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Factors Affecting Supply, Demand, and Prices of U.S. Rice

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ABSTRACT

This technical analysis updates the interrelationships of economic, institutional, and physical factors that affect supply, demand, and prices for U.S. rice in an earlier ERS report. Rice yields are affected by the climatic conditions in each area, technological changes, area in rice, and other factors. Lagged farm price did not appear to influence rice yields during 1950-83. Farm price deflated by cost of production, Government programs, and previous acreage affects area seeded to rice. Production response to a price change (elasticity) varies from 0.06 in Arkansas to 0.18 in California. Income and population are major variables affecting food rice and brewers rice consumption. Changes in retail price have a minor impact on demand. Total world exports are more elastic than U.S. exports, indicating U.S. commercial exports are moving into differentiated markets with a differentiated product.

Keywords: Rice, supply, demand, prices, elasticities, multipliers.

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SUMMARY

This technical analysis examines the interrelationships of economic, institutional, and physical factors affecting the supply, demand, and prices of U.S. rice since 1950.

Rice yields are affected by local climate, technological change, area in rice, and other factors. Area harvested has a negative effect on yields. Area planted to rice is responsive to farmers' price expectations. Production response to a price change (elasticity) varies from about 0.06 in Arkansas to 0.18 in California.

Income and population are the major variables affecting food rice and brewers rice consumption; changes in retail price have minor impact on demand. Rice millfeed, a small percentage of total agricultural feed, is influenced by the total quantity of rice milled and the general price level in the feed market. Current seed rice demand is influenced by price expectations for the coming year and previous acreage planted.

U.S. and Thailand export prices, Government exports, U.S. supply, and the exchange rate influence commercial exports. Government exports are less elastic with respect to price than commercial exports. The degree of substitution of P.L. 480 rice for commercial export sales is low. This is because of the different types of markets involved, the quality of production demanded, and credit terms.

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INTRODUCTION

This study estimates the economic relationships within the U.S. rice economy which determine the supply, demand, and price for U.S. rice. An econometric model based on theory and knowledge of economic relationships in the U.S. rice industry is developed, a statistical model for the supply, demand, and price segments of the economic model is formulated, estimated, and tested, and the statistical model is interpreted and applied to current conditions. The results are used to assist in developing forecasts of supply, demand, and prices in the rice industry and to evaluate the probable impacts of alternative public policies affecting the rice industry. See Holder and Grant for a history and current status of the U.S. rice industry.

THEORETICAL FRAMEWORK

The supply-demand-price relationships for rice, as with most major U.S. agricultural crops, are complex. Prices and uses in several market outlets are determined simultaneously, not only by the supply of rice, but also by certain factors outside the rice market structure that affect demand. The joint product aspect of rice milling, with differing demand relationships for each product, produces unique behavioral patterns for uses and prices. Many separate markets compete for rice and rice products, and prices adjust to ration supplies among the various markets. Since these outlets are growing at different rates, a model of the U.S. rice industry must allow for these adjustments.

Major Relationships

Principal economic relationships and variables involved in the U.S. rice economy are illustrated in figure 1. The upper part of figure 1 indicates the pattern of forces affecting production, yield, and acreage of rice. Weather is important because it affects yield. During the period 1955-1973, allotments limited acreage to specified levels and Government price supports stabilized prices. With restricted allotments and price supports above world levels, physical factors, such as weather, cultural practices, insects, and diseases, were more important in determining yearly changes in production than were economic forces. Producers adopted new cultural practices to increase yields. Under these conditions, changing technology was a significant causal factor. Since 1973, supply controls have been less restrictive and producers have been more responsive to economic factors, except for the Payment-in-Kind program in 1983.

Some factors affecting world prices appear in the lower left side of figure 1. The world price of rice is important to domestic producers since the United States, where rice production exceeds domestic use, is a major rice exporter, normally exporting about 60 percent of its crop. Except when Government programs interfere, domestic prices normally reflect the world supply-demand situation. The world rice price is determined by world supply-demand of rice, quantity available for export, income in the importing countries, and the supply of competing grains.

The domestic outlets are food, beer, feed, seed, and carryout (fig. 1). Utilization in the first two categories is assumed to depend, in part, on the level of price, income, population, consumption trends, and prices of competing commodities. Rice used in feed is related to the level of bran or millfeed prices, animal numbers, and prices of competing commodities. Seed use is determined largely by acreage planted.

The Economic Model

The economic model can be represented in a series of two dimensional graphs (sections A through N in fig. 2). These generalized price-quantity diagrams portray the U.S. rice markets at a given moment with all other factors held constant. Total demand for U.S. rice for human consumption is illustrated in section E. This curve is a horizontal summation of the demands for rice for food (section A), commercial milled exports (section B), Government milled exports (section C), and brewers use (section D). Milled rice stocks are ignored in this analysis since they are a relatively minor part of the total use. Total byproduct demand is shown in section H. It represents a horizontal summation of the demand for hulls (section F) and feed (section G). Total human consumption (section E) and total byproduct demand (section H) added together give a derived U.S. milled demand schedule for rough rice (section M). Rough rice, when milled, yields head rice, brokens, and screenings (polish, bran, and hulls). Head rice mixed with brokens, moves through food, commercial exports, and Government exports. Most of the remaining brokens and screenings are taken by the brewing industry. Bran, either separately or mixed with hulls and polish, is used as feed. Remaining hulls are (1) burned to generate steam and the ashes are used in other processes, (2) processed to extract furfural, (3) used for poultry litter, (4) used for mulch, or (5) dumped. Data on hull utilization or prices are not available. Total supply of hulls, however, is a fixed proportion of the quantity of rough rice milled.

Mill demand for rough rice (section M) coupled with seed demand (section K), export demand for rough rice (section L), and private and Government stock demand (sections I and J) form the total U.S. rice demand represented in section N. An aggregate supply curve is added in section N to illustrate how the model works. The sum of the various domestic demand schedules (food, brewer, feed, seed, private stocks, hulls) is represented by the line DT-DD. Export demand for U.S. rice is plotted as DW-DW. This demand schedule represents total world export demand with exports from other countries at some

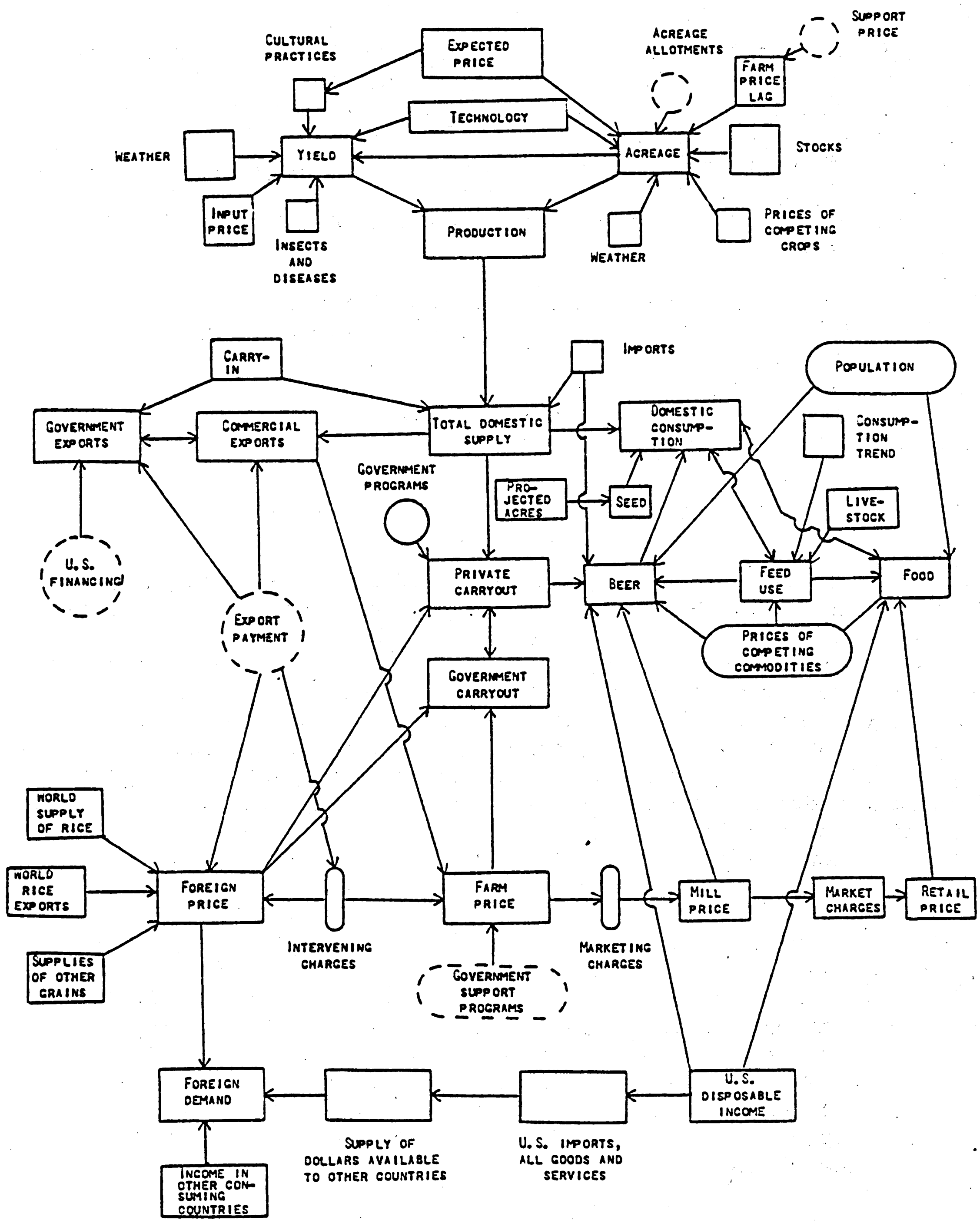

Figure 1. Major relationships in the rice economy

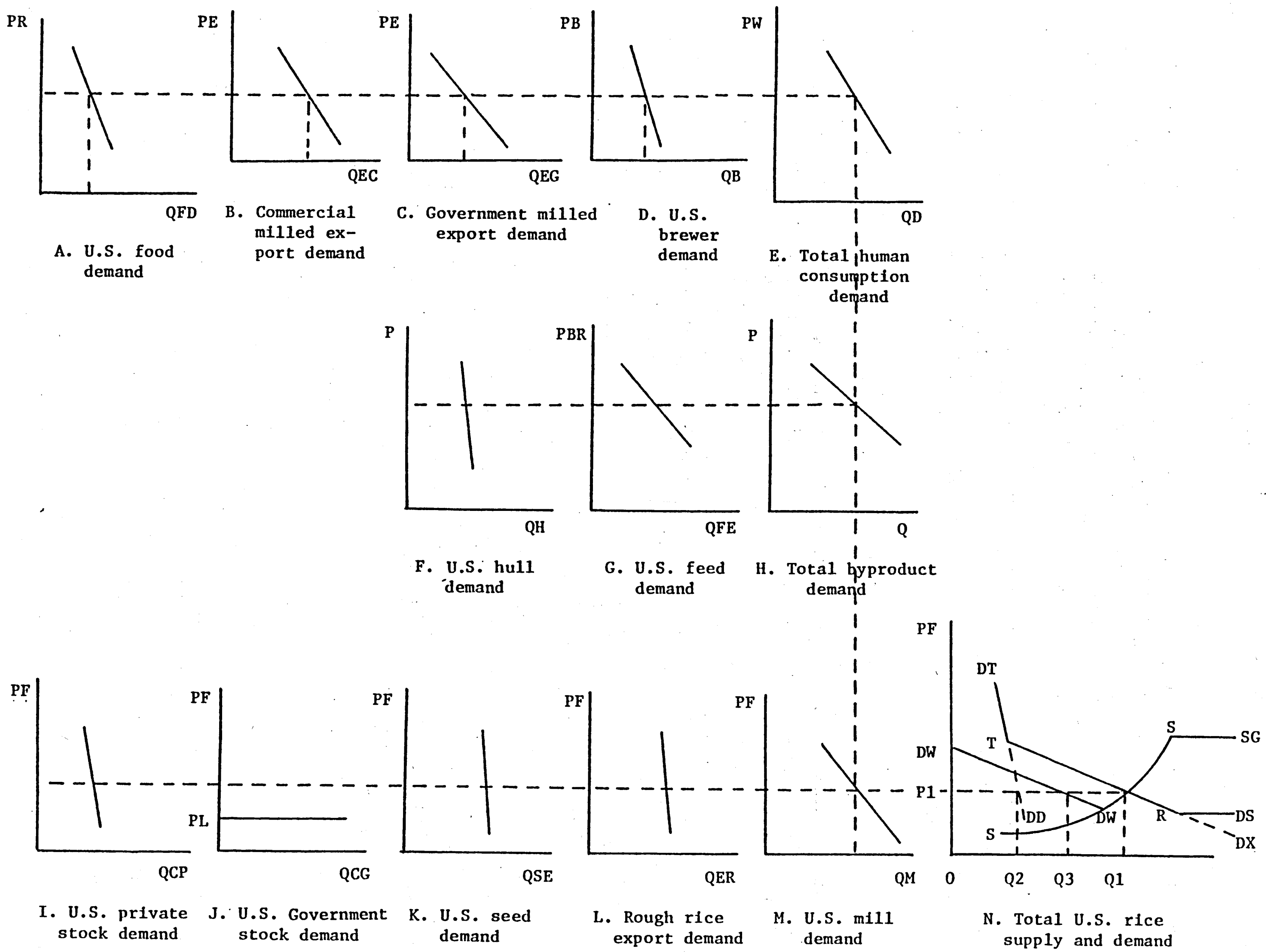

Figure 2. Graphic model of rice and rice byproducts markets

predetermined level. The line R-DS represents the Government nonrecourse loan program. Adding the Goverment nonrecourse loan program to total domestic and export demand results in the line DT-T-R-DS. The supply of rice without allotments and changes in carryover is represented by the curve S-S. Release of Government stocks in the nonrecourse loan program is represented by the line S-SG.

Equilibrium, with no Government programs, would be at P_1. At this price, the quantity Q_2 would be utilized domestically. The quantity Q_1 minus Q_2 (or Q_3) would be exported. The nonrecourse loan acts as a floor price in the event the supply curve shifts to the right or the export demand curve shifts to the left. In either instance, Government stocks would increase.

Production is a function of acres harvested times yield, with U.S. production a summation of the individual State's production. U.S. supply is U.S. production plus Government and private carryin. Rice imports into the United States are negligible.

The Statistical Model

The model used in this study is a simple representation of the underlying economic relationships observed in the rice sector. Economic theory, as illustrated in figure 2, supplemented by knowledge of the economic and institutional characteristics of the rice industry, as in figure 1, forms a basis for the construction of the model and classification of variables. The following relations are hypothesized for the U.S. rice industry:

Supply Section

1. $AM_t = F((RM_t{*}PF_{t-1}/COP_{t-1}), AM_{t-1}, D83_t)$
2. $AT_t = F((RT_t{*}PF_{t-1}/COP_{t-1}), AT_{t-1}, D83_t)$
3. $AL_t = F((RL_t{*}PF_{t-1}/COP_{t-1}), AL_{t-1}, D83_t)$
4. $AA_t = F((RA_t{*}PF_{t-1}/COP_{t-1}), AA_{t-1}, D83_t)$
5. $AC_t = F((RC_t{*}PF_{t-1}/COP_{t-1}), AC_{t-1}, D83_t)$
6. $AHM_t = F(AM_t)$
7. $AHT_t = F(AT_t)$
8. $AHL_t = F(AL_t)$
9. $AHA_t = F(AA_t)$
10. $AHC_t = F(AC_t)$
11. $YM_t = F(T_t, T_t^{1/2}, R3M_t, T7M_t, (FP/PF)_{t-1}, P89M_t)$
12. $YT_t = F(AHT_t, TE_t, R4T_t, T78T_t)$
13. $YL_t = F(T_t, T_t^2, P34L_t, P56L_t)$
14. $YA_t = F(AHA_t, T_t^{1/2}, TE_t, P89A_t, SC56A_t, T7A_t, D83_t)$

15. $YC_t = F(T_{75}, T_{74}^{1/2}, T6C_t)$

16. $QP_t = (YM_t)AHM_t + (YT_t)AHT_t + (YL_t)AHL_t + (YA_t)AHA_t + (YC_t)AHC_t$

17. $QS_t = QP_t + QCT_{t-1}$

Demand Section

18. $QFE_t = F[PBR_t, QM_t, PI_t]$

19. $QSE_t = F[(R*PF/COP)_t, AUS_t, T_t]$

20. $QFD_t = F[PR_t, YI_t, D59_t]POP_t$

21. $QB_t = F[(PB/PC)_t, YI_t, (QB/POP)_{t-1}]POP_t$

22. $QEC_t = F[(PE/PT)_t, QEG_t, QS_t, SDR_t]$

23. $QEG_t = F[(PE/PG-PS)_t, QS_t, GP2_t, (GEXP/PG-PS)_t]$

24. $QER_t = F[(PF/SDR)_t, QER_{t-1}, POL_t, IQP_t]$

25. $QCP_t = F[(PF/PG)_t, QCG_t, QS_t]$

26. $QCG_t = F[(PF/PG)_t, (PE/PT)_t, GP1_t, GP_t]$

27. $QH_t = F[QM_t, QH_{t-1}]$

28. $QM_t = QFD_t + QB_t + QFE_t + QH_t + QEC_t + QEG_t$

29. $QD_t = QM_t + QCP_t + QCG_t + QER_t + QSE_t$

Price Relationships

30. $PR_t = F[PW_t, T_t, PR_{t-1}]$

31. $PBR_t = F[PW_t, LU_t, PI_t]$

32. $PB_t = F[PW_t, PB_{t-1}]$

33. $PF_t = F[PW_t, T_t]$

34. $PE_t = F[(QWW/POPW)_t, QWE_t, (QWR/POPW)_t, (PG_t-PS_t), SDR_t]$

35. $PT_t = F[(QWW/POPW)_t, (QWR/POPW)_t, QWE_t, PT_{t-1}, SDR_t]$

36. $PW_t = PE_t + PS_t$

In these relations, equations 16, 17, 28, 29, and 36 are identities. Equation 27 is a technical relationship relating quantity of hulls to total quantity of rough rice milled.

