRBM/QUF}$	(15)	"	-0.352	-0.397	-0.534
Income flexibility					
$F_{PR/PDI}$[c]	(6)	"	neg.	neg.	neg.
$F_{PB/PDI}$	(7)	"	0.867	0.998	1.517
$F_{PT/PDPW}$	(14)	"	0.610	0.638	0.705

TABLE III (continued)

[a] E denotes an elasticity while F indicates a flexibility. The subscripts t, r and m are left out for simplicity. In the first row, for example, $E_{AC/PFSP}$ is read as the elasticity of acreage harvested with respect to the ratio of last year's farm price to the support price ($PFSP = PF_{rt-1}/SP_{rt-1}$).

[b] The elasticity or flexibility coefficients (pos.) are not presented due to the positive sign.

[c] The elasticity or flexibility coefficients (neg.) are not presented due to the negative sign.

[d] The elasticity or flexibility coefficients (ns) are not calculated because the relation between the comparable quantity and price is not found to be statistically significant.

farm price of rice to the support price of rice. These elasticities are somewhat lower[1] than the rice acreage elasticity (0.52 percent) obtained by Grant and Leath [6, p. 34] which was calculated at the 1975 values.

Price Elasticity of Demand

The price elasticity of demand for milled rice ending stocks with respect to the mill price of rice ($E_{ESTM/PW}$) is found to be inelastic. This is expected because milled rice is generally more perishable than rough rice. From equation (8) and in column 5 of Table III, the milled rice ending stocks (EST^*_{mt}) are indicated to fall by 0.527 percent if the mill price of rice (PW^*_{mt}) rises by 1 percent.

The U.S. rice export demand elasticity for Asia with respect to the U.S. export price of rice ($E_{QXAO/PX}$) is found to be inelastic in all of the selected periods. For instance, in 1950-78 the quantity of U.S. rice exports demanded in Asia ($QXAO^*_{mt}$) only declines by 0.768 percent when the U.S. export price of rice (PX^*_{mt}) increases by 1 percent.

The U.S. rice export demand elasticity for Africa ($E_{QXAF/PX}$) is elastic when evaluated at the mean value of the periods (1950-71 and 1950-78). That is, the quantity of U.S. rice exports demanded in this region ($QXAF^*_{mt}$) in 1950-78 declines by 1.125 percent if the U.S. export price of rice (PX^*_{mt}) rises by 1 percent. However, the demand for U.S. rice exports is inelastic when assessed at the average value of the period (1972-78). The quantity of U.S. rice demanded in this region

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[1] Such comparison of the coefficient from one analysis with those from another could be misleading because the averages depend on the particular years on which the analysis is based.

decreases only by 0.712 percent if the U.S. export price of rice increases by 1 percent.

Price Flexibility of Demand

If a price flexibility is less than one in absolute value, it is inflexible and it is flexible if it is greater than one in absolute value. Only under certain conditions the price flexibility is approximately equal to the reciprocal of the corresponding price elasticity. That is, when the cross flexibilities are zero (no substitute or complementary goods), then the reciprocal of the price flexibility sets the lower limit of the price elasticity of demand [25, pp. 52-53].

With these theoretical limitations, it is inappropriate to invert the flexibilities obtained from the estimated demand functions in this analysis because of the existence of nonzero cross effects. But the objective of this analysis is only to determine a rough approximation of the relationships of the flexibilities and elasticities so that some kind of generalization can be made. Thus, when a price flexibility is less than one in absolute value, then it can be inferred that such demand for U.S. rice is elastic and <u>vice versa</u>. That is, an inflexible price is consistent with an elastic demand, and a flexible price is consistent with an inelastic demand.

As presented in Table III, the farm price of rice flexibility of the derived demand for rough rice of U.S. rice mills ($F_{PF/QM}$) evaluated at the 1950-78 average values is found to be inflexible because it is less than one. That is, the farm price of rice (PF^*_{rt}) declines by 0.787 percent for a 1 percent increase in the quantity of rough rice milled (QM^*_{rt}). But the farm price of rice flexibility seems to be flexible when assessed at the 1972-78 average values implying that this derived demand was somewhat inelastic in that period.

The retail price of rice flexibilities ($F_{PR/QF}$) calculated from equation (6) for all the selected periods are less than one. Evaluating at the mean value of the period (1950-78), the retail price of rice (PR^*_{mt}) only increases by 0.545 percent if the quantity of milled rice used for food (QF^*_{mt}) rises by 1 percent. In other words, the domestic demand for milled rice used for food is elastic.

The Thai export price of rice flexibility ($F_{PT/QX}$) calculated from equation (14) for the period (1950-78) is greater than one. In other words, the 1.018 percent decline in the Thai export price of rice (PT^*_{mt}) is associated with a 1 percent increase in the quantity of world rice exports (QX_{mt}) demanded. This result implies that the demand for world rice exports is inelastic. However, the Thai export price of rice flexibility is found to be inflexible if evaluated at the 1972-78 average values implying that the world rice export demand during that period was elastic.

The demand for rice millfeed is elastic because the rice bran price flexibilities ($F_{PRBM/QUF}$) evaluated at the mean values of all the selected periods are inflexible. For example, in 1950-78 the rice bran price ($PRBM^*_t$) decreases by 0.397 percent if the quantity of rice millfeed (QUF^*_t) rises by 1 percent. This result is not surprising as there are many substitutes for rice millfeed in the U.S.

Income Elasticity and Flexibility

Income elasticity of demand is a measure of the responsiveness of quantity to changes in income while the price flexibility of income is a measure of the responsiveness of price to changes in income, other factors held constant. Both the income elasticity and flexibility are typically positive as quantity and price move directly with the shift in demand to the right.

The income elasticities associated with the demand for U.S. rice exports in Asia ($E_{QXAO/PDPA}$), Africa ($E_{QXAF/PDPA}$) and Europe ($E_{QXE/PDPE}$), evaluated at the mean values of the three selected periods, are all found to be greater than one. For instance, in 1950-78 the quantities of U.S. rice exports demanded in Asia ($QXAO^*_{mt}$), Africa ($QXAF^*_{mt}$) and Europe (QXE^*_{mt}) increase by 1.697, 1.836 and 1.889 percent when the respective per capita gross domestic product index in Asia, Africa and Europe increase by 1 percent.

The price of brewer rice income flexibility ($F_{PB/DPI}$), determined at the average value of the period (1950-78), is less than one. For instance, the price of brewer rice (PB^*_{mt}) rises by 0.998 percent as the U.S. per capita personal disposable income (DPI_t) increases by 1 percent. The price of brewer rice moves in the same (positive) direction as income.

The Thai export price of rice income flexibilities ($F_{PT/PDPW}$), as determined at the mean values of all the selected periods, is indicated to be less than one. For example, in 1950-78 the Thai export price of rice (PT^*_{mt}) only increases by 0.638 percent when the per capita world gross domestic product index ($PDPW_t$) rises by 1 percent.

Before concluding this section, some generalizations based on the computed elasticities and flexibilities above might be stated. Such generalizations could be useful in guiding the uses of these elasticities or flexibilities in the U.S. rice policy decisions.