Variables

The model developed for this study includes three groups of variables: (1) endogenous variables which are generated by the system that the model characterizes, (2) exogenous variables which are considered to be determined outside the rice industry, and (3) predetermined variables which are exogenous variables plus the lagged endogenous variables. The variables used in the model are defined as follows:

Endogenous Variables--Supply Section 1/

AM_t = 1,000 acres of rice planted, Mississippi

AT_t = 1,000 acres of rice planted, Texas

AL_t = 1,000 acres of rice planted, Louisiana

AA_t = 1,000 acres of rice planted, Arkansas

AC_t = 1,000 acres of rice planted, California

AHM_t = 1,000 acres of rice harvested, Mississippi

AHT_t = 1,000 acres of rice harvested, Texas

AHL_t = 1,000 acres of rice harvested, Louisiana

AHA_t = 1,000 acres of rice harvested, Arkansas

AHC_t = 1,000 acres of rice harvested, California

YM_t = Average yield, Mississippi, hundredweights per acre

YT_t = Average yield, Texas, hundredweights per acre, first and second crop

YL_t = Average yield, Louisiana, hundredweights per acre

YA_t = Average yield, Arkansas, hundredweights per acre

YC_t = Average yield, California, hundredweights per acre

QP_t = U.S. rice production, 1,000 hundredweights, rough rice

QS_t = Total U.S. rice supply, 1,000 hundredweights, rough rice

Endogenous Variables--Demand Section

PB_t = Price of brewers rice, f.o.b. mill, California, dollars per hundredweight

PBR_t = Price received for bran, f.o.b. mill, Houston, dollars per ton

1/ The subscript "t" in the following variables denotes the crop year. All exogenous and any lagged endogenous variables are assumed as predetermined.

PE_t = U.S. export price, U.S. No. 2 long grain, f.o.b. mill, Houston, dollars per hundredweight

PF_t = U.S. farm price of rice, dollars per hundredweight, rough rice

PR_t = Retail price of long grain rice (BLS), dollars per hundredweight

PT_t = Thailand export price, white rice, 100 percent 2nd grade, f.o.b. Bangkok, dollars per hundredweight

PW_t = U.S. mill price, U.S. No. 2 long grain, f.o.b. mill, Houston, dollars per hundredweight

QB_t = U.S. rice quantity utilized by brewers, 1,000 hundredweights, milled rice

QCG_t = U.S. ending rice carryover in Government hands, 1,000 hundredweights, rough rice

QCP_t = U.S. ending rice carryover in private hands, 1,000 hundredweights, rough rice

QD_t = Total utilization of U.S. rice, 1,000 hundredweights, rough rice

QEC_t = U.S. milled rice exports, commercial, 1,000 hundredweights, milled rice

QEG_t = U.S. milled rice exports, Government, 1,000 hundredweights, milled rice

QER_t = U.S. rough rice exports, 1,000 hundredweights, rough rice

QFD_t = 3-year moving average of U.S. rice quantity for food consumption, 1,000 hundredweights, milled rice

QFE_t = U.S. quantity of rice utilized for feed, 1,000 hundredweights, bran and millfeed

QH_t = Quantity of rice hulls, 1,000 hundredweights, hulls

QM_t = Quantity of rough rice milled, 1,000 hundredweights, rough rice

QSE_t = U.S. quantity of rice utilized for seed, 1,000 hundredweights, rough rice

Exogenous Variables--Supply Section

AHA_t = 1,000 acres of rice harvested, Arkansas

AHT_t = 1,000 acres of rice harvested, Texas

COP_t = Variable cost of production, dollars per acre 2/

$D83_t$ = Dummy variable for PIK program, 1983=1

FP_t = U.S. average price paid by farmers for ammonium sulfate in October and May, dollars per ton

$P34L_t$ = Average number of days with more than 0.1 inch precipitation during March and April at Crowley and Lake Charles, Louisiana

$P56L_t$ = Average number of days with more than 0.1 inch precipitation during May and June at Crowley and Lake Charles, Louisiana

$P89A_t$ = Average number of days with more than 0.1 inch precipitation during August and September at Little Rock and Stuttgart, Arkansas

$P89M_t$ = Average number of days with more than 0.1 inch precipitation during August and September at Greenville and Stoneville, Mississippi

$R3M_t$ = Average March rainfall at Greenville and Stoneville, Mississippi, inches

$R4T_t$ = Average April rainfall at Beaumont and Houston, Texas, inches

RA_t = Ratio of rice allotment to maximum acres of rice planted in Arkansas (1,560,000 acres)

RC_t = Ratio of rice allotment to maximum acres of rice planted in California (600,000 acres)

RL_t = Ratio of rice allotment to maximum acres of rice planted in Louisiana (682,000 acres)

RM_t = Ratio of rice allotment to maximum acres of rice planted in Mississippi (340,000 acres)

RT_t = Ratio of rice allotment to maximum acres of rice planted in Texas (642,000 acres)

$SC56A_t$ = Percent of sky cover in May and June at Little Rock, Arkansas

T_t = Time, where 1983 = 83

$T_t^{1/2}$ = Square root of time, where 1983 = $\sqrt{83}$

T_t^2 = Time squared, where 1983 = $(83)^2$

$T6C_t$ = Average June temperature at Chico and Sacramento, California, degrees Farenheit

$T7M_t$ = Average July temperature at Greenville and Stoneville, Mississippi degrees Fahrenheit

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2/ Variable costs of production are available for 1975-1983. All commodities production indices for 1950-1974 were used to estimate COP for that period.

$T7A_t$ = Average July temperature at Little Rock and Stuttgart, Arkansas, degrees Fahrenheit

T_{75} = Time, where the value = T when T > 74, otherwise value = 0

$T_{74}^{1/2}$ = Square root of time, where the value = T when T < 75, otherwise value = 0

$T78T_t$ = Average July and August temperature at Beaumont and Houston, Texas, degrees Fahrenheit

TE_t = Dummy variable for technology released in early 1960's, 1962 = 0.5, 1963-1983 = 1, 0 otherwise 3/

Exogenous Variables--Demand Section

AUS_t = 1,000 acres of rice planted, United States

$D59_t$ = Dummy for beginning of rice council and for admission of Hawaii into United States, 1959-1982 = 1

$GEXP_t$ = Government expenditures on Government aided exports, million dollars

GP_t = Dummy on Government export subsidy, 1958-1972 = 1

$GP1_t$ = Dummy, 1950-1957 = 1

$GP2_t$ = Dummy, 1955-1975 = 1

IQP_t = Italian production in milled rice, 1,000 metric tons, after 1974; constant at 700,000 metric tons prior to 1975

LU_t = Grain-consuming animal units, million units

PC_t = Average price received by U.S. producers for corn, dollars per bushel

PG_t = U.S. Government support price for rice, dollars per hundredweight, rough rice

PI_t = Index of prices received by producers for feed grain and hay, 1967 = 100

POL_t = Policy trend, where value is equivalent to T after 1975, 0 otherwise

POP_t = 50-State midyear population (adjusted in 1950's for Hawaii and Alaska), 100,000

$POPW_t$ = World population, millions

3/ Postemergent herbicide (propanil), short-season varieties, and ratoon cropping were recommended by the experiment stations in 1962. There was a slight lag, however, before full adoption occurred.

PS_t = U.S. export subsidy on long grain milled rice, dollars per hundredweight

QWE_t = World rice exports, million metric tons, milled rice

QWW_t = Total world wheat production, 1,000 metric tons

QWR_t = World rice production, 1,000 metric tons, rough rice

QP_t = U.S. rice production, 1,000 hundredweights, rough rice

QS_t = U.S. rice supply, 1,000 hundredweights, rough rice

R_t = ratio of rice allotment to maximum acres of rice planted in the United States (2,818,000 acres). During the years marketing quotas were not in effect, $R_t = 1$

T_t = Time, where 1982 = 82

YI_t = Index of per capita U.S. personal income, 1972 = 100

SDR_t = Ratio of U.S. dollar to Special Drawing Rights, average of quarterly dollars per Special Drawing Right, Oct.-Sept. period

DATA

Secondary data from various sources were used to measure the variables included in the model (USDA (a); USDA (b); USDA (c); NOAA; U.S. Senate). The time period was 1950 through 1982 for the demand section and 1950 through 1983 for the supply section. Dummy variables were created to depict changes in Government programs during this period. Data used in estimating the equations are given in the appendix.

EMPIRICAL RESULTS

The supply section of the model was considered to be independent of the demand section since supplies available during a particular marketing year are known and fixed at the beginning of the marketing year. Consequently, the parameters of the model's supply section were estimated separately from those of the demand section. The supply section consists of a recursive model for each producing State and, therefore, ordinary least squares (OLS) was used to estimate the parameters. The demand section is a more general simultaneous-equation model, and the parameters for the various demand equations were estimated using three-stage least squares (3SLS). Equations 16, 17, 28, 29, and 36 are identities which were not fitted statistically.

Interpretation of Estimated Coefficients

It can be demonstrated that the yield equation errors are uncorrelated with observed acreages so that OLS is the appropriate estimation procedure for each of the recursive supply models. Since the equation errors are normally distributed with zero mean and finite variance, OLS yields maxiumum likelihood estimates. The 3SLS estimates of the parameters of the demand model are consistent, asymtotically efficient, and have approximately a normal distribution. Therefore, the t-test can be used for approximate statistical inference concerning the estimated coefficients of the supply and demand equations. The t-values associated with each estimated coefficient are shown in parentheses under each estimate.

In interpreting the parameter estimates, an effort will be made to assess the validity of the estimates in relation to economic theory, i.e., the extent to which signs and relative magnitudes of the estimated parameters agree with our expectations will be noted. The performance of the model in terms of how well each component predicts values of endogenous variables will be examined in the next section. This section will focus on the coefficient estimates.

Supply Section

The supply section of the model is composed of five independent recursive submodels that contain planted acreage, harvested acreage, and yield equations for each of the major rice producing States.

The individual State approach was chosen so that the impact of selected weather variables on average yields could be measured in greater precision. The weather variables evaluated for inclusion in the structural equations may be categorized into four types: (1) average monthly rainfall between March and September, (2) average days of precipitation over 0.1 inch during specific months, (3) average temperature during specific months, and (4) percent sky cover during specific months. Two locations were selected within each State's major production area to measure each of the weather variables used.

Previous research has demonstrated that weather conditions during the planting and harvesting seasons have a major effect on rice yields. Rice planting dates are critical for the varieties grown in the United States. The distribution and amount of rainfall during March, April, and May can delay seeding and also affect crop development in the early stages. Seeding delay pushes critical stages of plant development beyond the period of maximum day length and sunlight during late June and tends to reduce yield. Since rice yields are positively related to the amount of sunlight, a higher percent of sky cover is generally detrimental to rice yields during the reproductive stage. Excessive rainfall during the harvest season causes shattering and lodging and usually reduces yield.

Lagged farm prices, a hypothesized indicator of farmers' price expectations, was tested by Grant and Leath and did not appear to influence rice yields during the 1950-1976 period. Rice prices were supported and stablized by Government programs during most years included in this study. Consequently, price variations were too small to have a statistically significant impact on yield. Price effects were tested in the model but no significant effects on yield were found. Other variables evaluated were technology and area harvested in rice.

In the rice industry, the flow of new technology was not evenly distributed over the period of this study. A separate variable was included to account for technology released in the early sixties. The impact of this technology was most evident in Texas, where average yield increased from 29 hundredweights per acre in 1961 to over 41 hundredweights per acre in 1963.

Other factors thought to be related to technology were represented by trend variables.

The second component of the supply sector is planted acreage. During the period 1955-1973, allotments and marketing quotas were in effect. The Secretary of Agriculture was required to announce an acreage allotment for rice for each year unless a national emergency occurred. Compliance with the acreage allotment was required for price support eligibility. If marketing quotas were in effect, producers were subject to fines approximating the crop value for any acreage harvested over their allotment. Marketing quotas were in effect if the total supply exceeded the normal supply and if marketing quotas were approved by two-thirds of the producers voting in a referendum.

A central problem over the time period in this analysis was the measurement of the price effect of Government programs (allotments and marketing quotas) restricting acreage during the period 1955-1973. Houck and Ryan demonstrated that this effect could be approximated by the formula:

$$PF'_{t-1} = (R)\ PF_{t-1}$$

where PF_{t-1} is the actual farm price lagged one year; PF'_{t-1} is the "effective" farm price; and R is some adjustment factor which embodies the planting restriction. When no marketing quotas apply, $R = 1.0$ and $PF'_{t-1} = PF_{t-1}$. As allotments restrict acreage (marketing quotas in effect) R lies between 0 and 1.0. In this study, expected farm price (PF_{t-1}) is farm price lagged one year or loan rate, whichever is greater. R is the allotted acreage in the years of restrictions divided by the largest planted acreage when restraints were not in effect by State.

An alternative to the "effective" farm price variable is "effective" net returns lagged one year. Expected net returns, defined in this case, take into account trend yields and expected farm price for program participants. In addition, program participants are allowed for deficiency/diversion payments within their allotment acres or bases in 1976, 1978, 1981, 1982, and 1983. Nonparticipants received no program payments and can expect only farm price lagged one year. Empirical results of acreage response equations using the "effective" net returns as shown in the appendix, however, are mixed. They improve the acreage equations for Arkansas, California, and Louisiana, but worsen the equations for Texas and Mississippi.

Farm price of competing crops, such as soybeans, is not included in the acreage equations since it was found to be statistically insignificant. The estimated acreage and yield equations for the various States are presented below.

Planted Acreage

The first component of the recursive supply model for each of the producing States is a planted acreage equation. The estimated coefficients for the variables affecting acreage planted are shown in equations 1 to 5 by State. The parameter estimates display theoretically appropriate signs. The t-value for each parameter estimate is shown in parentheses under each coefficient, and related statistics (coefficient of determination (R^2), mean ($\overline{AM}$), standard error (σ)) are presented below each equation.

1. Mississippi

$$AM_t = 5.1807 + 886.7827(RM_t{*}PF_{t-1})/COP_{t-1} + 0.7990AM_{t-1} - 65.1074D83_t$$

(2.61) (8.36) (1.78)

$R^2 = 0.84$ $\overline{AM} = 93.06$ $\sigma = 78.84$

2. Texas

$$AT_t = 181.5517 + 2782.9650(RT_t{*}PF_{t-1})/COP_{t-1} + 0.4167AT_{t-1} - 129.0392D83_t$$

(3.99) (3.25) (2.89)

$R^2 = 0.71$ $\overline{AT} = 501.00$ $\sigma = 74.94$

3. Louisiana

$$AL_t = 188.0102 + 3376.5006(RL_t{*}PF_{t-1})/COP_{t-1} + 0.4167AL_{t-1} - 125.6319D83_t$$

(4.70) (3.40) (2.56)

$R^2 = 0.71$ $\overline{AL} = 551.76$ $\sigma = 80.29$

4. Arkansas

$$AA_t = 20.7778 + 5095.2670(RA_t{*}PF_{t-1})/COP_{t-1} + 0.7936AA_{t-1} - 294.4996D83_t$$

(3.67) (9.37) (2.29)

$R^2 = 0.90$ $\overline{AA} = 634.50$ $\sigma = 323.62$

5. California

$$AC_t = 70.7203 + 3981.3940(RC_t{*}PF_{t-1})/COP_{t-1} + 0.4616AC_{t-1} - 89.5169D83_t$$

(5.83) (4.69) (1.76)

$R^2 = 0.80$ $\overline{AC} = 378.56$ $\sigma = 98.70$

"Effective" Farm Prices--The adjusted farm price received by farmers deflated by the variable cost of production for the previous crop was incorporated in the acreage equations for each State. The effective farm price for the previous crop or loan rate, whichever is greater, is assumed to reflect accurately the farmers' price expectations for the crop they are planting. An increase in expected price was found to have a significant impact on acreage in all States.

Lagged Acreage--The positive response of producers to previous acreage harvested indicates rice producers' planting decisions in response to economic incentives may follow a partial adjustment specification. In other words, rice farmers tend to have a lagged response due to fixity of resource stocks (such as land and machinery), Government allotments, risk aversion, and constraints of operator's management capacity. Disinvestment by producers may take more than one season for full adjustments to occur.

Dummy Variables--The acreage reduction and PIK program in 1983 sharply reduced rice acreage in all States by removing 1.2 million acres from production. A dummy variable, $D83_t$, was used in each acreage equation to reflect this policy. Acreage in Arkansas was the most responsive in absolute terms to the program because of its large rice acreage.

Harvested Acres

Since production is equal to harvested acreage times yield, the planted acreage forecasts in the model must be transformed to acres harvested. The relationships between harvested and planted acreage are given below:

6. $AHM_t = 0.97AM_t$

$$\begin{array}{l}(276.92)\end{array}$$

$R^2 = 0.99$ $DW = 2.91$ $\overline{AHM} = 90$ $\sigma = 0.0035$

7. $AHT_t = 0.99AT_t$

$$\begin{array}{l}(170.13)\end{array}$$

$R^2 = 0.99$ $DW = 2.08$ $\overline{AHT} = 495$ $\sigma = 0.0058$

8. $AHL_t = 0.99AL_t$

$$\begin{array}{l}(560.39)\end{array}$$

$R^2 = 0.99$ $DW = 1.85$ $\overline{AHL} = 547$ $\sigma = 0.0018$

9. $AHA_t = 0.98AA_t$

$$\begin{array}{l}(298.44)\end{array}$$

$R^2 = 0.99$ $DW = 2.27$ $\overline{AHA} = 624$ $\sigma = 0.0033$

10. $AHC_t = 0.99AC_t$

$$\begin{array}{l}(476.52)\end{array}$$

$R^2 = 0.99$ $DW = 0.85$ $\overline{AHC} = 374$ $\sigma = 0.0021$

Yields

The third component of the recursive supply model for each producing State is an equation relating yields to harvested acreage and other exogenous variables. The estimated coefficients are shown in equations 11 to 15 by State.

11. Mississipi

$$\underset{}{YM_t} = -38946.8 \underset{(-3.76)}{- 632.1636T_t} \underset{(4.15)}{+ 11365.99T_t^{1/2}} \underset{(-2.97)}{- 51.8946(FP/PF)_{t-1}}$$

$$- 25.4571R3M_t - 109.9240P89M_t - 80.2271T7M_t$$

$$(-1.84) \qquad (-3.97) \qquad (-2.96)$$

$$R^2 = 0.93 \quad D.W. = 1.94 \quad \overline{YM} = 36.43 \quad \sigma = 7.17$$

12. Texas

$$YT_t = 14103.71 + 1430.183TE_t - 1.1078AHT_t - 23.8852R4T_t - 125.91T78T_t$$

$$(11.25) \qquad (-1.69) \qquad (-1.27) \qquad (-3.17)$$

$$R^2 = 0.91 \quad D.W. = 1.73 \quad \overline{YT} = 38.70 \quad \sigma = 8.57$$

13. Louisiana

$$YL_t = - 1393.1 + 388.3650T_t - 2.4574T_t^2 - 57.2108P34L_t + 37.6170P56L_t$$

$$(8.29) \qquad (-7.05) \qquad (-3.41) \qquad (1.93)$$

$$R^2 = 0.94 \quad D.W. = 1.72 \quad \overline{YL} = 32.72 \quad \sigma = 6.68$$

14. Arkansas

$$YA_t = - 4819.1 + 1496.986T_t^{1/2} - 1.6168AHA_t - 74.3251P89A_t - 40.2794T7A_t$$

$$(6.25) \qquad (-5.50) \qquad (-2.07) \qquad (-1.57)$$

$$+ 146.7691SC56A_t + 602.1649TE_t - 1040.72D83_t$$

$$(1.93) \qquad (3.10) \qquad (-3.50)$$

$$R^2 = 0.95 \quad D.W. = 1.96 \quad \overline{YA} = 38.69 \quad \sigma = 8.84$$

15. California

$$YC_t = - 13513.2 + 194.1737T_{75} + 1732.943T_{74}^{1/2} + 61.5654T6C_t$$

$$(12.35) \qquad (11.03) \qquad (2.70)$$

$$R^2 = 0.91 \quad D.W. = 1.69 \quad \overline{YC} = 50.11 \quad \sigma = 11.24$$

Acreage Harvested--Acreage harvested was used in the equations to reflect the land area devoted to rice production in each State. Acreage increases had negative impacts on yields in Texas and Arkansas due to limited capital and human resources in the short run, decreases in the soybean-rice rotation ratio, and bringing marginal land into rice production. Acreage harvested in the other States did not show a significant (10-percent level) impact on yield.

Technology and trend--The technology variable, representing new technology developed in the early sixties (TE_t), was significant in yield equations for Texas and Arkansas. The impact was positive in both cases and very large in Texas. This large impact reflects the advent of second-crop rice production in Texas in the sixties as well as other improvements in production techniques. This technology variable accounted for most of the upward trend in average yields in Texas. Thus, the other trend variables were not included in the final analysis for this State.

Trend variables were included in the final specification for other States. Yield trends were positive for each State. In all cases except Mississippi, the rate of increase declined over time. In Louisiana the positive linear trend (T_t) was reduced over time through the negative coefficient on the squared term (T_t^2). The trend in Arkansas was increasing at a decreasing rate ($T_t^{1/2}$).

Rainfall--Rainfall during seeding time had a significant impact on yields in Mississippi, Texas, and Louisiana. March and April precipitation delays planting and thus reduces yields.

Precipitation--The average number of days of precipitation over 0.1 inch in selected months during the seeding and growing season (March to July) had different impacts at different locations. In Louisiana, preciptation in March and April ($P34L_t$) reduced yields, while precipitation during May and June ($P56L_t$) increased yields. The positive parameter estimate for $P56L_t$ does not agree with *a priori* expectation since low yields have been observed in years when rainfall was higher than normal during the growing season. Excess precipitation during harvest (August and September) had the expected effect of reducing yields.

Temperature--The relationship between yield and average temperature during selected months of the growing season depended on the location and month. In Mississippi, high average temperatures during July ($T7M_t$) had a negative impact on average yield. The same relationship existed in Texas for the July and August temperature ($T78T_t$), and in Arkansas for July and August temperature ($T78A_t$). In contrast, higher temperatures in June were found to be beneficial in California ($T6C_t$).

Sky Cover--A higher percent of sky cover is generally considered detrimental to rice growth and yields, but in May and June it has a positive effect on rice yields in Arkansas. According to Stansel, optimal water temperature for rice production ranges from 70°F to 88°F. A high percent of sky cover results in a moderation of extremes in water temperature which would lead to higher rice yields.

Supply Identities

It was noted before that the quantity produced (QP_t) in the United States and total supply (QS_t) are treated as exogenous variables in the demand section. In the model, U.S. production is determined from the harvested acreage and yield equations, and is defined as the sum of quantities (harvested acreage x yield per acre) produced in each State (equation 16). Total supply is defined as current production (QP_t) plus stocks in private (QCP_{t-1}) and Government (QCG_{t-1}) ownership that were carried over from the previous marketing year (equation 17).

16. $QP_t = (AHM_t*YM_t) + (AHT_t*YT_t) + (AHL_t*YL_t) + (AHA_t*YA_t) + (AHC_t*YC_t)$

17. $QS_t = QP_t + QCP_{t-1} + QCG_{t-1}$

The quantity of rice imported into the United States during 1950 to 1983 was negligible. Therefore, it is ignored as a component of supply in the model.

Demand Section

The demand section of the model is composed of a set of economic relationships which represent the several domestic and export outlets for U.S. rice. The parameters associated with the demand equations were estimated using three-stage least squares (3SLS). Thus, the parameter estimates for this simultaneous system of equations reflect the economic interrelationships that exist among the various outlets for U.S. rice. The parameter estimates are presented below by major outlet. The t-value for each parameter estimated is shown in parentheses under each coefficient. The related statistics, as given in the supply section, are not applicable with three-stage least squares estimation.

Feed

Rice millfeed, a mixture of bran, ground hulls, and polish, is one of the minor agricultural products used for feed. Thus, this market is influenced by the general price level for feed grains and hay (PI). Since millfeed is a byproduct of rice milling, the total quantity of rice milled (QM) is also a significant determinant of quantity. The signs on the coefficients in equation 18 were in accord with expectations. The coefficients were large in relation to their standard errors, especially the quantity of rough rice milled.

$$18.\quad QFE_t = \underset{}{-41.4161} - \underset{(-2.72)}{11.3458PBR_t} + \underset{(69.41)}{0.1086QM_t} + \underset{(4.21)}{5.2312PI_t}$$

Seed

The demand for seed in the current marketing year is determined largely by the acreage seeded to rice in the following year. However, the planted acreage in t+1 was not included in the specifications because it is an unknown when the model is used in a forecasting framework. The adjusted farm price and lagged planted acreage were found to influence planted acreage in each State and were included in the estimating equation for seed demand. A time trend was also included to reflect increases in seeding rates per acre that have occurred over time. The higher per acre rates are due primarily to a shift from drilled seeding to aerial seeding.

The latter method involved higher seeding rates. The parameter estimates associated with these variables are shown in equation 19. The signs associated with the coefficients agree with expectations.

$$19.\quad QSE_t = -1814.3200 + \underset{(4.61)}{18058.58((R*PF)/COP)_t} + \underset{(4.34)}{0.5093AUS_t} + \underset{(6.18)}{44.3146T}$$

Food

Food demand for rice consists of direct food use (including white rice, parboiled, precooked, brown, and flavored) and processed food use (including cereal, soups, baby food, package mixes, and other unclassified uses).

Economic theory suggests that food demand for rice is influenced by the retail price of rice, price of competing commodities, income, population, changes in tastes and habits, and other factors. Prices of potatoes, corn, and wheat products were evaluated in an early analysis by Grant and Leath. These competing products did not have any appreciable effect on food rice consumption. Consequently, prices of these substitutes were not included in the final specification by Grant and Leath. They were not examined in our model either. Income and population are the major variables affecting food rice consumption. Income and population are highly correlated. To avoid statistical problems in estimation, a per capita food demand equation was estimated, and the results were multiplied by population. Changes in the retail rice price, although significant at the 5-percent level, were found to have a very minor impact on demand. The estimated parameters in equation 20 agree in sign with *a priori* expectations and are significantly different from zero.

20. $QFD_t = (7.5119 - 0.04202PR_t + 0.02800YI_t + 0.1328D59)POP_t$

(-3.96) (12.10) (0.97)

Annual estimates of rice food demand are based primarily on milled shipment data. Actual consumption, not available on a periodic basis, lags behind milled shipments. To compensate for this lag and the mill to consumer fluctuations in projecting stocks, a 3-year moving average for rice food demand was used.

Brewers

Rice used by brewers, a relatively small portion of total starch inputs in the brewing industry, is influenced by the rapid growth in beer sales. Only a limited number of brewing firms use brewers rice. Although brewers rice competes with corn grits in this market, the adjustment in brewing recipes has been limited due to final product identity with rice. Thus, demand in this outlet is determined by a ratio of brewers rice price to corn price, economic variables reflecting growth in beer sales (income), lagged brewers use of rice, and population. The estimated equation was formulated on a per capita basis and the parameter estimates are shown in equation 21.

21. $QB_t = (1.2423 - 0.1511(PB/PC)_t + 0.003202YI_t$

(-5.02) (3.60)

$+ 0.6463(QB/POP)_{t-1})POP_t$

(9.02)

The signs on the coefficients agree with expectations and are significantly different from zero at the 1-percent probability level.

Exports

The quantity of milled rice exported from the United States under commercial arrangement was greater than that exported under Government programs and averaged nearly 70 percent of total exports during the study period. However, the relative quantities moving under each arrangement varied greatly from year to year and are determined in part by different variables. The U.S. export price (PE) and the Thailand export price (PT) are highly correlated; however, each is affected by Government programs in the respective countries. The ratio of these prices was assumed to influence U.S. commercial exports. The quantity exported under Government programs and the quantity produced also influence the demand for commercial exports. The shift in U.S. policy from a fixed exchange rate to a floating exchange rate in 1971 impacted U.S. rice exports. Grant and Leath did not include an exchange rate variable in the earlier model. The dollar to Standard Drawing Rights ratio (SDR) was added in this study and is significant at the 5-percent level in the commercial export equation. The estimated parameters associated with these variables for commercial exports are shown in equation 22. The magnitude of the coefficients and their associated signs are consistent with expectations.

$$22.\quad QEC_t = -12573.20 - \underset{(-7.00)}{17368.30(PE/PT)_t} - \underset{(-10.61)}{0.5765QEG_t}$$

$$+ \underset{(16.59)}{0.2718QS_t} + \underset{(5.21)}{31769.71SDR_t}$$

In contrast to commercial exports, the quantity exported under Government programs is influenced by the supply available, relationships between export price and U.S. loan rate, Government funding available for Government-sponsored exports, and the particular policy in effect. The parameter estimates for variables influencing Government exports are shown in equation 23.

$$23.\quad QEG_t = 2211.268 - \underset{(-1.77)}{2493.34(PE/(PG-PS))_t} + \underset{(2.83)}{0.05448QS_t}$$

$$+ \underset{(4.51)}{7024.950GP2_t} + \underset{(3.95)}{301.0375(GEXP/(PG-PS))_t}$$

Rough rice exports are a minor outlet in terms of total rice exports. Farm price and lagged exports were included in the structural equation and the parameter estimates are shown in equation 24. Rough rice was exported mainly for use as seed prior to 1975. Since that time Italy has imported U.S. rough rice during periods of low production. Price is not a major determining factor in determining rough rice exported.

$$24.\quad QER_t = 9469.908 - \underset{(-0.47)}{37.3423(PF/SDR)_t} + \underset{(3.32)}{0.2988QER_{t-1}} + \underset{(2.60)}{12.0403POL_t}$$

$$- \underset{(-5.57)}{12.8969IQP_t}$$

The price coefficient was negative as expected; however, the price effect is not significantly different from zero.

Carryover Stocks

U.S. carryover, both private and Government-held stocks, was influenced during 1950-1982 by Government programs. The relationships between the support price and actual price received by producers, the relationship between U.S. export price and a world price indicator, P.L-480 program, the export subsidy program, and allotment program all affected carryover stocks. The estimated parameters for variables that influence private and Government-owned stocks are shown in equations 25 and 26, respectively. The estimated parameters agree in sign with *a priori* expectations.

$$25.\quad QCP_t = -3137.86 - \underset{(-2.38)}{4897.67(PF/PG)_t} + \underset{(2.01)}{0.1306QCG_t} + \underset{(12.78)}{0.1868QS_t}$$

$$26.\quad QCG_t = -8181.47 - \underset{(-5.56)}{13381.6(PF/PG)_t} + \underset{(7.90)}{29320.06(PE/PT)_t} - \underset{(-4.55)}{8251.40GP1_t} - \underset{(-4.42)}{7243.98GP_t}$$

Hulls

Price and utilization data for hulls were not available. Accordingly, the equation for hulls (equation 27) was expressed as a technical relationship of quantity of milled rice using a standard ratio of hulls obtained per hundredweight of rough rice. Lag use of hulls was added to remove autocorrelation.

$$27.\quad QH_t = 742.9797 + \underset{(11.88)}{0.1289QM_t} + \underset{(3.15)}{0.2083QH_{t-1}}$$

Identities

The demand section is closed with identities representing the total quantity milled (equation 28) and total quantity demanded (equation 29).

$$28.\quad QM_t = QFD_t + QH_t + QFE_t + QB_t + QEC_t + QEG_t$$

$$29.\quad QD_t = QM_t + QCP_t + QCG_t + QER_t + QSE_t$$

The total quantity milled is the sum of all demands for milled rice. Total demand is the sum of quantities milled, carryover stocks, rough rice exports, and seed uses.

Price Relationships

Price relationships were specified to link the various demand components of the model. The relationships between price at various stages of the marketing process was established using the price equations. The model was formulated such that various domestic prices are directly related to the wholesale price established at the mill level (PW). The domestic price relationships assumed in the model are shown in equations 30-33.

$$30.\quad PR_t = -9.8935 + \underset{(22.81)}{0.9535PW_t} + \underset{(4.49)}{0.1633T} + \underset{(19.72)}{0.5347PR_{t-1}}$$

31. $PB_t = 1.2263 + 0.1906PW_t + 0.4012PB_{t-1}$

$$\begin{array}{cc} (7.24) & (5.54) \end{array}$$

32. $PBR_t = -\ 8.3568 + 1.0198PW_t + 0.1922LU_t + 0.1901PI_t$

$$\begin{array}{ccc} (5.35) & (0.93) & (9.85) \end{array}$$

33. $PF_t = -\ 0.6773 + 0.4275PW_t + 0.01949T$

$$\begin{array}{cc} (36.67) & (3.15) \end{array}$$

Changes in the price at the wholesale level (PW) do not generally result in immediate changes in the retail price (PR) and in the price of brewers rice (PB). To account for this lag in price response a partial adjustment scheme was hypothesized for the retail and brewer price relationships (equations 30 and 31). The distributed lag in price adjustments at the brewers and retail level to changes in the wholesale price is given by the coefficient estimate for the lagged dependent variables.

The price of bran (PBR) is affected by changes in the wholesale price (PW), the number of grain-consuming animal units (LU), and the index for feed grains and hay (PI). The coefficients were positive as expected (equation 32). The farm price (PF) was assumed to be directly related to the wholesale price (PW) and a trend variable was included to account for gradual upward adjustment and Government support of farm prices that occurred during the study period (equation 33).

The U.S. export price (PE) and the Thailand export price (PT) were hypothesized to be determined by world rice production per capita (QWR/POPW), world rice exports (QWE), world wheat production per capita $(QWW/POPW)_t$, and dollars per Standard Drawing Right (SDR). The estimated coefficients associated with each of these variables are shown in equations 34 and 35. The U.S. export price was hypothesized to be influenced by the U.S. support rate minus any export subsidy. There are lags in the adjustment of Thailand prices to changes in world supply conditions; therefore, a partial adjustment scheme was assumed for the Thailand export price equation.

34. $PE_t = -\ 39.9621 + 0.02909(QWR/POPW)_t - 0.4982QWE_t - 0.042102(QWW/POPW)_t$

$$\begin{array}{ccc} (0.32) & (-1.64) & (-0.59) \end{array}$$

$+\ 1.0734(PG\text{-}PS)_t + 44.6659SDR_t$

$$\begin{array}{cc} (9.91) & (7.42) \end{array}$$

35. $PT_t = -33.2543 - 0.012586(QWR/POPW)_t - 0.5540QWE_t + 0.00432(QWW/POPW)_t$

$$\begin{array}{ccc} (0.16) & (-2.09) & (0.07) \end{array}$$

$+\ 0.3596PT_{t-1} + 42.1532SDR_t$

$$\begin{array}{cc} (7.87) & (7.83) \end{array}$$

The coefficients for per capita world rice and wheat production were not significantly different from zero. The signs of the other estimated coefficients agree with expectations. U.S. and Thailand export prices are responsive to changes in volume of rice traded in the world market, as was expected. Both U.S. and Thailand export prices are also sensitive to a change in exchange rates.

The U.S. export price (PE) was linked to the domestic wholesale price (PW) in the model through an identity involving the export subsidy established by the U.S. Government (PS). This relationship is expressed in equation 36. This subsidy was discontinued after 1972 so domestic price currently responds directly to changes in world market conditions.

36. $PW_t = PE_t + PS_t$

MODEL VALIDATION

The performance of an econometric model depends on how well the model predicts the behavior of the system on which it is based. The performance of the rice model was evaluated using two different approaches: visual comparison of actual and estimated values over the estimation period and various test statistics. Since the demand and supply sections were estimated differently, discussion of their validity is separate.

Test Criteria

There are several goodness of fit criteria for evaluating individual equations within a model (Kost). Though none is perfect, the criteria can increase subjective confidence in the model and help evaluate changes in the model. The measures used for each equation are:

1. Root mean square error (RMSE) =

$$\sqrt{\frac{1}{N} \sum_{t=1}^{N} (\hat{Y}_t - Y_t)^2}$$

2. Root mean square percentage error (RMS%E) =

$$\sqrt{\frac{1}{N} \sum_{t=1}^{N} \left[\frac{\hat{Y}_t - Y_t}{Y_t}\right]^2}$$

3. Theil's decomposition coefficient (U_D) =

$$\frac{(1-R^2)\, S_Y^2}{\frac{1}{N} \sum_{t=1}^{N} (\hat{Y}_t - Y_t)^2}$$

4. Theil's inequality coefficient (U_1) =

$$\frac{\sqrt{\frac{1}{N} \sum_{t=1}^{N} ((\hat{Y}_t - Y_{t-1})^2 - (Y_t - Y_{t-1}))^2}}{\sqrt{\frac{1}{N} \sum_{t=1}^{N} (\hat{Y}_t - Y_{t-1})^2} + \sqrt{\frac{1}{N} \sum_{t=1}^{N} (Y_t - Y_{t-1})^2}}$$

5. Coefficient of determination (R^2) =

$$\frac{\sum_{t=1}^{N} (Y_t - \bar{Y})^2 - \sum_{t=1}^{N} (Y_t - \hat{Y}_t)^2}{\sum_{t=1}^{N} (Y_t - \bar{Y})^2},$$

where Y_t, $\hat{Y}_t$, and $\bar{Y}$ are actual value, predicted value, and mean of the endogenous variable Y, respectively, and N is the number of observations. In the case of RMSE and RMS%E, the smaller the error, the better the fit. To indicate a better fit using Theil's coefficient U_D should approach 1, while U_1 should approach 0. R-squared measures the proportion of the variation explained by a linear regression of estimates on actual values. The frequency of turning point errors for an endogenous variable was determined by comparing the sign of actual change with that of the estimated change.