From the elasticities and flexibilities evaluated at the average values of the selected periods (1950-71, 1950-78 and 1972-78), some general trends in their magnitudes can be observed. The price elasticities of rice stock (milled basis) and U.S. rice export demands seem to have trended downward; while the price flexibilities of derived demand for rough rice (at U.S. mills), demand for rice millfeeds and milled rice used for food have trended upward, and that of the demand for world rice exports has trended downward. In other words, the demand for U.S. rice at various levels of the markets seem to have become more inelastic or less elastic in the recent past. One important factor that might have caused these trends is the worldwide shortage of rice in 1972-74 during which the export demands for U.S. rice not only shifted to the right but have their structural coefficients changed. Since the major portion of U.S. rice supply is exported, any substantial change in the volumes of U.S. rice exports could also affect both the derived and final demand for rice in the domestic markets.

Among the domestic demand for rice (excluding stocks), the derived demand for rough rice of U.S. rice mills is the least inflexible or the least elastic while the demand for rice millfeed is the most inflexible or the most elastic. The demand for milled rice used for food is also moderately inflexible. These findings are not surprising because rough rice is the only input used in rice milling. There are several substitutes for milled rice used for food and rice millfeeds. That is, the greater is the number of substitutes for a product the more elastic is the demand for that same product.

The U.S. rice export demand of Asia is more inelastic than that of Africa as assessed at the mean value of the period (1972-78). This might be because rice is the most important staple food in most Asian countries but less important in Africa. Essentially the demand for rice in Asia is more inelastic since there are fewer substitutes for rice in this region. The relatively larger magnitudes of elasticities for U.S. rice export demand of Africa are indicative of a larger number of substitutes for rice.

Finally, certain comparisons between the domestic and the export demands for U.S. rice could also be made. In terms of elasticities, the domestic demand for milled rice used for food are more elastic than any of the U.S. rice export demand either of Asia or Africa. These results are as expected because there are relatively few substitutes for rice in Asia and Africa. In the U.S., however, several substitutes for rice are available and rice is not one of the major food grains. For these reasons, the quantity demanded for rice in the U.S. is highly responsive to a small change in the price of rice.

Since the elasticities and flexibilities evaluated at the average values of 1950-71 and 1972-78 represent the two extreme values, it seems plausible to use those calculated at the 1950-78 average values if the nature of the policies to be decided on is of general types. But the elasticities or flexibilities determined in the most recent past could be more applicable to the current situations.

E. EFFECTS OF SELECTED REDUCED FORM COEFFICIENTS ON THE PRICES AND QUANTITIES OF U.S. RICE

The reduced form coefficients are derived from the 3SLS estimates of the demand model by solving the equilibrium levels of the endogenous prices and quantities given a base set of data for the lagged endogenous and exogenous demand variables. The 3SLS results are selected because of the asymptotically efficient properties of the estimated coefficients.

The 3SLS structural equations as estimated take the form (matrix notation):[1]

(23) $\lambda y_t = \gamma Y_{t-1} + \beta X_t$

where:

y_t = the g × 1 vector of the endogenous variables

λ = the g × g matrix of the coefficients associated with y_t

Y_{t-1} = the f × 1 vector of the lagged endogenous variables

γ = the g × f matrix of the coefficients associated with Y_{t-1}

X_t = the h × 1 vector of the exogenous variables (including the intercept)

β = the g × h matrix of the coefficients associated with X_t

To compute the reduced form coefficients, premultiply both sides of equation (23) by λ^{-1} yielding:

(24) $y_t = \lambda^{-1}\gamma Y_{t-1} + \lambda^{-1}\beta X_t$

The $\lambda^{-1}\gamma$ are the dynamic multipliers and the $\lambda^{-1}\beta$ are the impact multipliers. The dynamic multipliers indicate how changes in each of the

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[1] Since equation (23) is made up of the 3SLS estimated structural equations, it is written without the error term. Also, the conventional notation (hat) to denote the estimated variable is dropped to reduce the complexity.

lagged endogenous variables influence the values of the endogenous variables, and the impact multipliers show the immediate effects of changes in each of the exogenous variables on the values of the endogenous variables. These reduced form coefficients indicate both the direct and indirect effects of a given change in the predetermined variable.

The key exogenous and lagged endogenous variables in Table IV are selected from both the domestic and export structural equations so that the impacts originating in different components of the demand model can be examined. These selected exogenous and lagged endogenous variables include the quantity of rough rice supplied in the U.S. (QS_{rt}), farm price of corn (PFC_t), quantity of world rice exports (QX_{mt}), per capita gross domestic product index of the world ($PDPW_t$) and the last year's Thai export price of rice (PT_{mt-1}). Since the demand model is in linear form, the dynamic and impact multipliers in Table IV are presented in multiples of what is derived (Appendix C). The reduced form coefficients on the U.S. export price of rice (PX^*_{mt}) are not presented in Table IV because they are identical with those obtained for the U.S. mill price of rice (PW^*_{mt}) by virtue of the identity equation (20).

U.S. Rough Rice Supply

The quantity of rough rice supplied in the U.S. (QS_{rt}) is treated as an exogenous variable in the demand model. Any change in this variable is expected to affect the endogenous prices and the utilization levels of U.S. rice. The 10 million cwt. increment in this variable is about 11 percent of its arithmetic mean (89,568,966 cwt.) in Table I, p. 42. In the last decade, changes in the quantity of rough rice supplied in the U.S. average about 11 million cwt. per year.

TABLE IV

SELECTED IMPACT AND DYNAMIC MULTIPLIERS OF THE DEMAND MODEL

Endogenous Variables	Unit	Selected Lagged Endogenous and Exogenous Variables				
		QS_{rt} 10 Million Cwt.	PFC_t 0.25/Bu.	QX_{mt} 15 Million Cwt.	$PDPW_t$ 5%	PT_{mt-1} $1/Cwt.
PF^*_{rt}	$/cwt.	0.000	0.279	-0.414	0.115	0.154
EST^*_{rt}	1,000 cwt.	2,069.130	500.843	442.041	-123.015	-164.861
PR^*_{mt}	$/cwt.	0.000	2.270	-0.449	0.125	0.167
PB^*_{mt}	"	0.000	-0.244	-0.161	0.045	0.060
EST^*_{mt}	1,000 cwt.	0.000	-81.775	116.432	-32.400	-43.424
$QXAO^*_{mt}$	"	0.000	-781.815	-321.404	89.440	119.869
$QXAF^*_{mt}$	"	0.000	-222.171	272.291	-75.775	-101.552
QXE^*_{mt}	"	0.000	-110.239	158.732	-44.175	-59.200
$QXWH^*_{mt}$	"	0.000	254.505	65.330	-18.180	-24.365
PT^*_{mt}	$/cwt.	0.000	0.000	-1.073	0.300	0.400
$PRBM^*_t$	"	0.000	0.007	-0.005	0.001	0.002
QF^*_{mt}	1,000 cwt.	0.000	-201.012	63.602	-17.700	-23.721
QB^*_{mt}	"	0.000	381.345	171.308	-47.670	-63.890
QUF^*_t	"	0.000	-88.181	60.971	-16.965	-22.740
PW^*_{mt}	$/cwt.	0.000	0.570	-1.017	2.790	0.374