Supply Model

The coefficient of variation (C.V.) associated with each of the equations in the supply model is shown in table 1. The C.V. expresses the standard error of the estimate for each equation as a percentage of the mean of the dependent variable. Thus, this statistic allows comparison of the estimating power of

Table 1--Summary of goodness of fit statistics for each endogenous variable in the supply model, 1950-83 simulation

Endogenous variable	Mean	Standard error of estimate	Coefficient of variation	RMSE	RMS%E	U_d	U_1	R^2	Turning point errors
YC	5011	352	7.02	678.7	.193	.87	.0000	.95	9
YL	3273	161	4.93	365.1	.177	.88	.0000	.97	11
YM	3643	212	5.81	498.7	.180	.87	.0000	.96	10
YA	3869	224	5.90	436.5	.180	.99	.0000	.97	8
YT	3869	269	6.96	484.9	.185	.96	.0000	.95	10
AC	379	46	12.05	59.0	.207	.99	.0003	.89	5
AL	552	46	8.29	106.5	.188	.98	.0001	.84	9
AM	93	33	35.21	30.3	.337	.14	.0059	.92	10
AA	634	110	17.31	116.1	.225	.92	.0002	.95	8
AT	501	43	8.55	92.3	.189	1.00	.0002	.84	11
AHC	374	5	1.26	57.7	.206	.99	.0003	.89	5
AHL	547	6	1.05	106.0	.190	.98	.0001	.84	9
AHM	91	3	2.73	29.9	.348	.13	.0061	.92	8
AHA	624	14	2.18	111.0	.224	.87	.0002	.95	9
AHT	494	17	3.47	91.0	.188	.99	.0002	.84	11
QP	85684	---	---	10110.3	.189	.99	.0000	.98	10
QS	103683	---	---	10643.5	.184	.83	.0000	.98	8

--- not estimated

equations with small values for the dependent variable with those having large values. For example, Mississippi has small average acreage in comparison to Arkansas, and the acreage equation for Mississippi (equation 1) had a relatively small standard error of the estimate (33). In comparison, the standard error of the estimate for the acreage equation for Arkansas (equation 4) was 99; however, the equation for Arkansas provides better estimates when judged on the basis of the coefficient of variation.

The RMSE and RMS%E approach expectations except for the Mississippi acreage equation. The coefficient of variation, RMS%E, U_D, and U_1, point to this equation as the weakest. However, Mississippi has the smallest production of the States modeled. A large estimation error would have a small relative impact on total production.

Actual and estimated dependent variables for the supply section are shown in figures 3 to 14. In most instances, the estimated values approximate the values fairly accurately.

Demand Model

The simultaneity of the demand model and the use of nonlinear variables in several equations required using a method to solve a simultaneous system of nonlinear equations to estimate the endogenous variables. The SIMNLIN procedure was used to estimate the endogenous variables for validating the model (SAS). Model simulation spanned 1950-1982, the same period used to estimate the equations.

Criteria for overall goodness of fit evaluation are limited. The weighted mean square error for the system at 1.16 and weighted R-square for the system at 0.99 indicate a relatively low error and high explanatory power of the overall model. Subjective evaluation of the overall model must also consider the response of the individual equations. Table 2 summarizes several measures of goodness of fit for each estimated variable. The RMSE and RMS%E are low except for QER and QEG. The U_D (residual) coefficients are erratic, ranging from 0.02 (QEG) to 0.99 (QCP). They should approach 1. Thiel's inequality coefficient (U_1) approaches zero in all cases. R-squares are above 0.80 for all equations except QCG and QEG.

An examination of the actual and estimated values for the endogenous variables indicates that the equations have a relatively proportionate distribution between overestimation and underestimation. No major distribution skewness occurs. The missed turning point errors ranged from a low of 2 on QD to a high of 16 on PF.

Model performance may be further evaluated by visual comparison of the actual data plotted against the estimated value obtained from the model (figs. 15 through 33). In most instances, the estimated values closely approximate the actual values.

The goodness of fit statistics and visual observation of the model suggest a tracking ability over the 1950-1982 period good enough to make the model usable. The final test of the model will depend upon how well the equations project behavior of demand after 1982.

Table 2--Summary of goodness of fit statistics for each endogenous variable in the demand model, 1950 to 1982 simulation

Endogenous variable	Mean	Standard deviation	Coefficient of variation	RMSE	RMS%E	U_d	U_1	R^2	Turning point errors
QFE	8564	3228	38.4	1156.03	0.180	0.24	0.0000	0 .97	5
QSE	2912	879	30.2	366.50	.114	.89	.0000	.91	8
QFD	17661	4634	26.2	836.75	.043	.58	.0000	.98	6
QB	4913	1983	40.4	386.13	.089	.84	.0000	.98	13
QEC	20640	14068	68.2	6068.40	.683	.22	.0000	.93	13
QEG	12245	7149	58.4	5048.04	.730	.29	.0001	.79	10
QER	796	1349	169.4	739.90	18.172	.11	.0159	.84	15
QCP	10903	9133	83.8	3275.03	.362	.99	.0000	.93	7
QCG	6724	7810	116.2	7883.71	--	.02	.0444	.61	14
QH	13438	4831	35.9	1512.62	.137	.48	.0000	.97	12
QM	77462	29494	38.1	10684.00	.181	.25	.0000	.96	8
QD	98846	40844	41.3	5104.70	.061	.79	.0000	.99	2
PR	29.11	12.67	43.5	3.63	.109	.61	.0044	.97	5
PB	6.41	1.67	26.0	1.00	.151	.78	.0218	.84	11
PBR	46.21	15.80	34.2	5.39	.112	.70	.0026	.95	11
PF	6.51	1.55	39.2	1.51	.190	.50	.0330	.89	16
PE	13.05	6.35	48.7	3.64	.237	.51	.0207	.90	9
PT	10.78	5.33	49.5	2.44	.186	.94	.0178	.89	8
PW	13.80	5.76	41.7	3.57	.204	.51	.0171	.88	10

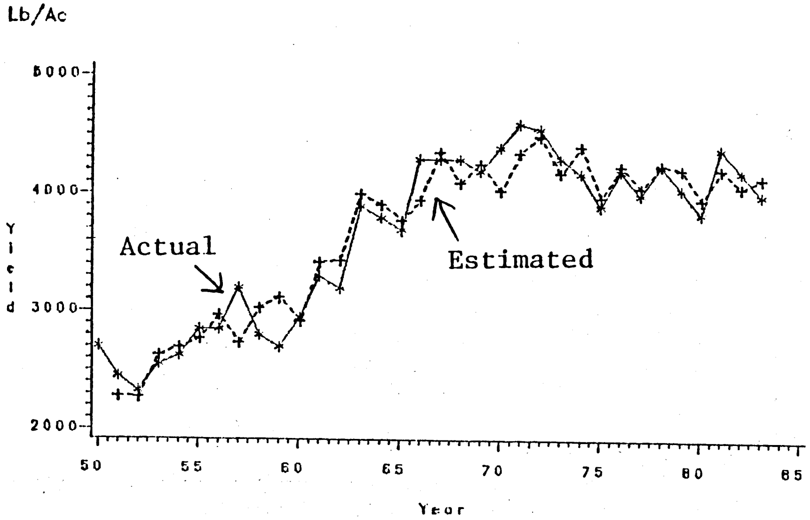

FIG. 3--Mississippi: Yield per harvested acre, 1950-83

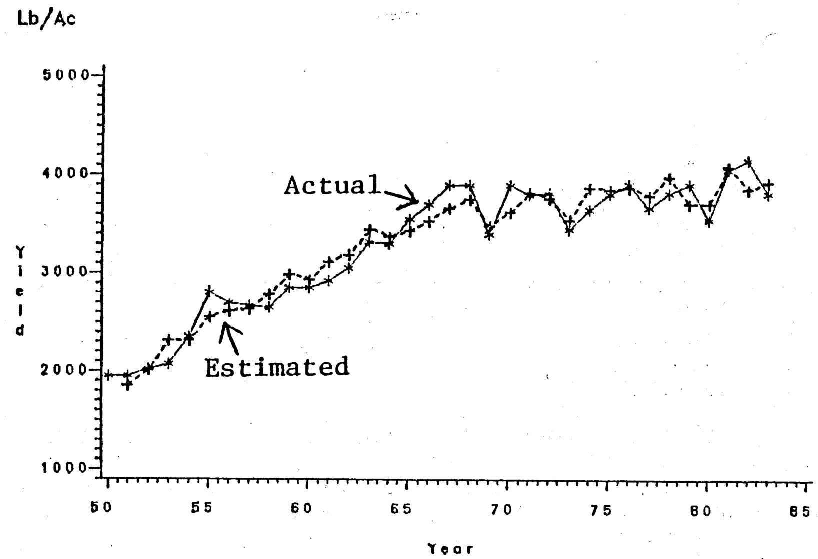

FIG. 4--Louisiana: Yield per harvested acre, 1950-83

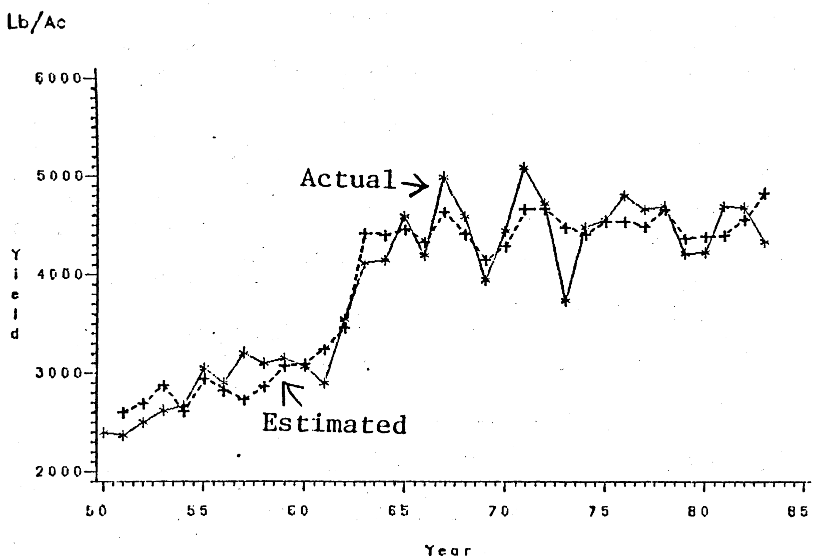

FIG. 5--Texas: Yield per harvested acre, 1950-83

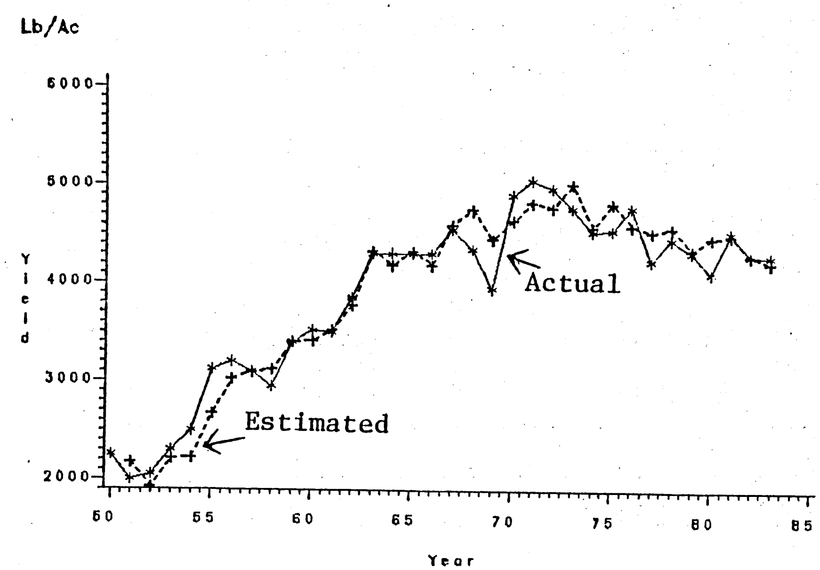

FIG. 6--Arkansas: Yield per harvested acre, 1950-83

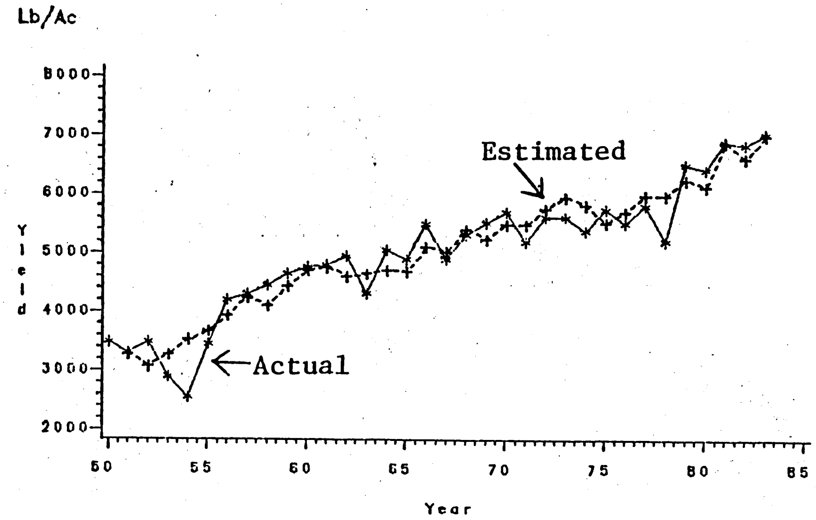

FIG. 7--California: Yield per harvested acre, 1950-83

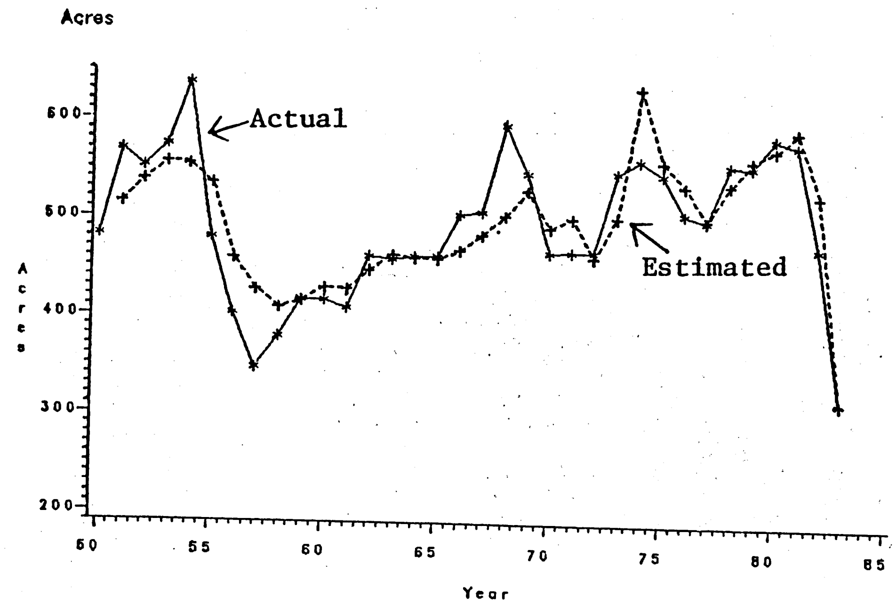

FIG. 8--Texas: Harvested acres, 1950-83

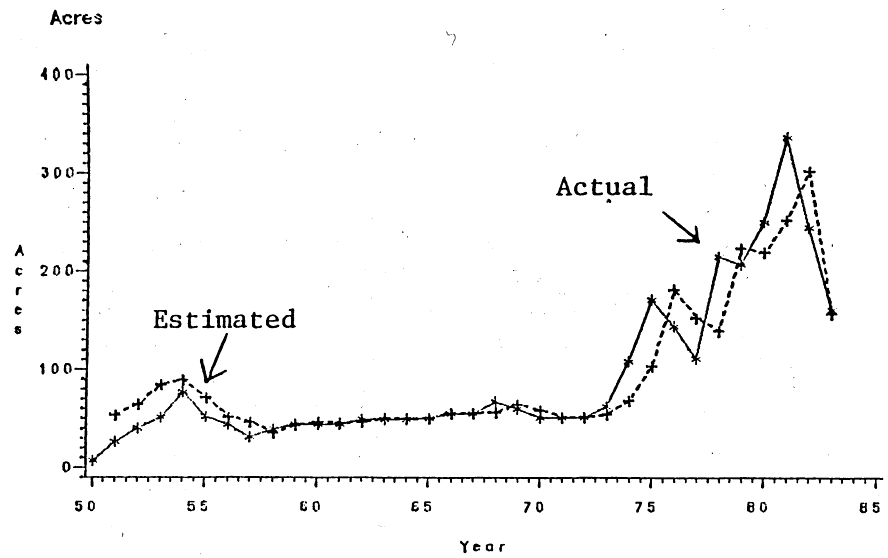

FIG. 9--Mississippi: Harvested acres, 1950-83

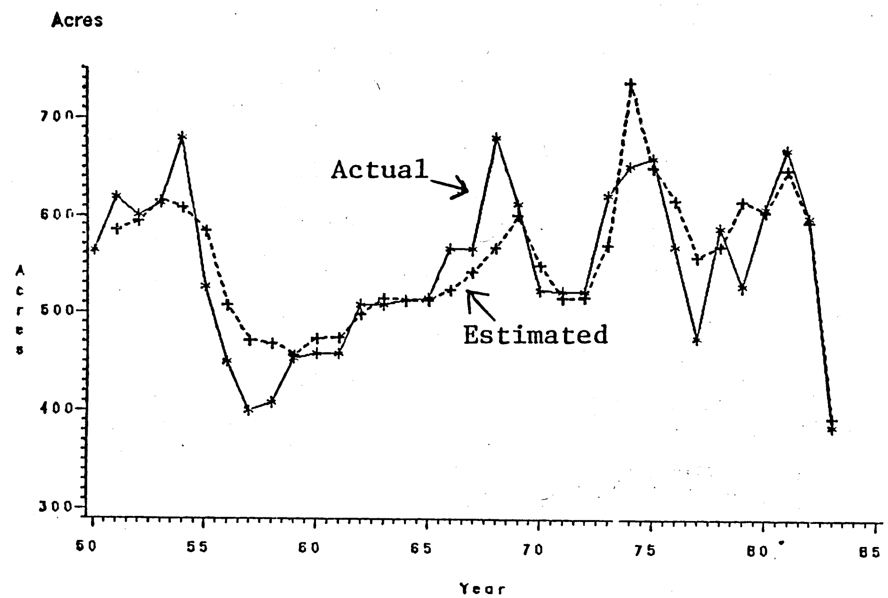

FIG. 10--Louisiana: Harvested acres, 1950-83

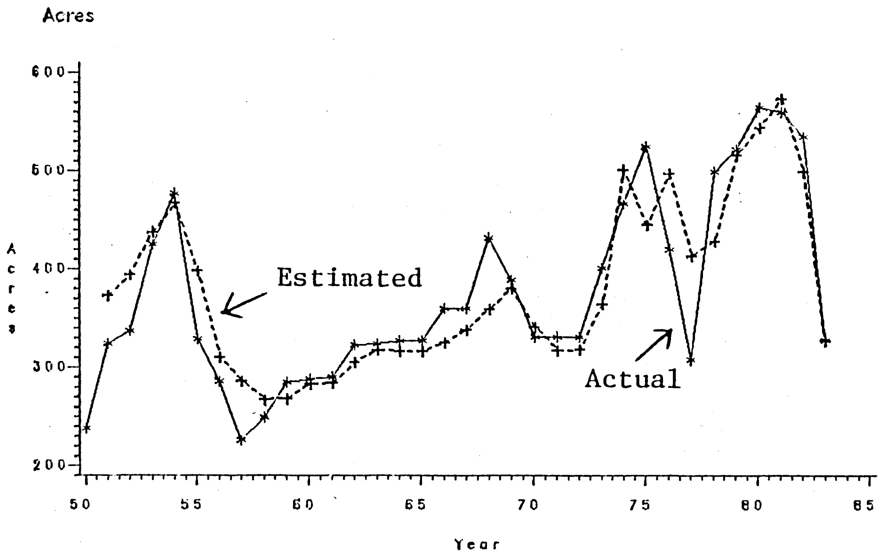

FIG. 11--California: Harvested acres, 1950-83

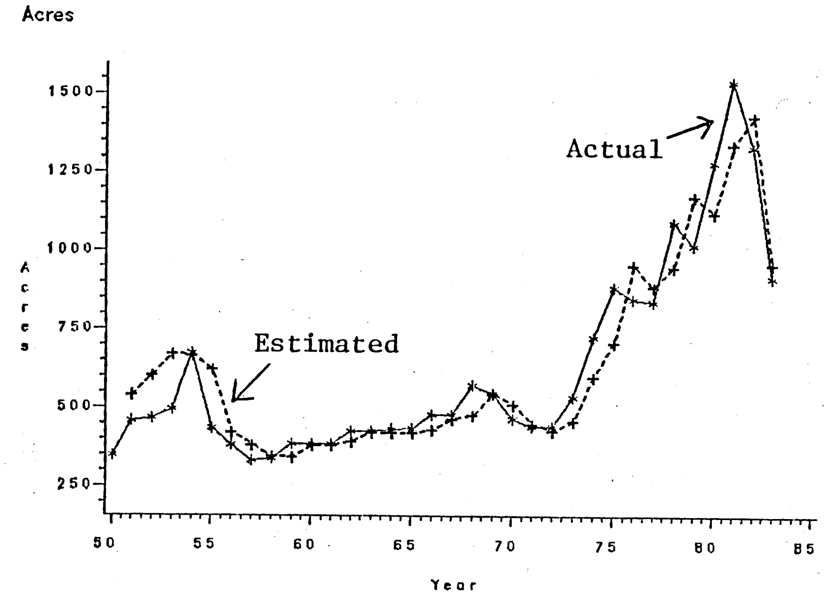

FIG. 12--Arkansas: Harvested acres, 1950-83

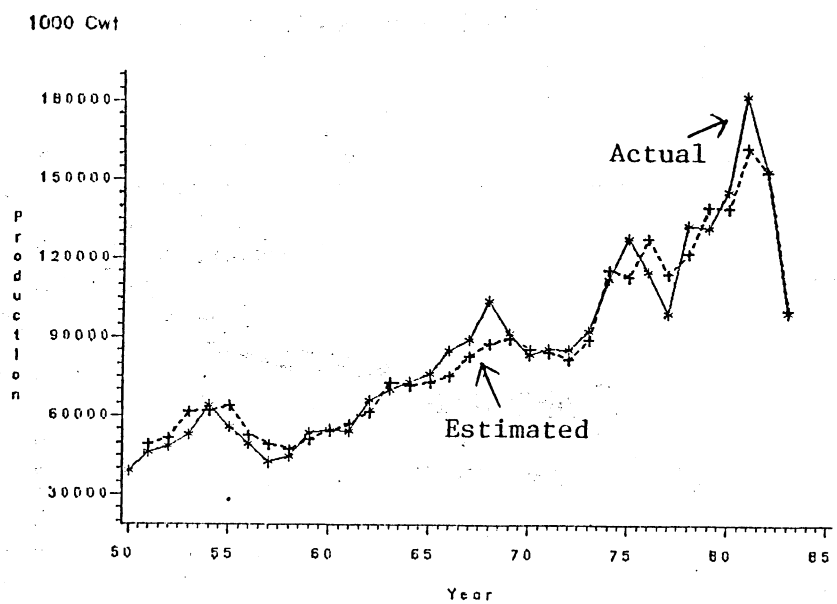

FIG. 13--United States: Production, 1950-83

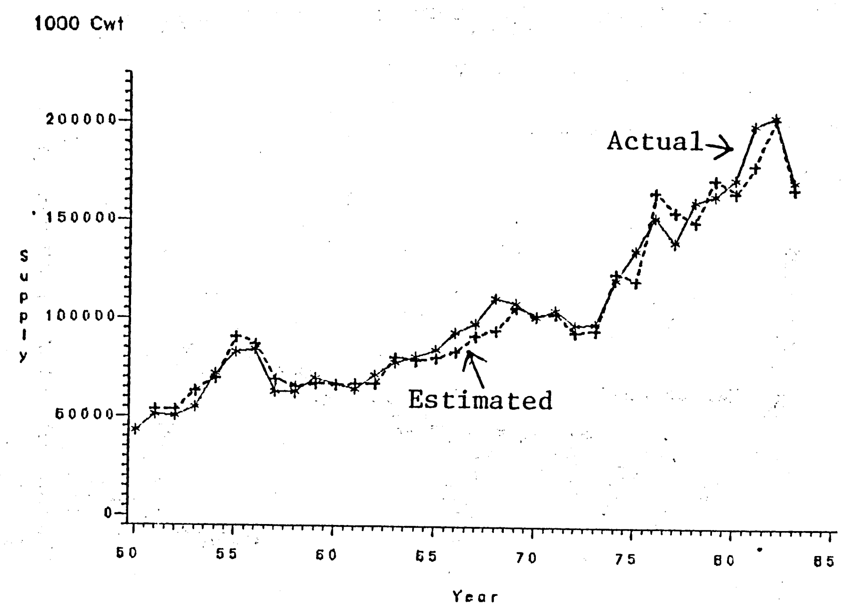

FIG. 14--United States: Supply, 1950-83

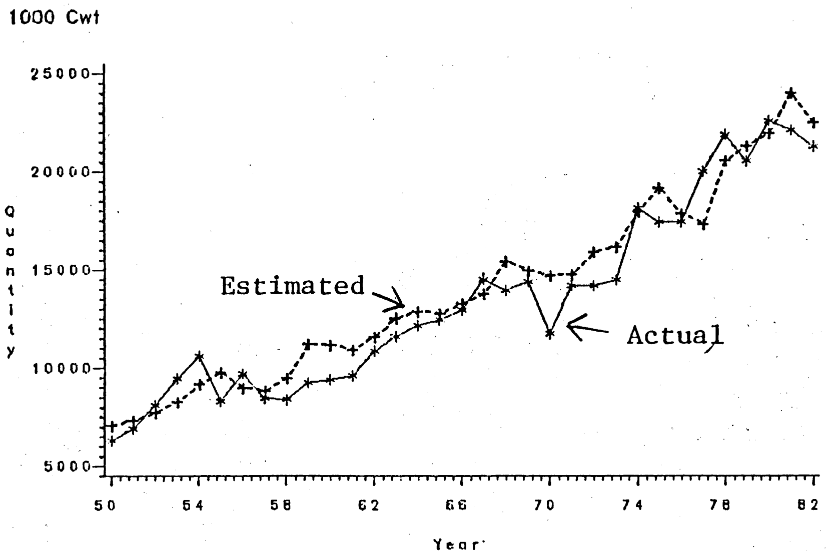

FIG. 15--Feed demand, actual and estimated, 1950-82

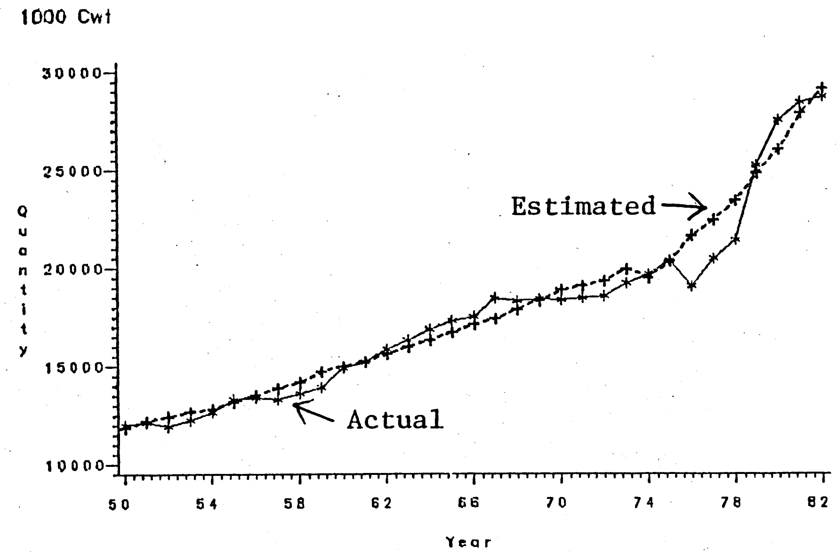

FIG. 16--Food demand, actual and estimated, 1950-82

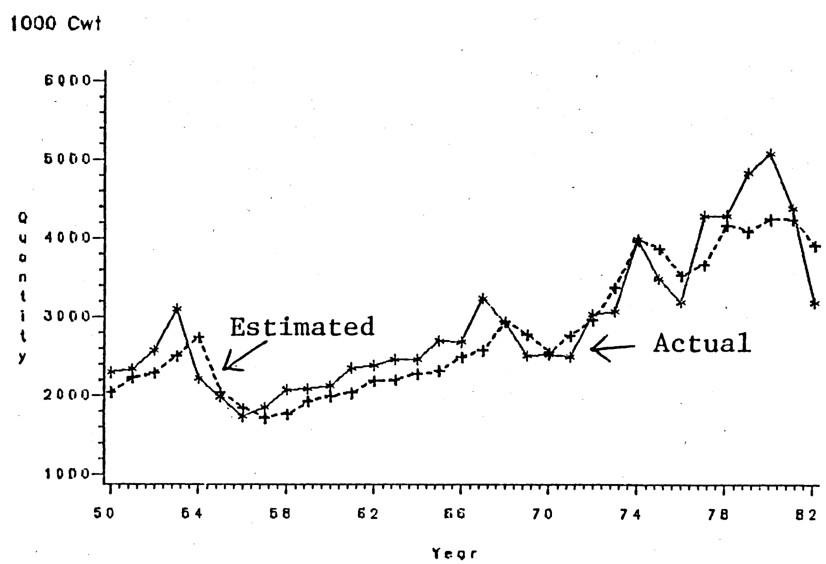

FIG. 17--Seed demand, actual and estimated, 1950-82

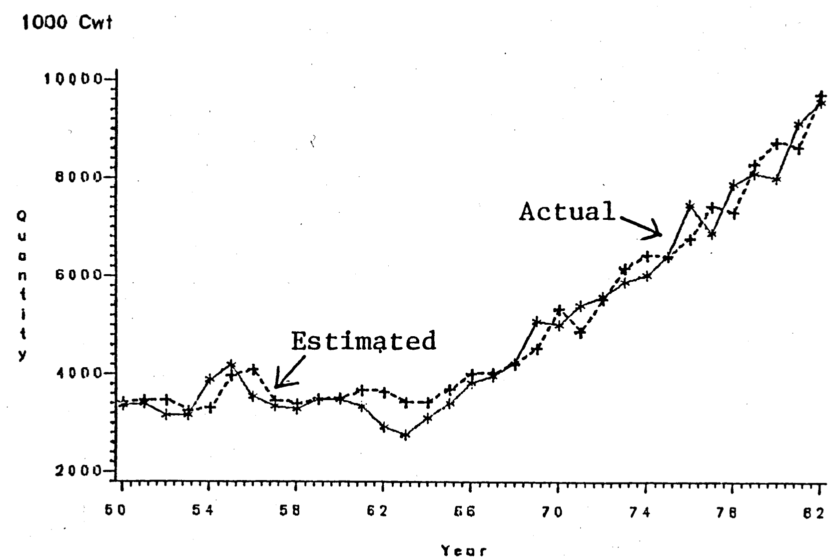

FIG. 18--Brewers demand, actual and estimated, 1950-82

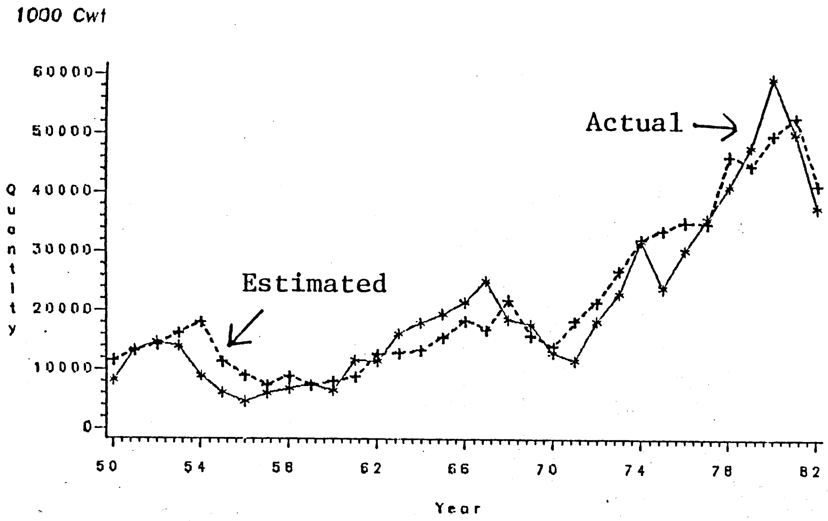

FIG. 19--Commercial exports, actual and estimated, 1950-82