TABLE IV (continued)

Endogenous Variables	Unit	Selected Lagged Endogenous and Exogenous Variables QS_{rt} 10 Million Cwt.	PFC_t 0.25/Bu.	QX_{mt} 15 Million Cwt.	$PDPW_t$ 5%	PT_{mt-1} \$1/Cwt.
QXT^*_{mt}	1,000 cwt.	0.000	-859.720	174.948	-48.685	-65.248
QM^*_{rt}	"	0.000	-849.343	587.262	-163.425	-219.022
QD^*_{rt}	"	2,069.130	-348.500	1,029.303	-286.437	-383.884

From Table IV, the 10 million cwt. increase in the quantity of rough rice supplied results in an increase of 2,069,130 cwt. in the quantity of total rough rice ending stocks (EST^*_{rt}), but it has no effect on the other endogenous quantities and prices of rice. The rise in the total quantity of rice in the U.S. rice markets (QD^*_{rt}) by 2,069,130 cwt. is directly attributed by the increase in the quantity of total rough rice ending stocks by means of the identity equation (22). Based on these results, the model is only able to account for about 21 percent of the 10 million cwt. increment in U.S. rice supply.

U.S. Farm Price of Corn

In Table IV, an increase of 25 cents per bushel in the farm price of corn (PFC_t) results in an increase of 2.27 dollars per cwt. in the U.S. retail price of rice (PR^*_{mt}) and a reduction of 201,012 cwt. in the quantity demanded for milled rice used for food (QF^*_{mt}). The relation between the farm price of corn and the retail price of rice are direct, equation (6).

A rise in the farm price of corn also affects the price of brewer rice (PB^*_{mt}) directly as they appear in equation (7). That is, an increase in this variable by 25 cents per bushel results in a decrease of 24.4 cents per cwt. in the price of brewer rice because corn and brewer rice are complementary inputs in beer brewing in the U.S. The 381,345 cwt. rise in the quantity of brewer rice (QB^*_{mt}) is partly associated with this decrease in the price of brewer rice.

A given change in the farm price of corn also affects the other endogenous prices and quantities of rice indirectly. Increasing the farm price of corn by 25 cents per bushel results in an increase of 57 cents per cwt. in the U.S. mill price of rice (PW^*_{mt}) which in effect influences the U.S. export price of rice (PX^*_{mt}) to rise by the same magnitude. Thus, the rise in this U.S. export price of rice leads to the respective decreases in the quantities demanded for U.S. rice exports in Asia ($QXAO^*_{mt}$), Africa ($QXAF^*_{mt}$) and Europe (QXE^*_{mt}) by 781,815, 222,171 and 110,239 cwt. but an increase of 254,505 cwt. in the quantity demanded for U.S. rice exports in the Western Hemisphere. The net effect on the total quantity demanded for U.S. rice exports is a decline of 859,720 cwt.

Through the retail price of rice, the price of brewer rice and the U.S. mill price of rice, the given increase in the farm price of corn influences the farm price of rice (PF^*_{rt}) to increase by 27.9 cents per cwt. This rise in the farm price of rice results in a 849,343 cwt. decrease in the quantity of rough rice milled (QM^*_{rt}) at U.S. rice mills.

This rise in the farm price of corn also influences the price of rice bran ($PRBM^*_t$) to rise by 0.7 cent per cwt. Such an increase in the price of rice bran and the decrease in the quantity of rough rice milled result in a reduction of 88,181 cwt. in the quantity of rice millfeed.

Theoretically, the rise in the farm price of rice should have led a decline in the quantity of total rough rice ending stocks (EST^*_{rt}), but the dominant effect of the reduction in the quantity of rough rice milled causes it to rise by 500,843 cwt. The decrease in the quantity of rough rice milled, the rise in the quantity of U.S. rice exports to the Western Hemisphere ($QXWH^*_{mt}$) and the U.S. mill price of rice result in a decrease of 81,775 cwt. in the quantity of milled rice ending stocks (EST^*_{mt}). The net effect on the total quantity of U.S. rice in the markets as a whole is a decrease of 348,500 cwt.

Quantity of World Rice Exports

The U.S. rice exports face a considerable competition from the rice exports of other rice exporting countries in the international rice markets. Thus, it is useful to determine the effects of a given change in the quantity of world rice exports (QX_{mt}), excluding the quantity of U.S. rice exports, on both the endogenous prices and quantities of U.S. rice. The impact multipliers in column 5 of Table IV are associated with a 15 million cwt. increase in the quantity of this exogenous variable. The magnitude of this increment is about 12 percent of its arithmetic mean (125,656,276 cwt.) in Table I, page 42.

Since the quantity of world rice exports appeared in the demand function for the world rice exports, equation (14), a given change in this exogenous variable affects the Thai export price of rice (PT^*_{mt}) directly. Therefore, the decrease in the Thai export price of rice by 1.073 dollars per cwt. is associated with the 15 million cwt. increase in the quantity of world rice exports.

Such a given rise in the quantity of world rice exports affects the U.S. export price of rice (PX^*_{mt}) indirectly through the Thai export price of rice. That is, in order for the U.S. to remain competitive with the rest of the world in rice exports, the U.S. mill price of rice (PW^*_{mt}) from which the U.S. export price of rice is directly derived must fall. Thus, this increase in the quantity of world rice exports results in a decrease in the U.S. mill price of rice by 1.017 dollars per cwt. This also means a decrease of 1.017 dollars per cwt. in the U.S. export price of rice which results in the increases in the quantities demanded for U.S. rice exports in Africa ($QXAF^*_{mt}$) by 272,291 cwt., in Europe

(QXE^*_{mt}) by 158,732 cwt. and in the Western Hemisphere ($QXWH^*_{mt}$) by 65,330 cwt. but a decrease of 321,404 cwt. in the quantity demanded for U.S. rice exports in Asia ($QXAO^*_{mt}$). After the consideration of the increases and decreases in the quantities demanded for U.S. rice exports on a regional basis, the net gain on the total quantity demanded for U.S. rice exports is indicated to be only 174,948 cwt.

The same (positive) increase in the quantity of world rice exports affects the U.S. farm price of rice (PF^*_{rt}) indirectly through the Thai export price of rice and the U.S. mill price of rice by a decrease of 41.4 cents per cwt. This decrease in the U.S. farm price of rough rice results in an increase of 587,262 cwt. in the quantity of rough rice milled (QM^*_{rt}) at U.S. rice mills.

The U.S. retail price of rice (PR^*_{mt}) and the quantity of milled rice used for food (QF^*_{mt}) are also influenced by this given change in the quantity of world rice exports. The retail price of rice is affected through the mill price of rice; the quantity of milled rice used for food is influenced through the retail price of rice and the quantity of rough rice milled at U.S. mills. That is, the retail price of rice decreases by 44.9 cents per cwt., while the quantity of milled rice used for food increases by 63,602 cwt.