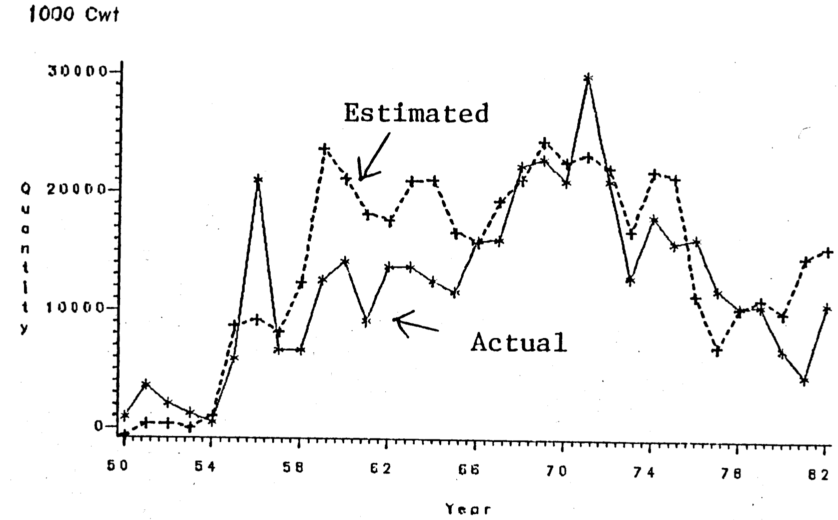

FIG. 20--Government exports, actual and estimated, 1950-82

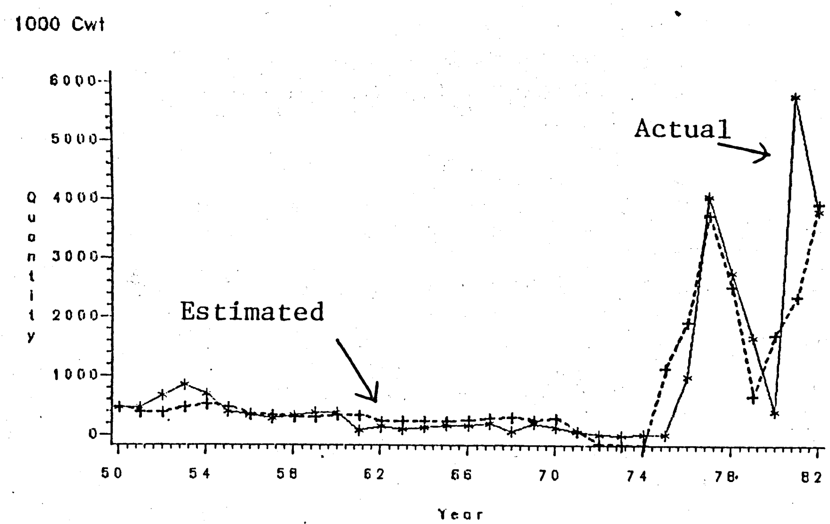

FIG. 21--Rough rice exports, actual and estimated, 1950-82

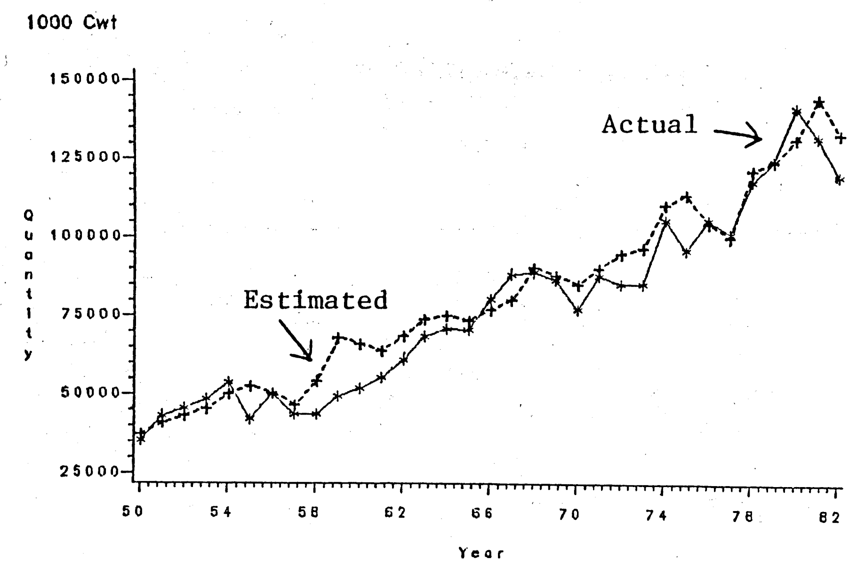

FIG. 22--Commercial stocks, actual and estimated, 1950-82

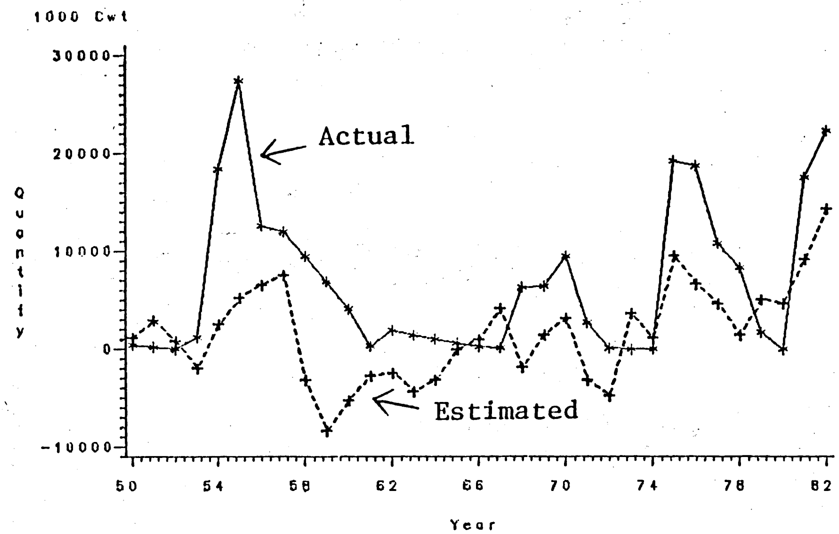

FIG. 23--Government stocks, actual and estimated, 1950-82

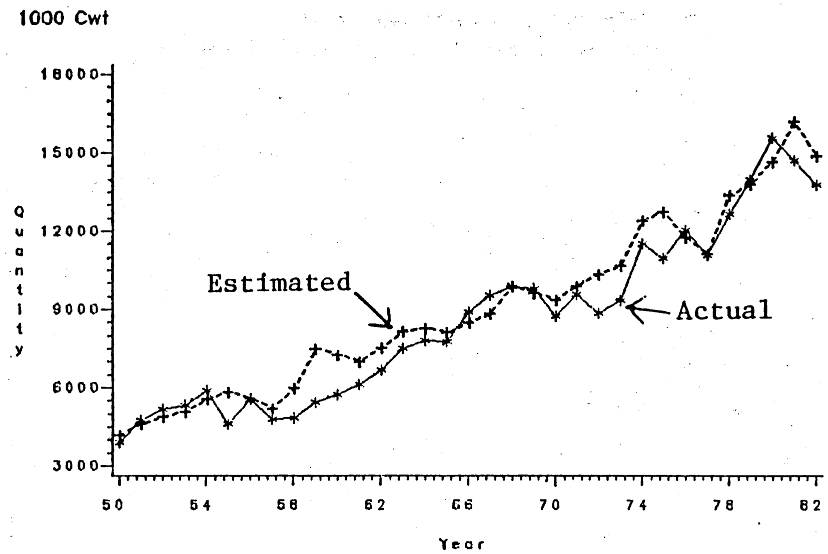

FIG. 24--Total utilization, actual and estimated, 1950-82

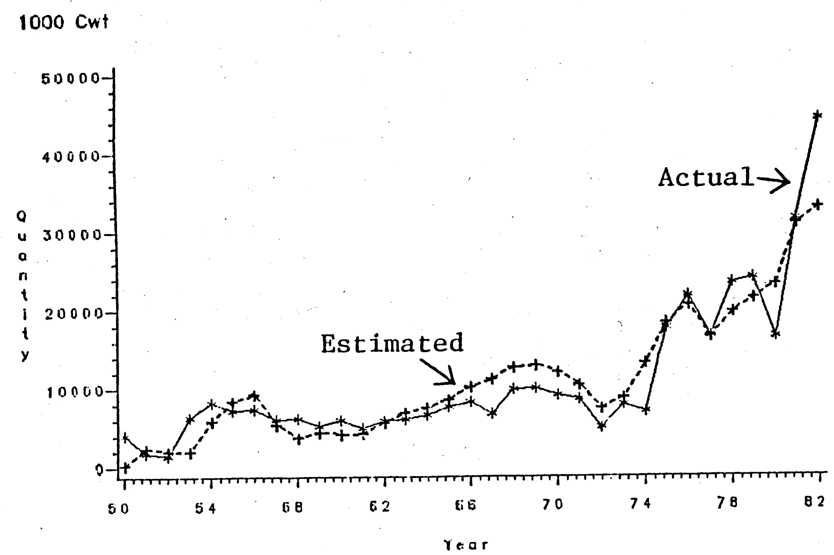

FIG. 25--Quantity of hulls, actual and estimated, 1950-82

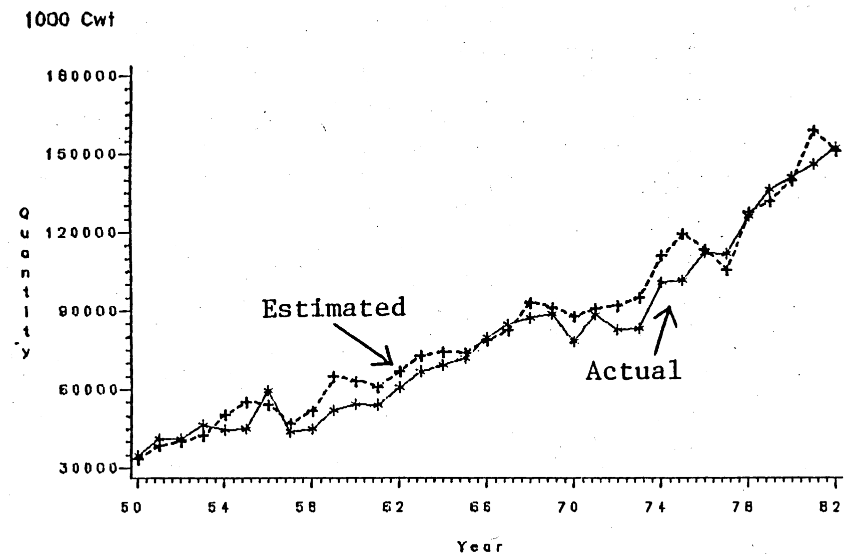

FIG. 26--Rough rice milled, actual and estimated, 1950-82

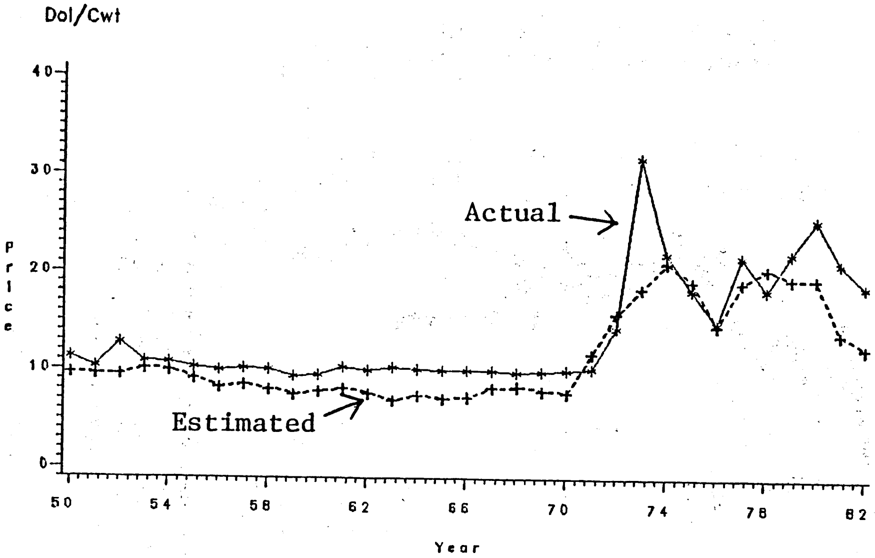

FIG. 27--U.S. mill price, actual and estimated, 1950-82

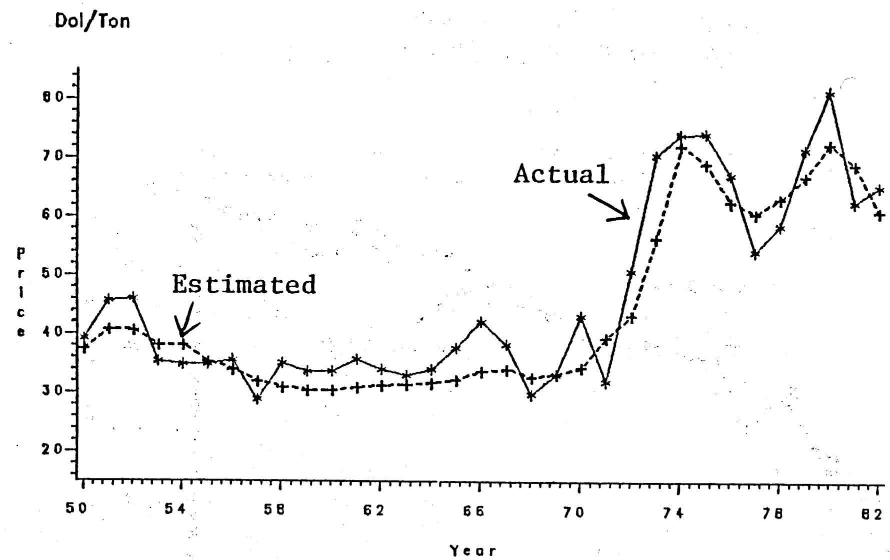

FIG. 28--U.S. bran price, actual and estimated, 1950-82

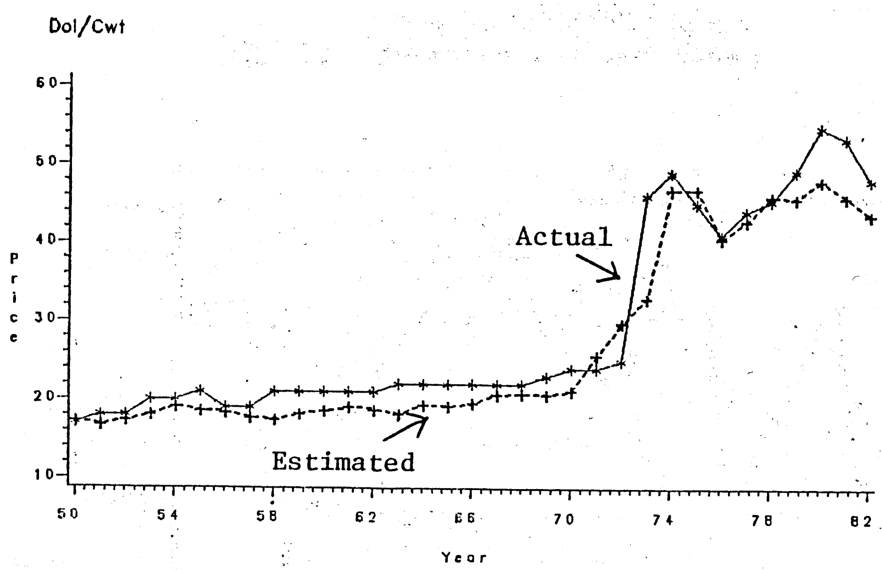

FIG. 29--U.S. retail price, actual and estimated, 1950-82

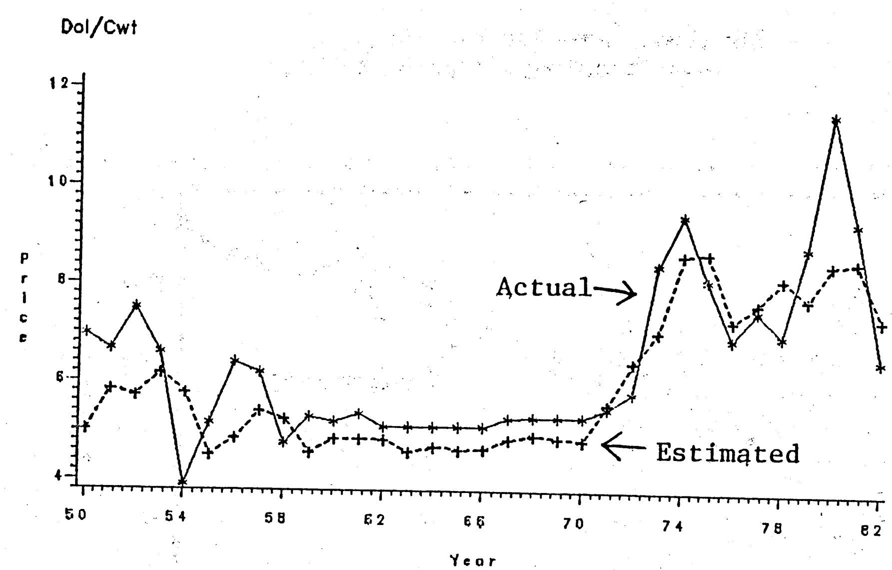

FIG. 30--U.S. brewers price, actual and estimated, 1950-82

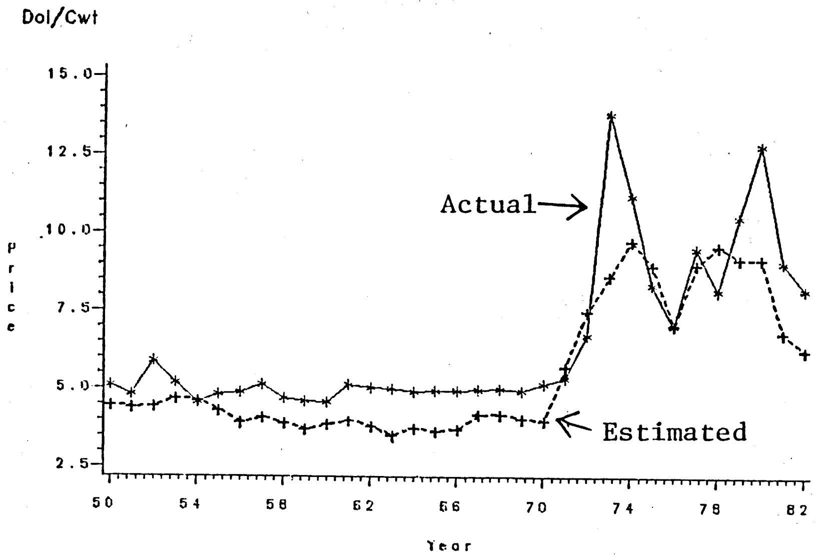

FIG. 31--U.S. farm price, actual and estimated, 1950-82

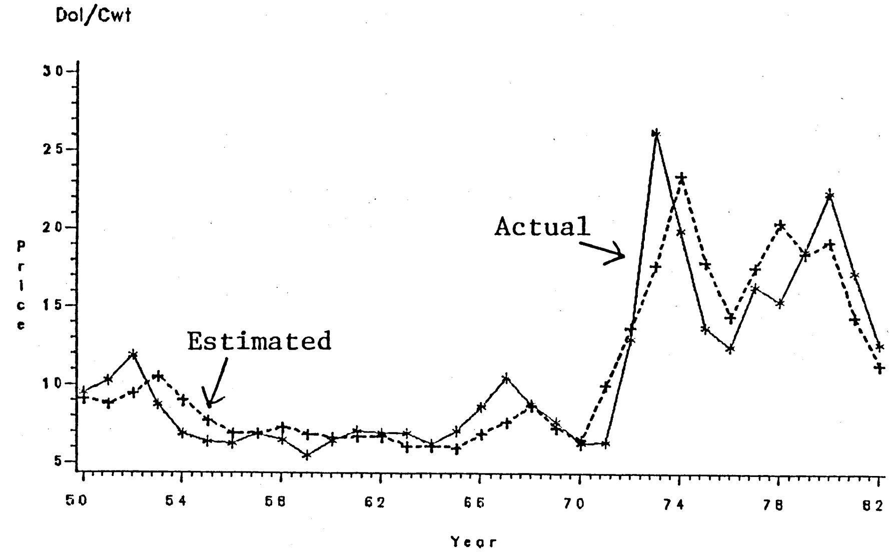

FIG. 32--Thailand price, actual and estimated, 1950-82

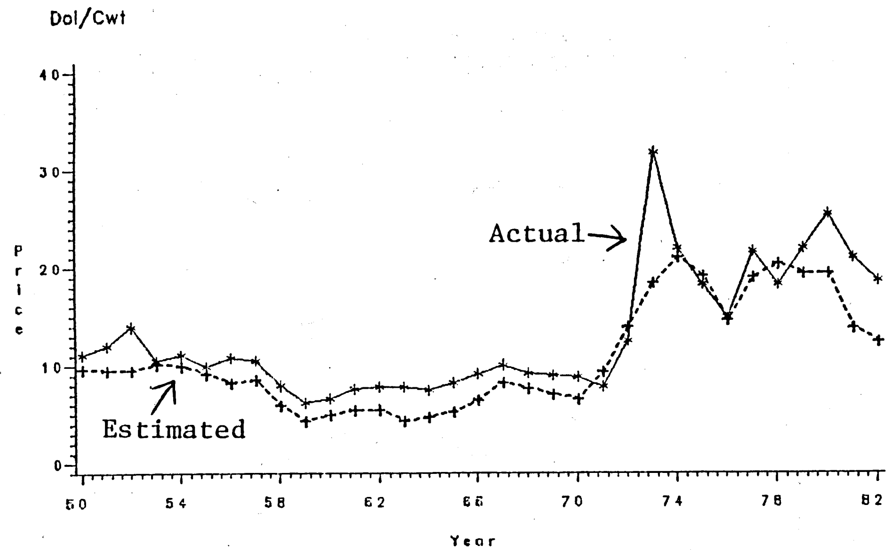

FIG. 33--U.S. export price, actual and estimated, 1950-82

ELASTICITIES AND MULTIPLIERS

Both elasticities and multipliers were calculated using 1982 data. Estimated elasticities by other researchers are also presented in this section.

Elasticities

Production and demand elasticity calculated with the structural model for 1982 are presented in tables 3 and 4. Elasticities were computed at the price level in the market that the structural equation represents.

Area

The short run elasticity of planted acreage with respect to effective farm price deflated by cost of production ranged from a low of 0.09 in Arkansas and Mississippi to a high of 0.18 in California. Using each State's share of acreage as weights, the estimated elasticity of U.S. acreage with respect to lagged farm price was 0.13 for 1982. That is, a 0.13-percent change in acreage was associated with a 1-percent change in the deflated effective farm price in the same direction. Kincannon, using equations based on 1923-1940 and 1948-1954 data, estimated elasticity of U.S. rice acreage with respect to lagged farm price, deflated by the index of prices paid, at 0.33 for 1954. He found also that yield during the same period was not appreciably affected by lagged, deflated farm price. The research reported here also indicates no farm price-yield relationship.

Yield

Although yield is not directly affected by price changes, the acreage changes in response to price changes do affect yields. The elasticity of average yield with respect to harvested acreage ranged from 0 in three of the States to -0.35 in Arkansas. Again, using State shares of the acreage as weights, the estimated elasticity for U.S average yield with respect to acreage harvested is -0.16.

Table 3--Estimated rice supply elasticities, 1982

State	$E_{A/P}$	$E_{Y/A}$	EQ/P[a]
Mississippi	0.0887	0	0.0887
Texas	.1465	-.0730	.1358
Louisiana	.1407	0	.1407
Arkansas	.0944	-.3456	.0618
California	.1843	0	.1843
United States[b]	.1254	-.1559	.1101

[a] $E_{Q/P} = E_{A/P}\ (1 + E_{Y/A})$

[b] Weighted by 1982 State acreage.

Production

The short run elasticity of production with respect to deflated effective farm price is a combination of the direct effect of acreage changes in response to price changes and yield changes in response to acreage changes. The estimated production elasticities with respect to the deflated effective farm price for 1982 ranged from 0.06 in Arkansas to 0.18 in California. The weighted average elasticity for the United States was 0.11. That is, a 1-percent change in price will result in a 0.11-percent average change in production in the same direction.

Domestic Feed Demand

The elasticity of domestic rice feed demand with respect to the price of rice bran was estimated to be -0.05 in 1982. That is, a 0.05-percent change in rice milled feed use was associated with a 1-percent change in the opposite direction of the price of rice bran. Rice millfeed, a relatively small portion of the total feed market and commanding very few alternative uses, would be expected to have a low response to price change. Grant and Leath found the identical elasticity in 1975 for this outlet. The cross-elasticity between rice millfeed use and the index of feed grain prices at 0.08 indicates very little effect on rice millfeed use relative to a change in feed grain prices and the very minor role rice millfeed plays in the total feed picture. There was very little change in this elasticity from the earlier study by Grant and Leath.

Domestic Food Demand

The elasticity of per capita domestic food demand with respect to the retail rice price was at -0.18 for 1982. That is, a 0.18-percent change in per capita food demand of rice was associated with a 1-percent change in the opposite direction in the retail price. With this condition, changes in the retail rice price had little effect on direct food use of rice.

Several researchers have estimated the elasticity of total U.S. domestic demand with respect to farm price for various time periods as: -0.07 (Grant and Leath, 1975); -0.04 (Brandow, 1955-1957); -0.56 (Mehren and Thuroczy,

Table 4--Estimated demand elasticities, 1982

Endogenous variable	PR_t	PBR_t	PB_t	PF_t	PE_t	PT_t	YI_t	PC_t	PI_t	QEG_t	SDR_t	QCG_t
QFE_t		-0.05*							0.08*			
QSE_t				0.20*								
$(QFD/POP)_t$	-0.18*						0.60*					
$(QB/POP)_t$			-0.09*				0.19*	0.09*				
QEC_t					-0.68*	0.68*				-0.16*	0.92*	
QEG_t					-0.53*							
QER_t				-0.07							0.07	
QCP_t				-0.11*								0.07*
QCG_t				-0.60*	1.93*	-1.93*						
QWE_t					-3.16*	-1.93*						

* = Regression coefficient significant at 10-percent level.

1952). All these estimates of demand elasticity are relatively low (inelastic), i.e., price changes have little impact on quantity demanded for food.

The income elasticity of per capita domestic demand for rice as a food was estimated to be 0.6 in 1982. That is, a 0.6-percent change in per capita food demand for rice was associated with a 1-percent change in the same direction in the index of per capita income. This compares with estimates of elasticity of total domestic use with respect to income of 0.23 for 1975 by Grant and Leath, 0.61 for 1966 by Grant and Moore, 0.46 for 1954 by Kincannon, and 0.99 for 1952 by Mehren and Thuroczy. The decline in income elasticity over time reversed between 1975 and 1982. The impact of rising incomes on per capita direct food use of rice was of diminishing magnitude up to 1975, but in 1982 is near that found by Grant and Moore and Kincannon.

Domestic Brewer Demand

Prices for brewers rice and corn tend to move together creating estimation problems when both are included as separate variables in the equation. A ratio between brewers price and corn price was used. This assumes that a 10-percent increase in corn price has the same effect as a 10-percent decrease in brewers price. Thus, the elasticity of demand for brewers rice with respect to brewers price at a -0.09 is the same, except for the sign, as for the cross-elasticity with respect to corn price. The income elasticity at 0.19 is less than that for direct food demand and slightly larger than that found by Grant and Leath. No other estimates of these elasticities by other researchers are available.

U.S. Export Demand

U.S. exports were grouped into three categories for this study, commercial milled rice, Government milled rice, and rough rice. Equations were estimated for each category.

The U.S. milled rice commercial export elasticity with respect to the U.S. export price at -0.68 is slightly larger than the U.S. milled rice Government export elasticity with respect to the same price (-0.53). *A priori* expectations point to Government exports being more responsive to price changes than commercial exports.

The cross-elasticity of U.S. commercial milled exports to U.S. Government exports was -0.16 in 1982. The degree of substitution of P.L.-480 rice for commercial export sales is relatively low. Differentiated markets, quality of product demand, and credit terms limit substitution between these markets.

Rough rice exports were not siginificantly affected by the U.S. farm price. The farm price variable in the rough rice export equation had the correct sign. However, reliance upon this elasticity should be viewed with caution.

The elasticity of demand for world rice exports with respect to the U.S. export price was at -3.16 in 1982. Grant and Moore estimated the world export elasticity with respect to the U.S. average export value at -1.56 and the partial elasticity of U.S. exports to the same price at -8.05 in 1966. The estimated 1982 elasticity for total world exports (-3.16) is greater than that for U.S. commercial exports (-0.68). In a purely competive market, the elasticity for the United States should be greater than that for the total world export demand. In the real world, world rice markets are not purely competitive. The U.S. commercial rice exports are moving into differentiated markets with a differentiated product.

The shift in U.S. policy from a fixed to a floating exchange rate has impacted U.S. rice exports. Earlier studies did not include a measure for the changing value of the U.S. dollar in relation to other currencies. The elasticity of U.S. exports to the dollar to Standard Drawing Rights Ratio (SDR) was at 0.92 for QEC in 1982. As SDR increases, commercial exports (QEG) increase. A strong dollar has the opposite effect.

U.S. Carryover Demand

U.S. carryover was grouped into two categories for this analysis: that in private hands and that held by the Government. During 1950-1982 the private sector of the U.S. rice industry carried over enough rice to meet market and pipeline demands. Excess stocks were usually channeled into Commodity Credit Corporation (CCC) stocks. For this reason, the elasticity of demand for private carryover with respect to U.S. farm price of rice would be expected to be much lower than the elasticity of demand for Government carryover with respect to the same price series. They were -0.11 for private carryover and -0.6 for Government carryover.

World Demand

The coefficients for per capita world rice demand on U.S. and Thailand export prices were not significantly different from 0 at the 10-percent level. Thus, elasticity estimates from the revised model for 1982 were not valid. However, Grant and Leath found the elasticity of per capita world rice demand with respect to the U.S. export price was -0.74 in 1975 and, with respect to Thailand export price, was at -0.51 in 1975. Mehren and Thuroczy estimated the elasticity of world production (a rough estimate of consumption) with respect to the price of rice in London at -0.225 for 1938. Their estimate was based on 1922-1938 data. Grant and Moore, using equations estimated for 1934-1966 data minus the two periods 1941-1945 and 1954-1958, estimated the elasticity of per capita world demand with respect to the U.S. export value at -0.61 for 1966. World War II interrupted world rice production, trade, and demand. Although the conflict ended in 1945, the impact lasted much longer. For example, the low elasticity for 1938 had increased nearly threefold by 1966, but little change has occurred since then.

Multipliers 4/

Changes outside the U.S. rice market set off a chain reaction of adjustments in rice demands, prices, and stocks. Multipliers measure the effect of these changes on demands, prices, and ending stocks, which is the quantity and direction of change in an endogenous variable with respect to a one-unit change in an exogenous variable. Multipliers are the coefficients of the

4/ Multipliers for the supply model are equivalent to the coefficients in equations 1 through 15.

reduced form of the model, which defines endogenous variables in terms of the exogenous variables. However, the derivation of the reduced form equations was complicated by the presence of nonlinear endogenous variables. Due to the nonlinearity of the model, the reduced form cannot generally be determined exactly, but the system can still be solved by the Newton or Gauss-Seidel solution methods (Bianchi and others). Impact multipliers may be defined as partial derivatives of the conditional expectation of each current endogenous variable regarding each current exogenous variable, all other exogenous variables being held constant. Multipliers were obtained using numerical derivatives and the Newton method to solve the system of simultaneous equations (Goldberger). In nonlinear models, multipliers are a function of the exogenous variables. Thus, those presented in table 5 are for the 1982 levels for the exogenous variables.

An increase in rice demand in a specific outlet, resulting from a change in an exogenous variable by a given amount, does not necessarily mean an increase in total rice demand by the same amount. For example, a 0.1 increase in the dollar to Standard Drawing Right Ratio (SDR) raises commercial exports (QEC) by 4.2 million hundredweight. However, total disappearance increased only 3.1 million hundredweight as declines in food (QFD), brewer (QB), and Government exports and rough rice (QEG and QER) partially offset the increases in commercial (QEC) and other uses (QH, QFE, QSE). The rise in SDR increases rice prices. Most of the exogeneous variables produce a similarly interrelated effect.

CONCLUDING REMARKS

Detailed modeling of any complex industry presents problems. Refinements in the number of demand outlets requires more variables and equations creating estimation problems, i.e. adding observations to have enough degrees of freedom to estimate the model, but the observations added may not have much bearing on current conditions. An alternative approach is to use a limited number of more current observations and estimate only single equations for each outlet, but with possible simultaneity bias. We chose to add observations and use three-stage least squares. The model tracks through time reasonably well.

A second area of concern deals with the low elasticity of demand for U.S. commercial exports (-0.68) but a larger elasticity for total world export (-3.16). This implies that the industry has developed U.S. commercial rice export markets to the extent U.S. rice is differentiated from rice originating from Thailand or other countries. How long this differentiation will hold with the current price (1984) differences between U.S. rice and rice from other exporters is unknown. Past history cannot help us here.

A third area of concern deals with the reversal in the impact of income on food demand. The increase in income elasticity over that found by Grant and Leath may be due to a shift in ethnic populations in the seventies rather than increases in income. It may be partly due to shifts in consumer habits. Determining the true cause is difficult with the limited time and resources available for this report.

However, even with these problems, the model tracks through time well enough to make the model usuable. The final test will depend upon how well the equations project behavior after the estimation period.

Table 5--Effect of changes in exogenous variables on endogenous variables, demand, 1982

Exogenous variables	Endogenous variables						
	QFE	PBR	QM	QSE	PF	QDF	PR
PI	3.51223	0.1901	4.03195	0	0	0	0
R	0	0	0	497.814	0	0	0
PC	52.4528	0	482.991	0	0	0	0
COP	0	0	0	-2.14566	0	0	0
ACRE	0	0	0	0.5093	0	0	0
T	-2.26834	0	-20.8871	45.8317	0.01949	-15.9264	0.1633
YI	10.3145	0	94.9768	0	0	64.988	0
D59	43.8999	0	404.234	0	0	308.229	0
POP	2.3869	0	21.9788	0	0	12.5951	0
$(QB/POP)_{t-1}$	213.648	0	1967.29	0	0	0	0
POL	0	0	0	0	0	0	0
SDR	2719.22	45.5503	29797.7	1486.3	19.0947	-4153.63	42.5889
QER_{t-1}	0	0	0	0	0	0	0
PG	-298.495	1.09465	-2634.21	35.7185	0.458878	-99.8191	1.02349
QS	0.0419975	0	0.386718	0	0	0	0
PS	268.533	-0.0748533	2464.86	-2.44246	-0.0313785	6.82571	-0.0699869
GP1	0	0	0	0	0	0	0
GP	0	0	0	0	0	0	0
QH_{t-1}	0.0296674	0	0.27318	0	0	0	0
PR_{t-1}	-7.42731	0	-68.3914	0	0	-52.1484	0.5347
PB_{t-1}	-7.56214	0	-69.633	0	0	0	0
LU	-2.49125	0.1922	-2.85989	0	0	0	0
(QWR/POPW)	-10.5505	0.029666	-94.051	0.968	0.012436	-2.70518	0.0277373
QWE	0.344477	-0.508064	-49.9072	-16.5781	-0.212981	46.3293	-0.475034
(QWW/POPW)	12.0365	-0.0429356	106.348	-1.40099	-0.0179986	3.91521	-0.0401443
GEXP	2.25392	0	20.7543	0	0	0	0
PT_{t-1}	84.2941	0	776.189	0	0	0	0
IQP	0.0753307	0	0.693652	0	0	0	0
GP2	423.803	0	3902.42	0	0	0	0

continued--

Table 5--Effect of changes in exogenous variables on endogenous variables, demand, 1982 (continued)

Exogenous variables	Endogenous variables					
	PE	PT	QEG	QER	QCP	QCG
PI	0	0	0	0	0	0
R	0	0	0	0	0	0
PC	0	0	0	0	0	0
COP	0	0	0	0	0	0
ACRE	0	0	0	0	0	0
T	0	0	0	-0.667702	-15.9112	-32.0402
YI	0	0	0	0	0	0
D59	0	0	0	0	0	0
POP	0	0	0	0	0	0
$(QB/POP)_{t-1}$	0	0	0	0	0	0
POL	0	0	0	12.0403	0	0
SDR	44.6659	42.1532	-13681.5	-449.034	-16148.9	-35681.9
QER_{t-1}	0	0	0	0.2988	0	0
PG	1.0734	0	-627.578	-15.7206	619.991	3243.5
QS	0	0	0.05448	0	0.1868	0
PS	-1.0734	0	629.122	1.07499	-327.906	-2655.33
GP1	0	0	0	0	-1077.63	-8251.4
GP	0	0	0	0	-946.064	-7243.98
QH_{t-1}	0	0	0	0	0	0
PR_{t-1}	0	0	0	0	0	0
PB_{t-1}	0	0	0	0	0	0
LU	0	0	0	0	0	0
(QWR/POPW)	0.02909	-0.012586	-8.91047	-0.426041	3.994	87.875
QWE	-0.4982	-0.554	152.602	7.29644	210.766	632.621
(QWW/POPW)	-0.042102	0.00432	12.8961	0.616609	-0.775559	-88.8587
GEXP	0	0	36.9825	0	-0.0359535	-0.275295
PT_{t-1}	0	0.3596	0	0	-130.484	-999.113
IQP	0	0	0	-12.8969	-0.116609	-0.892872
GP2	0	0	7024.95	0	-0.116609	-0.892872

continued--

Table 5-- Effect of changes in exogenous variables on endogenous variables, demand, 1982 (continued)

Exogenous variables	Endogenous variables					
	QB	PB	QEC	QH	PW	QD
PI	0	0	0	0.519719	0	4.03195
R	0	0	0	0	0	497.814
PC	368.281	0	0	62.2575	0	482.991
COP	0	0	0	0	0	-2.14566
ACRE	0	0	0	0	0	0.5093
T	0	0	0	-2.69234	0	-23.6745
YI	7.43184	0	0	12.2425	0	94.9768
D59	0	0	0	52.1058	0	404.234
POP	4.16381	0	0	2.83307	0	21.9788
$(QB/POP)_{t-1}$	1500.06	0	0	253.584	0	1967.29
POL	0	0	0	0	0	12.0403
SDR	-1126.66	8.51332	42199.3	3840.92	44.6659	-20995.9
QER_{t-1}	0	0	0	0	0	0.2988
PG	-27.0756	0.20459	-1241.69	-339.55	1.0734	1249.28
QS	0	0	0.240392	0.0498479	0	0.573518
PS	1.85145	-0.01399	1240.8	317.72	-0.0734	-519.749
GP1	0	0	0	0	0	-9329.03
GP	0	0	0	0	0	-8190.04
QH_{t-1}	0	0	0	0.243513	0	0.27318
PR_{t-1}	0	0	0	-8.81565	0	-68.3914
PB1	-53.0951	0.4012	0	-8.97569	0	-69.633
LU	0	0	0	-0.368639	0	-2.85989
(QWR/POPW)	-0.733771	0.00554455	-59.0279	-12.1232	0.02909	-1.64004
QWE	12.5667	-0.0949569	-255.317	-6.43304	-0.4982	784.198
(QWW/POPW)	1.06199	-0.00802464	62.7298	13.7083	-0.042102	15.9293
GEXP	0	0	-21.1573	2.67523	0	20.4431
PT_{t-1}	0	0	591.844	100.051	0	-353.409
IQP	0	0	0.52891	0.0894118	0	-13.2127
GP2	0	0	-4049.35	503.022	0	3901.41

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Appendix table 1--Data for demand section