Similarly, the indirect effects of a given rise in the quantity of world rice exports could be examined on the price of brewer rice (PB^*_{mt}), quantity of brewer rice (QB^*_{mt}), price of rice bran ($PRBM^*_t$) and the quantity of rice millfeed (QUF^*_t). The given increase in this exogenous variable results in a decrease in the price of brewer rice by 16.1 cents per cwt. and a decline in the price of rice bran by 0.5 cent per cwt. The decrease in the price of brewer rice and the rise in the quantity of rough rice milled leads to an increase of 171,308 cwt. in the quantity of brewer rice. Analogously, the fall in the price of rice bran and the rise in the quantity of rough rice milled result in an increase in the quantity of rice millfeed by 60,971 cwt.

The increase in the quantity of milled rice ending stocks (EST^{*}_{mt}) by 116,432 cwt. is associated with the rise in the quantity of rough rice milled, the decline in the mill price and to a certain extent the reduction in the quantity of U.S. rice exports demanded in Asia. The increase in the quantity of rough rice ending stocks by 442,041 cwt. is mainly attributed by the fall in the farm price of rice. Finally, the positive net effect on the total quantity of U.S. rice in the market is shown to be 1,029,303 cwt.

Per Capita Gross Domestic Product Index of the World

As mentioned earlier, the per capita gross domestic product index of the world ($PDPW_t$) is used as the proxy for the per capita income of the world. A given change in this variable is expected to affect the endogenous prices and quantities of U.S. rice indirectly through the Thai export price of rice (PT^{*}_{mt}).

The 5 percent rise in the per capita gross domestic product index of the world affects the Thai export price of rice directly, by virtue of behavioral equation (14), which increases it by 30 cents per cwt. This increase in the Thai export price of rice is attributed by the increase in the demand for the world rice exports due to the given increase in this exogenous variable.

Through the Thai export price of rice, the rise in the per capita gross domestic product index results in an increase of 2.79 dollars per cwt. in the U.S. mill price of rice (PW^*_{mt}). Identical increase in the U.S. export price of rice (PX^*_{mt}) is also experienced which leads to the respective decreases in the quantities demanded for U.S. rice exports in Africa ($QXAF^*_{mt}$), Europe (QXE^*_{mt}) and the Western Hemisphere ($QXWH^*_{mt}$) by 75,775, 44,175 and 18,180 cwt. but an increase of 89,440 cwt. in the quantity demanded for U.S. rice exports in Asia ($QXAO^*_{mt}$).

Through the Thai export price of rice and the U.S. mill price of rice, the rise in the per capita gross domestic product index of the world also results in a 11.5 cents per cwt. increase in the U.S. farm price of rice (PF^*_{rt}). This increase in the U.S. farm price of rice in turn causes a decrease of 163,425 cwt. in the quantity of rough rice milled (QM^*_{rt}).

The retail price of rice (PR^*_{mt}) and the quantity of milled rice used for food in the U.S. (QF^*_{mt}) are indirectly influenced by this world's per capita gross domestic product index. The 5 percent increase in this exogenous variable leads to a rise in the retail price of rice by 12.5 cents per cwt. This increase in the retail price of rice and the decrease in the quantity of rough rice milled result in a reduction of 17,700 cwt. in the quantity of milled rice used for food in the U.S.

Because of the relationships between the U.S. farm price of rice and the Thai export price of rice, any change in the per capita gross domestic product index of the world also influences the price of brewer rice (PB^*_{mt}) and the quantity of brewer rice (QB^*_{mt}). Increasing this exogenous variable by 5 percent results in an increase of 4.5 cents per cwt. in the price of brewer rice. This increase in the price of brewer rice as well as the fall in the quantity of rough rice milled at U.S. rice mills cause the quantity of brewer rice to decline by 47,670 cwt.

A given change in the world's per capita gross domestic product index affects the quantity of rice millfeed and the price of rice bran indirectly through the quantity of rough rice milled. So, the 5 percent rise in this exogenous variable results in an increase of 0.1 cent per cwt. in the price of rice bran and a decrease of 16,965 cwt. in the quantity of rice millfeed.

The total quantity of rough rice ending stocks (EST^*_{rt}) decreases by 123,015 cwt. and the quantity of milled rice ending stocks declines by 32,400 cwt. when the per capita gross domestic product index of the world is increased by 5 percent. Finally, the same (positive) increase in this exogenous variable leads to a reduction of 286,437 cwt. in the total quantity of U.S. rice in the markets.

Lagged Thai Export Price of Rice

A given increase in the last year's (lagged) Thai export price of rice (PT_{mt-1}) first affects the current Thai export price of rice (PT^*_{mt}) directly. As the corresponding dynamic multiplier indicates, the one dollar per cwt. rise in this lagged endogenous variable is shown to increase the demand for the world rice exports that results in an increase of 40 cents per cwt. in the current Thai export price of rice.

The same (positive) change in the lagged Thai export price of rice also affects the U.S. mill price of rice (PW^*_{mt}) indirectly through the current Thai export price of rice by an increase of 37.4 cents per cwt. The U.S. export price of rice (PX^*_{mt}) also increases by the same magnitude. Therefore, the 37.4 cents rise in the U.S. export price of rice results in the decreases in the quantities of U.S. rice exports demanded in Africa ($QXAF^*_{mt}$) by 101,552 cwt., Europe (QXE^*_{mt}) by 59,200 cwt. and the

Western Hemisphere ($QXWH^*_{mt}$) by 24,365 cwt. but an increase of 119,869 cwt. in the quantity of U.S. rice exports demanded in Asia ($QXAO^*_{mt}$). The net reduction in the total quantity of U.S. rice exports demanded in all of the four regions is only 65,248 cwt.

The U.S. farm price of rice (PF^*_{rt}) is affected by the given change in the lagged Thai export price of rice through the current Thai export price of rice and the U.S. mill price of rice. The 15.4 cents per cwt. increase in the U.S. farm price of rice leads to a decrease of 219,022 cwt. in the quantity of rough rice milled (QM^*_{rt}).

The U.S. retail price of rice (PR^*_{mt}) is shown to rise by 16.7 cents per cwt. when the lagged Thai export price of rice is increased by one dollar per cwt. Because of this increase in the retail price of rice and the decrease in the quantity of rough rice milled, the quantity of milled rice used for food declines by 23,721 cwt.

Similarly, the one dollar per cwt. increase in the lagged Thai export price of rice affects the U.S. mill price of brewer rice (PB^*_{mt}) by an increase of six cents per cwt. The reduction in the quantity of rough rice milled as well as the rise in the price of brewer rice result in a decrease of 63,890 cwt. in the quantity of brewer rice. The same (positive) rise in this lagged endogenous variable influences the price of rice bran ($PRBM^*_t$) to increase by 0.2 cent per cwt. and the quantity of rice millfeed to decrease by 22,740 cwt.

Because of the rise in the U.S. mill price of rice and the reduction in the quantity of rough rice milled as caused by the one dollar per cwt. increase in the lagged Thai export price of rice, the quantity of milled rice ending stocks (EST^*_{mt}) is indicated to fall by 43,424 cwt. The decrease in the total quantity of rough rice ending stocks (EST^*_{rt})

by 164,861 cwt. is associated with the resultant increase in the farm price of rice as caused by the same rise in this lagged endogenous variable. As is apparent, different magnitudes of changes have occurred in the quantities of U.S. rice in the various market outlets, but as a whole, the net reduction in the total quantity of U.S. rice in the market resulting from the one dollar per cwt. increase in the lagged Thai export price of rice is only 383,884 cwt.

CHAPTER IV

SUMMARY AND CONCLUSIONS

A. SUMMARY

Rice is one of the most important food grains in the world because it is the staple food for about one-half of the world's population. While it is mainly consumed where it is grown, the U.S. and a few other countries export more of the rice they produce than is used for domestic consumption. This study is primarily on the distribution of U.S. rice and its by-products domestically and internationally.

To establish a frame of reference for this study, some past literature were reviewed. All of these past studies were important one way or the other in the conceptualization of the problem, but the publication by O'Caroll and Traylor [16] as well as that by Grant and Leath [6] had major contribution in the analytical framework for this research.

The objectives of this study were: 1) to formulate and estimate, using statistical techniques, the farm-level supply of, and the various demand functions for, U.S. rice; 2) to use the results obtained to calculate the price and income elasticities or flexibilities; and 3) to determine and evaluate the effects of the selected dynamic and impact multipliers on each of the endogenous prices and quantities of U.S. rice.

This study used annual time-series data covering the period from 1950 through 1978. All of these data were obtained from various secondary sources. The price and income variables were corrected for inflation by the "appropriate" deflators based on the 1967 dollars.

The U.S. rice production and distribution system were assumed to be reasonably competitive. So, based on this assumption, the supply function of U.S. rice was derived from the relationships of the acreage harvested with certain economic factors at the farm level, while the demand functions for U.S. rice were specified according to the flows of rice from the farm to the various market outlets with certain economic variables that affect and accordingly guide these flow processes.

The supply model, consisting of one behavioral and two identity equations, used eight variables. Using ordinary least squares (OLS), the acreage harvested behavioral equation was estimated in order to determine the U.S. rough rice production (estimated acreage harvested times yield per acre) and supply (estimated production plus beginning stocks).

The demand model used 19 endogenous and 20 predetermined (exogenous plus lagged endogenous) variables. Out of the 19 endogenous variables, 15 of which were each used as the variables of normalization in one of the behavioral equations. That is, a behavioral equation was specified for the farm price of rough rice, total rough rice ending stocks, retail price of rice, price of brewer rice, milled rice ending stocks, U.S. rice exports to Asia, U.S. rice exports to Africa, U.S. rice exports to Europe, U.S. rice exports to the Western Hemisphere, Thai export price of rice, price of rice bran, quantity of milled rice used for food in the U.S., quantity of brewer rice, quantity of rice millfeed and the mill price of rice. The remaining four endogenous variables were included in identities. That is, an identity equation was specified for the total U.S. rice exports, U.S. export price of rice, quantity of rough rice milled at U.S. mills and the total quantity of U.S. rice (rough basis) in the markets. With the assumptions of a vertical annual supply curve and that the various behavioral equations were interdependent in the demand model, two-stage least squares (2SLS) and three-stage least squares (3SLS) were employed in the estimation of this model. The 3SLS results were reported because they were found to be better than those obtained from the two-stage least squares.

The "goodness" of fit of the single-equation supply model was validated using the set of statistical tests such as the R^2, F-ratio and the standard error, while the performance of the demand model as a whole was evaluated on how closely the "ex post" simulation values of each endogenous variable tracked the actual values in the series using the RMS (root-mean-square) percent error criterion and graphs. Since there is no clear-cut rule as to what level of the RMS percent error is acceptable, the 40 percent upper limit was considered satisfactory.

The elasticity of U.S. rice acreage harvested was calculated from the OLS estimated acreage harvested equation. The price elasticities, price flexibilities, income elasticities and income flexibilities were determined from the 3SLS behavioral equations as estimated in the demand model. These elasticities and flexibilities were evaluated at the mean values of the three selected periods (1950-71, 1950-78 and 1972-78) to enable a rough approximation of their trends.

In order to determine the direct and indirect effects of any given changes in the exogenous or lagged endogenous variables on each of the endogenous variables in the system, the impact and dynamic multipliers were derived from the 3SLS estimates of the demand model. The impacts of the given changes in the quantity of U.S. rough rice supplied, farm price of corn, quantity of world rice exports, per capita gross domestic product index of the world and the last year's Thai export price of rice on the endogenous prices and quantities of rice were investigated.

B. CONCLUSIONS

Based upon the assumptions and results obtained from each of the supply and demand models, some conclusions can be arrived at. These findings could be useful in guiding certain U.S. rice policy decisions.

Most of the variations in the U.S. rice supply, as inferred from the estimated rice acreage harvested, were found to be influenced by the last year's ratio of the farm price of rice to the support price of rice, last year's U.S. rice acreage harvested and the previous year's government rough rice ending stocks. Soybeans were not found to compete for rice acreage.

The elasticity of U.S. rice acreage harvested with respect to the last year's ratio of the farm price of rice to the support price of rice was indicated to be highly inelastic suggesting a limited alternative use for rice land. This should be the case because rice production in the U.S. is highly mechanized and a large portion of the total cost of operation is fixed. This elasticity is slightly lower than that calculated by Grant and Leath [6, p. 34].

From the results of the demand model, corn was found to be a substitute for milled rice used for food and barley was indicated to be a substitute for brewer rice in the U.S. Rice seemed to be an inferior good when it is used for food in the U.S. The U.S. export price of rice was found to help explain only the variations in the quantities of U.S. rice exports demanded in Asia and Africa but not in Europe and the

Western Hemisphere. With the exception of the Western Hemisphere, the regional per capita incomes were found to be important in influencing the regional demand for U.S. rice exports. Rice exports from other countries, particularly Thailand, were indicated to compete strongly with U.S. rice exports, and the competitive position of the U.S. rice exports seemed to increase when the prevailing world price of rice increased. U.S. wheat exports were not found to compete with U.S. rice exports implying that wheat is a weak substitute for rice in most of these rice importing countries.

The calculated price of rice elasticities were indicated to have trended downward, while the calculated price of rice flexibilities were found to trend upward in the recent past. However, the Thai export price of rice flexibility was shown to have become more inflexible recently. In other words, the demand for U.S. rice which was inelastic had become more inelastic and the demand for U.S. rice which was elastic had become less elastic or even inelastic in the recent years. It is apparent that the quantities of rice are getting less responsive to a given change in the price of rice over the years.

In terms of price elasticities, the demand for U.S. rice exports was found to be inelastic compared to the demand for U.S. rice in the domestic market. This should be the case because there are more substitutes for rice in the U.S. Based on the magnitudes of these calculated elasticities and flexibilities, evaluated at the mean values of the period (1972-78), some implications could be made about the total revenue obtained from the sales of U.S. rice in each market outlet. Because of the fact that the demand for U.S. rice exports in Asia and Africa was inelastic, the U.S. export price of rice could be raised in order to increase total revenue from rice sales in these two regions. In the domestic market, however, total revenue from rice could be increased by reducing the retail price of rice and the price of rice bran. This is possible because these prices were found to be highly inflexible.

The only income elasticities indicated to have trended upward were those associated with the demand for U.S. rice exports in Asia. This suggests that the U.S. rice exports could still be expanded if the income of this region increases. Less prospects could be expected for the expansions of U.S. rice export markets in Africa, Europe and the Western Hemisphere because of the downward trends in the income elasticities associated with the demand for U.S. rice exports in these regions. In the U.S., the market for brewer rice could be expanded as U.S. per capita personal income increases.

Based on the impact multiplier analysis, any reasonable increase in the quantity of U.S. rice supply did not seem to affect the prices and utilization levels of U.S. rice but only the level of the total rough rice ending stocks. Therefore, any policy (by the U.S. government) aimed at controlling U.S. farm price of rice by means of regulating U.S. rice production seemed to be ineffective. Perhaps, part of the reason being that the U.S. rice economy is (reasonably) competitive.

The impact multipliers generated by a given change in the farm price of corn confirmed that corn is a substitute for rice at the wholesale and retail level, but it is a complement to rice at the brewer level. The impacts of this exogenous variable were limited to the U.S. prices and quantities; it had no effect on the Thai export price of rice. This implies that any changes in the U.S. export price of rice and U.S. rice exports, due to a change in a domestic factor, would be insignificant in influencing the international rice trade.

The U.S. rice prices and distributions were indicated to change if the volume of world rice trade changed. This is due to the direct relation between the world price of rice and the U.S. price of rice. Because of the fact that any increase in the volume of world rice trade is associated with a decrease in the world price of rice, it is evident that the U.S. would have to reduce the export price of rice to a level in order to compete effectively with the rest of the world. This could imply the revival of the rice export payment if the U.S. mill price of rice is considerably higher than the prevailing world price of rice. Evidence was also found that the U.S. seemed to increase rice exports to Africa, Europe and the Western Hemisphere when the rice exports to Asia declined. Asia seemed to be less dependent to the U.S. rice exports if rice could be obtained elsewhere.

A change in the demand for world rice exports due to a given change in the world's per capita income was indicated to influence the prices and distributions of U.S. rice. In particular, the volume of U.S. rice exports demanded in Asia was indicated to rise as the world's per capita income increased.

The pricing of U.S. milled rice at the wholesale level was shown to be indirectly influenced by the lagged world price of rice through the current world price of rice. Therefore, it could be inferred that the U.S. rice prices are connected to the world price of rice.

Although the estimated demand model as a whole was somewhat satisfactory, some of its estimated individual components such as the rice stock and U.S. rice export demand functions were unsatisfactory, perhaps, due to the presence of the government portions and the possibility of improper specifications of these behavioral equations. Despite the poor results obtained from the regional demand functions for U.S. rice exports, these regional disaggregations were justified because they were able to isolate the effects of the regional variables.

Given the nature of the time-series data used in this study, the results of both the supply and demand models for the U.S. rice economy were reasonable; however, there is always room for further improvement in future research. The performance of the demand model could probably be improved if the government portions of the rice ending stocks and exports were treated as exogenous in the system. If the total U.S. rice exports are to be disaggregated on a regional basis, a careful specification of these structural equations is necessary; and if these disaggregated U.S. rice exports contain government rice exports, some dummy variables might be necessary to account for the effects of certain institutional (noneconomic) variables. Because of the lesser degree of speculations involved in rice marketing, the rice stocks could be excluded in the system estimations; or if they are included, they need to be specified carefully. Finally, if data were available, the demand functions for each length of grains should be treated individually.

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APPENDIXES

APPENDIX A

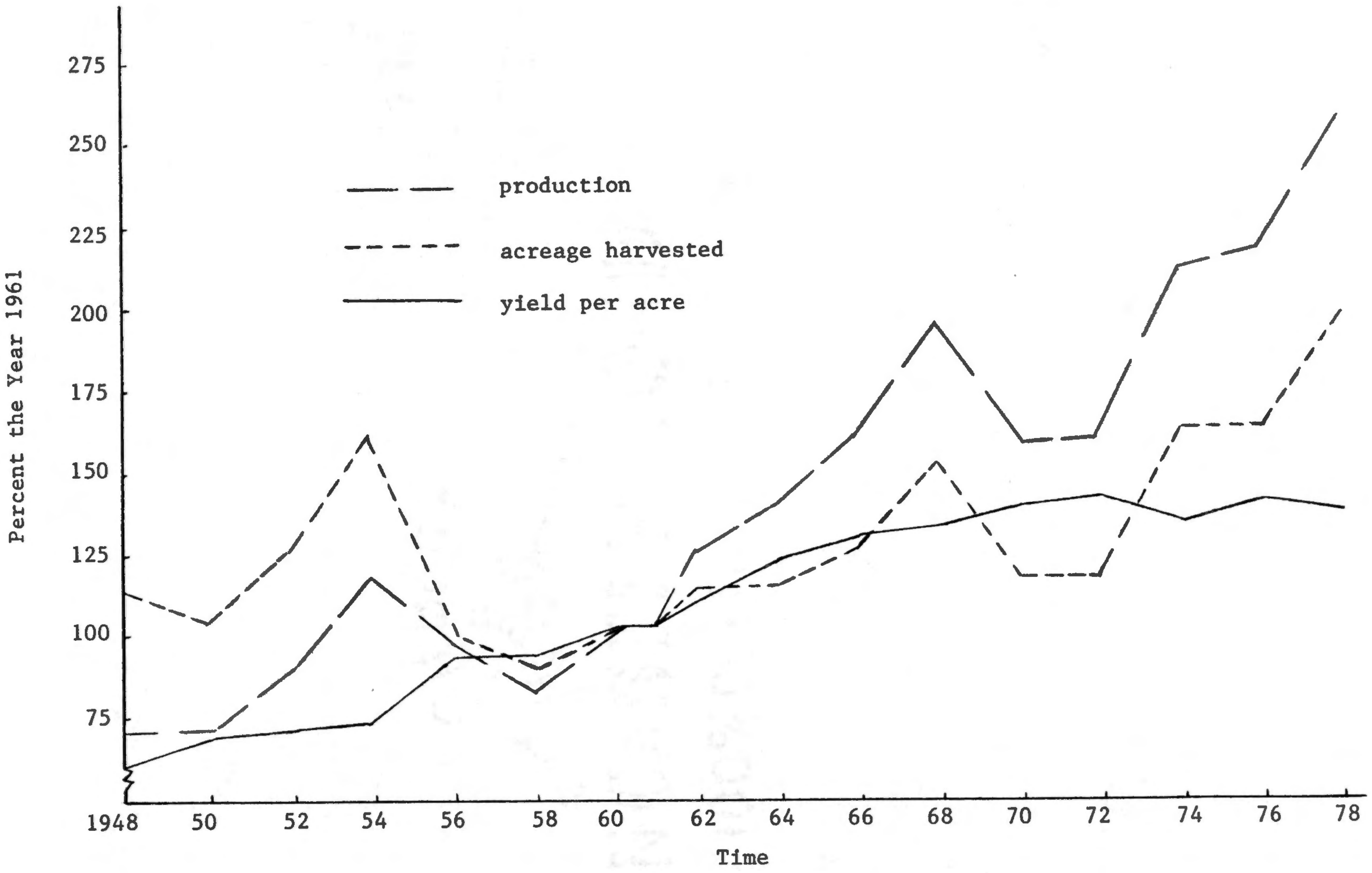

Figure A-1. Rice Acreage, Yield and Production in the U.S.

APPENDIX B

APPENDIX B

TWO-STAGE LEAST SQUARE RESULTS[1]

(1) $$\widehat{PF}^*_{rt} = -194.576 - \underset{(3.904)^s}{0.0001QM^*_{rt}} + \underset{(9.173)^s}{0.316PT^*_{mt}} + \underset{(2.554)^s}{0.080PR^*_{mt}} + \underset{(3.104)^s}{0.101T_t}$$

$R^2 = 0.895$ S.E. = 0.401 D.W. = 1.346

(2) $$\widehat{EST}^*_{rt} = -14028.100 + \underset{(0.938)}{2199.844PF^*_{rt}} - \underset{(1.043)}{869.785PT^*_{mt}}$$

$$+ \underset{(4.869)^s}{226.850QS_{rt}} - \underset{(2.420)^s}{10920.200D1S}$$

$R^2 = 0.601$ S.E. = 5546.351 D.W. = 1.153

(3) $$\widehat{PR}^*_{mt} = -1603.78 - \underset{(0.950)}{0.0005QF^*_{mt}} + \underset{(3.354)^s}{8.326PFC_t} - \underset{(1.835)^s}{8.268PDI_t}$$

$$+ \underset{(1.351)}{0.311PW^*_{mt}} + \underset{(2.441)^s}{0.836T_t}$$

$R^2 = 0.674$ S.E. = 2.056 D.W. = 1.364

(4) $$\widehat{PB}^*_{mt} = 524.129 - \underset{(0.930)}{0.0002QB^*_{mt}} + \underset{(2.133)^s}{2.644PFB_t} - \underset{(1.304)}{1.802PFC_t}$$

$$+ \underset{(1.923)^s}{0.331PF^*_{rt}} + \underset{(1.987)^s}{3.110PDI_t} - \underset{(3.193)^s}{0.269T_t}$$

$R^2 = 0.829$ S.E. = 0.585 D.W. = 1.835

(5) $$\widehat{EST}^*_{mt} = 952.691 - \underset{(1.699)^s}{79.921PW^*_{mt}} + \underset{(5.287)^s}{0.029QM^*_{rt}}$$

$R^2 = 0.568$ S.E. = 676.258 D.W. = 0.954

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[1] The asterisk (*) denotes an endogenous variable while the "s" indicates that the coefficient of the corresponding variable is significantly different from zero at the 10 percent level.

(6) $$\widehat{\mathrm{QXAO}}^*_{mt} = -6321.840 - \underset{(2.517)^s}{1888.240}\mathrm{PX}^*_{mt} + \underset{(2.211)^s}{1874.592}\mathrm{PT}^*_{mt} + \underset{(2.617)^s}{366.110}\ \mathrm{PDPA}_t$$

$$- \underset{(0.952)}{2088.830}\mathrm{ERPH}_t + \underset{(0.325)}{1100.925}\mathrm{PXW}_t$$

$R^2 = 0.775$ S.E. = 5183.190 D.W. = 1.655

(7) $$\widehat{\mathrm{QXAF}}^*_{mt} = 503.435 - \underset{(0.710)}{227.791}\mathrm{PX}^*_{mt} + \underset{(0.086)}{30.055}\mathrm{PT}^*_{mt} + \underset{(5.430)^s}{68.604}\mathrm{PDPA}_t$$

$$+ \underset{(0.031)}{0.4310}\mathrm{FI}_t - \underset{(0.479)}{691.102}\mathrm{PXW}_t$$

$R^2 = 0.648$ S.E. = 2025.518 D.W. = 0.577

(8) $$\widehat{\mathrm{QXE}}^*_{mt} = 5535.752 - \underset{(1.165)}{258.978}\mathrm{PX}^*_{mt} + \underset{(0.412)}{100.254}\mathrm{PT}^*_{mt} + \underset{(1.963)^s}{56.481}\mathrm{PDPE}_t$$

$$- \underset{(1.301)}{1339.240}\mathrm{ERG}_t - \underset{(1.017)}{9.8640}\mathrm{FI}_t + \underset{(0.349)}{367.754}\mathrm{PXW}_{mt}$$

$R^2 = 0.803$ S.E. = 1361.623 D.W. = 1.714

(9) $$\widehat{\mathrm{QXWH}}^*_{mt} = 2810.750 + \underset{(2.370)^s}{449.081}\mathrm{PX}^*_{mt} - \underset{(2.190)^s}{427.383}\mathrm{PT}^*_{mt} - \underset{(0.987)}{0.240}\mathrm{QPWH}_{rt}$$

$$+ \underset{(0.665)}{21.250}\mathrm{PDPLA}_t - \underset{(2.132)^s}{16.8880}\mathrm{FI}_t + \underset{(1.122)}{870.164}\mathrm{PXW}_t$$

$R^2 = 0.405$ S.E. = 1105.671 D.W. = 1.417

(10) $$\widehat{\mathrm{PT}}^*_{mt} = 8.321 - \underset{(1.501)}{0.0001}\mathrm{QX}_{mt} + \underset{(1.539(}{0.330}\mathrm{PT}_{mt-1} + \underset{(1.431)}{0.050}\mathrm{PDPW}_t$$

$R^2 = 0.368$ S.E. = 2.456 D.W. = 1.594

(11) $$\widehat{\mathrm{PRBM}}^*_t = 0.969 - \underset{(4.325)^s}{0.0001}\mathrm{QUF}^*_t + \underset{(0.581)}{0.0006}\mathrm{FGPI}_t + \underset{(7.276)^s}{0.033}\mathrm{PWB}_t$$

$R^2 = 0.816$ S.E. = 0.158 D.W. = 1.841

$$\widehat{QF}^*_{mt} = -326639 - \underset{(0.637)}{37.132PR^*_{mt}} + \underset{(2.330)^s}{0.64QM^*_{rt}} + \underset{(2.306)^s}{172.781T_t} \tag{12}$$

$R^2 = 0.911$ S.E. = 960.228 D.W. = 2.348

$$\widehat{QB}^*_{mt} = -403995 - \underset{(0.565)}{0.013QM^*_{rt}} + \underset{(3.803)^s}{2995.618PFC_t} - \underset{(2.792)^s}{512.060PF^*_{rt}} + \underset{(3.224)^s}{207.757T_t} \tag{13}$$

$R^2 = 0.822$ S.E. = 661.261 D.W. = 0.912

$$\widehat{QUF}^*_t = 44644.910 + \underset{(9.662)^s}{0.111QM^*_{rt}} + \underset{(0.673)}{6.530PWB_t} - \underset{(0.660)}{22.951T_t} \tag{14}$$

$R^2 = 0.971$ S.E. = 441.617 D.W. = 1.633

$$\widehat{PW}^*_{mt} = -0.499 + \underset{(10.324)^s}{2.098PF^*_{rt}} - \underset{(1.495)}{0.063PW_{mt-1}} + \underset{(1.817)^s}{0.146PT^*_{mt}} \tag{15}$$

$R^2 = 0.962$ S.E. = 0.565 D.W. = 1.208

APPENDIX C

TABLE C-1

DYNAMIC AND IMPACT MULTIPLIERS OF THE DEMAND MODEL

Endogenous Variables	Predetermined Variables[a]																		
	PT_{mt-1}	PW_{mt-1}	QS_{rt}	DPI_t	T_t	PFB_t	PFC_t	$PDPA_t$	$ERPM_t$	OFI_t	PXW_t	$PDPE_t$	ERG_t	$PDPLA_t$	$QPWH_{rt}$	QX_{mt}	$PDPW_t$	$FGPI_t$	PWB_t
PF^*_{rt}	0.15	-0.01	0.00	-1.61	0.33	0.00	1.12	-0.05	0.21	b	-0.21	-0.01	0.09	-0.01	0.00	b	0.02	0.00	b
EST^*_{rt}	-164.86	-17.44	0.21	-2,878.72	584.23	0.00	2,003.37	-96.23	378.07	6.15	-373.06	-17.60	165.26	-10.11	0.10	0.03	-24.60	0.00	-1.59
PR^*_{mt}	0.17	-0.03	0.00	-10.96	1.17	0.00	9.08	-0.08	0.32	0.15	-0.31	-0.02	0.14	-0.01	b	b	0.03	0.00	b
PB^*_{mt}	0.06	b	0.00	1.55	-0.11	2.26	-0.98	-0.02	0.09	b	-0.09	b	0.04	b	b	b	0.01	0.00	b
EST^*_{mt}	-43.42	8.81	0.00	577.51	-103.38	0.00	-327.10	34.04	-133.75	-2.18	131.97	6.23	-58.46	3.58	-0.03	0.01	-6.48	0.00	0.56
$QXAO^*_{mt}$	119.87	73.48	0.00	4,493.69	-911.98	0.00	-3,127.26	482.62	-2,166.54	-9.60	1,544.16	27.47	-257.98	15.79	-0.15	-0.02	17.89	0.00	2.48
$QXAF^*_{mt}$	-101.55	20.88	0.00	1,276.99	-259.16	0.00	-888.69	111.50	-167.71	1.25	-311.89	7.81	-73.31	5.49	-0.04	0.02	-15.16	0.00	0.70
QXE^*_{mt}	-59.20	10.36	0.00	633.63	-128.59	0.00	-440.96	21.18	-83.22	-9.05	88.17	77.25	-725.44	2.23	-0.02	0.01	-8.84	0.00	0.35
$QXWH^*_{mt}$	-24.37	-23.92	0.00	-1,462.84	296.88	0.00	1,018.02	-48.90	192.12	-18.80	875.40	-8.94	83.98	37.03	-0.35	b	-3.64	0.00	-0.81
PT^*_{mt}	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	b	0.06	0.00	0.00
$PRBM^*_t$	b	b	0.00	-0.07	0.01	0.00	0.03	-0.01	0.03	b	-0.03	b	0.01	b	0.00	0.00	b	b	0.03
QF^*_{mt}	-23.72	8.54	0.00	1,217.83	45.72	0.00	-804.05	49.27	-193.59	-3.15	191.02	9.01	-84.62	5.18	-0.05	b	-3.54	0.00	0.81
QB^*_{mt}	-63.89	6.82	0.00	831.12	-61.56	0.00	1,525.38	40.99	-161.06	-2.62	158.92	7.50	-70.40	4.31	-0.04	0.01	-9.53	0.00	0.68
QUF^*_t	-22.74	12.16	0.00	876.75	-133.47	0.00	-352.73	80.02	-314.40	-5.11	310.22	14.63	-137.43	8.41	-0.08	b	-3.39	0.00	7.94
PW^*_{mt}	0.37	-0.05	0.00	-3.28	0.67	0.00	2.28	-0.11	0.43	0.01	-0.42	-0.02	0.19	-0.01	b	b	0.06	0.00	b
PX^*_{mt}	0.37	-0.05	0.00	-3.28	0.67	0.00	2.28	-0.11	0.43	0.01	-0.42	-0.02	0.19	-0.01	b	b	0.06	0.00	b
QXT^*_{mt}	-65.25	80.80	0.00	4,941.47	-1,002.86	0.00	-3,438.88	566.40	-2,225.35	-36.20	2,195.83	103.59	-972.75	59.53	-0.56	0.01	-9.74	0.00	2.72
QM^*_{rt}	-219.02	117.12	0.00	8,444.69	-1,255.55	0.00	-3,397.37	770.72	-3,028.13	-49.25	2,987.97	140.95	-1,323.66	81.01	-0.76	0.04	-32.69	0.00	12.71
QD^*_{rt}	-383.88	99.68	0.21	5,565.97	-671.33	0.00	-1,394.00	674.49	-2,650.06	-43.10	2,614.91	123.36	-1,158.40	70.89	-0.67	0.07	-57.29	0.00	11.12

[a] Predetermined variables include the lagged endogenous and the exogenous variables.

[b] The dynamic or impact multiplier is non zero at five decimal places.

VITA

Richard S. Gunting was born in Sepulot, Sabah, East Malaysia, on July 4, 1951, the oldest son of Mr. and Mrs. Gunting. He belongs to one of the Murut Tribes in the interior of North Borneo. He was brought up in a long-house community which practices slash and burn agriculture as a part of its lifestyle.

He attended Government Primary School, Sepulot (1960-64), Government Secondary School, Keningau (1965-69) and La Salle Secondary School, Kota Kinabalu (1970-71). He entered Mara Institute of Technology, a junior college, in West Malaysia in 1972, and graduated with a Diploma in Planting Industry and Management in 1975.

He received a four-year scholarship under the Mara Institute of Technology Young Lecturer Schemes, which was financed by the Federal Government of Malaysia, to pursue his studies in the field of agricultural economics in the U.S. He was enrolled in the Department of Agricultural Economics and Rural Sociology at The University of Tennessee, Knoxville, in 1976, and completed his Bachelor of Science degree in March, 1977, Master of Science degree in March, 1979, and the Doctor of Philosophy degree in June, 1981.

He is married to the former Nelly Yeo Lian Neo of Tangkak, Johore, West Malaysia, in December, 1977. They have a daughter, Elaine Geok, who was born on January 20, 1981. Upon his graduation, he returned to his home country, Malaysia, and was employed as a lecturer at Mara Institute of Technology.