T	QFE	QSE	QB	QEC	QEG	QER	QCP	QCG	QH	QM	QD	PW	PR
1950	3892	2295	3367	8139	897	469	4124	395	6290	35400	42221	11.25	17.00
1951	4746	2340	3395	13350	3583	471	1813	227	6907	43200	48812	10.35	18.00
1952	5188	2575	3165	14657	2065	672	1507	8	8089	45700	49983	12.85	18.00
1953	5342	3103	3170	13926	1272	847	6346	1200	9447	48500	56470	10.90	20.00
1954	5892	2222	3882	8928	463	706	8255	18445	10624	53600	72255	10.75	20.00
1955	4620	1988	4176	6157	5899	401	7244	27374	8312	42200	79587	10.30	21.00
1956	5536	1735	3549	4638	20999	346	7401	12555	9696	50400	80081	10.05	19.00
1957	4804	1849	3348	6063	6691	280	6157	12012	8430	43700	62843	10.20	19.00
1958	4840	2071	3278	6867	6661	327	6214	9455	8424	43700	61236	10.10	21.00
1959	5446	2092	3488	7726	12601	385	5277	6867	9236	49500	67634	9.45	21.00
1960	5726	2119	3482	6459	14184	379	5948	4132	9392	52000	65936	9.55	21.00
1961	6094	2350	3338	11701	09134	79	5015	314	9605	55400	63767	10.25	21.00
1962	6678	2383	2911	11424	13766	143	5870	1860	10833	60800	71163	10.00	21.00
1963	7508	2458	2767	16232	13788	105	6104	1435	11610	68300	78165	10.30	22.00
1964	7808	2464	3095	17934	12555	126	6633	1044	12125	71000	81276	10.15	22.00
1965	7766	2702	3391	19487	11648	169	7618	621	12451	70600	82755	10.05	22.00
1966	8876	2688	3828	21471	15961	160	8279	232	12952	80200	91882	10.00	22.00
1967	9520	3235	3952	25133	16082	206	6698	86	14516	88100	97612	10.05	22.00
1968	9880	2932	4215	18708	22292	67	9886	6325	13966	89100	107998	9.80	22.00
1969	9800	2510	5089	17863	22957	193	10029	6417	14395	86500	106247	9.90	23.00
1970	8720	2531	5000	13052	21044	140	9167	9467	11736	77300	99271	10.05	24.00
1971	9580	2500	5407	11624	29979	62	8687	2747	14196	87900	103379	10.20	24.00
1972	8840	3032	5585	18324	21100	16	4991	148	14224	85400	94547	14.45	25.00
1973	9340	3069	5875	22934	12911	6	7842	0	14511	85400	95277	31.75	46.00
1974	11520	4003	6015	31949	18065	10	7053	4	18141	105600	117358	22.05	49.00
1975	10940	3500	6391	23941	15842	10	17661	19214	17438	95800	136185	18.35	45.00
1976	12037	3200	7450	30341	16216	994	21780	18721	17441	105685	150380	14.95	41.00
1977	11045	4300	6885	35718	11931	4059	16626	10772	19998	101219	136968	21.70	44.00
1978	12654	4300	7872	41129	10476	2773	23318	8300	21880	117961	156652	18.30	45.40
1979	13955	4850	8093	47831	10621	1670	23979	1700	20565	124340	156489	22.05	49.10
1980	15564	5100	8001	59485	6934	414	16493	0	22591	141192	163199	25.55	54.80
1981	14705	4400	9123	50222	4683	5785	31487	17500	22143	131922	191094	21.15	53.40
1982	13757	3200	9560	37713	10786	3812	44312	22320	21304	119536	193180	18.70	48.00

continued--

Appendix table 1--Data for demand section (continued)

T	PBR	PB	PF	PE	PT	QFD	SDR	PI	D59	QP	QER_{t-1}	QS	GP1	GP
1950	39.15	6.95	5.09	11.10	9.49	12353	1.00	111	0	38820	696	43100	1	0
1951	45.75	6.65	4.82	12.00	10.23	11980	1.00	130	0	46089	469	51100	1	0
1952	46.00	7.50	5.87	14.00	11.87	12057	1.00	134	0	48193	471	50500	1	0
1953	35.35	6.60	5.19	10.50	8.78	11817	1.00	118	0	52834	672	54800	1	0
1954	34.80	3.90	4.57	11.10	6.90	12838	1.00	117	0	64193	847	71800	1	0
1955	34.80	5.15	4.81	9.90	6.40	13416	1.00	105	0	55902	706	82800	1	0
1956	35.50	6.40	4.86	10.85	6.22	13626	1.00	105	0	49459	401	84500	1	0
1957	28.90	6.20	5.11	10.50	6.87	13209	1.00	95	0	42935	346	63100	1	0
1958	35.05	4.75	4.68	8.02	6.47	13099	1.00	89	0	44760	280	63100	0	1
1959	33.60	5.30	4.59	6.22	5.53	14516	1.00	90	1	53647	327	70100	0	1
1960	33.60	5.20	4.55	6.65	6.43	14115	1.00	87	1	54591	385	67000	0	1
1961	35.60	5.35	5.14	7.61	7.04	16137	1.00	87	1	54198	379	64700	0	1
1962	34.05	5.10	5.04	7.79	6.93	15295	1.00	89	1	66045	79	71400	0	1
1963	33.00	5.10	5.01	7.77	6.91	16158	1.00	95	1	70269	143	78000	0	1
1964	33.95	5.10	4.90	7.46	6.23	17492	1.00	96	1	73166	105	81200	0	1
1965	37.70	5.10	4.93	8.21	7.09	16902	1.00	100	1	76281	126	84600	0	1
1966	42.10	5.10	4.95	9.14	8.61	17435	1.00	104	1	85020	169	93300	0	1
1967	38.25	5.28	4.97	10.00	10.48	18184	1.00	100	1	89379	160	97900	0	1
1968	29.85	5.30	5.00	9.16	8.81	19728	1.00	91	1	104142	206	110900	0	1
1969	33.10	5.30	4.95	8.97	7.67	16994	1.00	96	1	91904	67	108300	0	1
1970	43.20	5.30	5.17	8.84	6.33	18414	1.00	101	1	83805	193	101700	0	1
1971	31.95	5.48	5.34	7.85	6.39	18597	1.09	106	1	85768	140	105000	0	1
1972	50.90	5.80	6.73	12.54	12.97	18287	1.18	105	1	85439	62	97400	0	1
1973	70.50	8.43	13.80	31.75	26.25	18789	1.20	162	1	92765	16	98100	0	0
1974	74.01	9.43	11.20	22.05	19.92	20598	1.22	242	1	112386	6	120300	0	0
1975	74.13	8.13	8.35	18.35	13.74	19569	1.16	230	1	128437	10	135500	0	0
1976	67.10	6.92	7.02	14.95	12.47	20974	1.16	218	1	115648	10	152600	0	0
1977	54.13	7.50	9.49	21.70	16.37	16557	1.24	181	1	99223	994	139800	0	0
1978	58.51	7.00	8.16	18.30	15.42	23763	1.30	184	1	133170	4059	160600	0	0
1979	71.50	8.80	10.50	22.05	18.60	23868	1.29	207	1	131947	2773	163600	0	0
1980	81.29	11.53	12.80	25.55	22.36	27957	1.29	239	1	146150	1670	172100	0	0
1981	62.50	9.31	9.05	21.15	17.24	30702	1.13	255	1	182742	414	199600	0	0
1982	65.14	6.51	8.18	18.70	12.70	26466	1.09	218	1	154216	5785	203800	0	0

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Appendix table 1--Data for demand section (continued)

T	QH_{t-1}	PR_{t-1}	R	YI	POP	PC	$(QB/POP)_{t-1}$	PG	PS	LU	PB_{t-1}	QWR/POPW	QWE	QWW/POPW	PT_{t-1}
1950	7173	18	1.00	35.3	151.7	1.52	2.19	4.56	0	76.6	4.85	67.40	4.10	67.4	8.37
1951	6290	17	1.00	38.0	154.3	1.66	2.21	5.00	0	76.3	6.95	68.40	5.00	67.9	9.49
1952	6907	18	1.00	39.2	157.0	1.52	2.19	5.04	0	72.7	6.65	71.80	5.10	79.6	10.23
1953	8089	18	1.00	41.0	159.6	1.48	2.01	4.84	0	72.0	7.50	76.50	4.40	77.6	11.87
1954	9447	20	1.00	41.0	162.4	1.43	1.98	4.92	0	73.7	6.60	73.10	4.60	72.9	8.78
1955	10624	20	0.66	43.1	165.3	1.35	2.38	4.66	0	74.5	3.90	77.50	5.50	75.9	6.90
1956	8312	21	0.57	45.1	168.2	1.29	2.52	4.57	0	72.9	5.15	79.70	6.60	81.7	6.40
1957	9696	19	0.51	46.7	171.3	1.11	2.10	4.72	0	71.4	6.40	76.70	6.30	78.3	6.22
1958	8430	19	0.51	47.5	174.1	1.12	1.95	4.48	2.08	73.9	6.20	82.50	6.60	88.1	6.87
1959	8424	21	0.57	49.3	177.9	1.05	1.88	4.38	3.22	73.2	4.75	77.90	6.70	82.9	6.47
1960	9236	21	0.57	50.4	180.8	1.00	1.96	4.42	2.90	73.8	5.30	77.50	6.40	80.0	5.53
1961	9392	21	0.57	51.6	183.7	1.10	1.93	4.71	2.64	74.8	5.20	76.19	6.50	74.2	6.43
1962	9605	21	0.63	53.7	186.6	1.12	1.82	4.71	2.21	76.7	5.35	77.18	7.10	82.2	7.04
1963	10833	21	0.63	55.5	189.3	1.11	1.56	4.71	2.53	76.0	5.10	77.82	8.00	86.4	6.93
1964	11610	22	0.64	59.5	191.9	1.17	1.46	4.71	2.69	74.3	5.10	88.02	8.00	85.0	6.91
1965	12125	22	0.64	63.4	194.4	1.16	1.61	4.50	1.84	74.4	5.10	77.86	7.60	80.2	6.23
1966	12451	22	0.70	67.7	196.6	1.24	1.75	4.50	.86	77.2	5.10	77.70	7.40	92.0	7.09
1967	12952	22	0.70	71.4	198.8	1.03	1.95	4.55	0	77.1	5.10	87.18	6.90	86.9	8.61
1968	14516	22	0.84	76.6	200.7	1.08	1.99	4.60	.64	78.4	5.28	87.34	6.80	94.3	10.48
1969	13966	22	0.76	81.7	202.7	1.16	2.10	4.72	.93	78.5	5.30	87.86	7.50	87.3	8.81
1970	14395	23	0.65	87.9	205.1	1.33	2.51	4.86	1.21	80.0	5.30	86.85	7.90	86.9	7.67
1971	11736	24	0.65	93.8	207.7	1.08	2.44	5.07	2.35	80.2	5.30	86.30	8.10	95.4	6.33
1972	14196	24	0.65	100.0	209.9	1.57	2.61	5.27	1.91	79.4	5.48	81.95	8.20	91.6	6.39
1973	14224	25	0.77	111.8	211.9	2.55	2.67	6.07	0	78.5	5.80	87.65	7.70	97.7	12.97
1974	14511	46	1.00	120.9	213.9	3.02	2.79	7.54	0	69.8	8.43	85.36	7.52	92.6	26.25
1975	18141	49	1.00	131.5	216.0	2.54	2.81	8.52	0	74.8	9.43	88.87	8.06	88.4	19.92
1976	17438	45	1.00	141.9	218.0	2.15	2.96	6.19	0	76.0	8.13	86.12	10.17	104.2	13.74
1977	17441	41	1.00	154.5	220.2	2.02	3.42	6.19	0	77.6	6.92	88.46	9.46	91.8	12.47
1978	19998	44	1.00	171.5	222.6	2.25	3.13	6.40	0	80.3	7.50	90.92	11.52	104.9	16.37
1979	21880	45	1.00	189.9	225.1	2.52	3.54	6.79	0	82.1	7.00	86.93	12.63	97.7	15.42
1980	20565	49	1.00	208.1	227.7	3.11	3.60	7.12	0	80.6	8.80	88.33	13.22	98.4	18.60
1981	22591	55	1.00	230.7	229.8	2.50	3.51	8.01	0	77.3	11.53	90.16	12.38	98.4	22.36
1982	22143	53	1.00	242.9	232.1	2.65	3.97	8.14	0	78.5	9.31	89.81	11.88	103.3	17.24

Appendix table 2--Data for supply section

T	YA	YC	YL	YM	YT	AHA	AHT	AHC	AHL	AHM
50	2322.17	3040.93	1801.22	.	2837.44	346	482	238	563	7
51	2299.42	3261.36	1853.03	2277.25	2539.32	457	569	324	619	26
52	2135.79	3065.04	2010.81	2263.22	2672.38	466	552	337	600	40
53	2494.30	3270.82	2307.88	2625.50	2851.51	494	574	425	612	51
54	2207.15	3524.72	2305.75	2694.05	2518.81	672	637	477	679	77
55	2966.51	3666.72	2554.19	2763.45	2997.13	434	480	329	526	52
56	3078.04	3927.71	2611.79	2962.60	2886.47	382	403	286	450	44
57	3170.54	4230.76	2631.75	2733.84	2823.47	332	347	226	400	31
58	3130.12	4095.69	2781.20	3024.89	2889.40	336	379	249	408	39
59	3329.37	4439.84	2976.09	3114.15	3067.76	383	417	285	453	44
60	3396.58	4693.77	2927.24	2918.92	3099.23	384	417	288	458	44
61	3512.71	4755.92	3111.12	3415.63	3257.50	384	409	290	458	44
62	3708.95	4607.84	3183.70	3437.21	3444.08	426	462	323	508	49
63	4305.48	4643.56	3436.91	4002.79	4423.88	426	459	324	508	49
64	4156.14	4696.89	3370.16	3907.34	4398.86	430	462	327	513	49
65	4297.80	4690.88	3427.61	3778.25	4453.48	434	462	327	515	50
66	4106.47	5099.61	3525.98	3948.41	4286.41	477	505	360	565	55
67	4568.48	5021.17	3659.41	4355.53	4608.43	477	508	360	565	55
68	4596.84	5397.52	3752.86	4097.90	4314.82	572	597	432	679	67
69	4438.02	5231.33	3477.56	4261.55	4132.49	548	548	389	611	60
70	4706.96	5486.10	3619.17	4031.39	4320.54	466	467	331	523	51
71	4830.69	5481.55	3818.76	4347.57	4708.45	441	468	331	522	51
72	4742.05	5750.25	3760.49	4491.63	4658.18	441	468	331	522	51
73	4884.38	5953.60	3539.58	4181.49	4431.29	533	549	401	620	62
74	4358.94	5817.64	3871.57	4408.72	4492.82	725	562	467	650	108
75	4520.92	5513.34	3854.20	3976.75	4556.99	885	548	525	658	171
76	4758.80	5707.52	3873.06	4241.86	4573.69	847	508	420	568	144
77	4594.52	5990.96	3786.10	4056.79	4494.13	837	501	308	475	111
78	4326.75	5978.89	3984.40	4250.39	4641.16	1090	558	499	587	215
79	4584.11	6253.10	3710.30	4216.81	4376.72	1020	557	522	528	207
80	4200.32	6133.29	3712.05	3961.68	4381.55	1280	586	565	607	250
81	4160.73	6887.71	4089.76	4220.68	4413.54	1540	579	560	667	337
82	4442.12	6613.98	3859.30	4066.47	4617.55	1330	474	535	598	245
83	4280.00	6995.93	3927.22	4140.26	4824.01	915	318	328	385	161

continued--

Appendix table 2--Data for supply section (continued)

T	T6C	T7M	T7A	T78T	T^2	$T^{1/2}$	T_{75}	TE	$T_{74}^{1/2}$	D83	$(FP/PF)_{t-1}$
50	69.85	78.90	79.70	83.375	2500	7.07107	0	0.0	7.07107	0	.
51	71.45	81.95	81.70	86.750	2601	7.14143	0	0.0	7.14143	0	13.0255
52	66.30	84.10	83.75	84.900	2704	7.21110	0	0.0	7.21110	0	13.7344
53	67.70	81.90	81.50	83.795	2809	7.28011	0	0.0	7.28011	0	11.6695
54	69.90	85.20	85.30	85.625	2916	7.34847	0	0.0	7.34847	0	13.4489
55	70.30	82.05	82.60	83.475	3025	7.41620	0	0.0	7.41620	0	14.9672
56	72.65	82.75	81.80	85.075	3136	7.48331	0	0.0	7.48331	0	14.0618
57	75.70	81.25	81.80	84.725	3249	7.54983	0	0.0	7.54983	0	13.8453
58	71.65	80.50	81.45	85.150	3364	7.61577	0	0.0	7.61577	0	11.5362
59	75.40	80.75	79.50	82.425	3481	7.68115	0	0.0	7.68115	0	12.8312
60	77.70	82.70	80.15	83.225	3600	7.74597	0	0.0	7.74597	0	12.8214
61	76.90	79.20	79.90	81.825	3721	7.81025	0	0.0	7.81025	0	12.7143
62	72.70	83.35	81.45	85.450	3844	7.87401	0	0.5	7.87401	0	11.3521
63	71.50	80.25	80.35	84.000	3969	7.93725	0	1.0	7.93725	0	11.2897
64	70.60	81.50	82.55	84.050	4096	8.00000	0	1.0	8.00000	0	10.3792
65	68.75	81.85	82.45	83.675	4225	8.06226	0	1.0	8.06226	0	10.7347
66	73.65	83.60	84.20	83.750	4356	8.12404	0	1.0	8.12404	0	10.7911
67	70.65	78.55	77.85	81.425	4489	8.18535	0	1.0	8.18535	0	10.6566
68	75.05	80.45	79.25	82.750	4624	8.24621	0	1.0	8.24621	0	11.0262
69	70.65	83.45	84.70	84.725	4761	8.30662	0	1.0	8.30662	0	10.7300
70	73.10	80.95	79.95	84.500	4900	8.36660	0	1.0	8.36660	0	10.6162
71	71.35	81.15	80.75	81.600	5041	8.42615	0	1.0	8.42615	0	10.1064
72	74.05	80.10	80.45	81.175	5184	8.48528	0	1.0	8.48528	0	9.6348
73	75.70	82.75	81.55	81.700	5329	8.54400	0	1.0	8.54400	0	7.8083
74	71.85	82.10	82.95	82.275	5476	8.60233	0	1.0	8.60233	0	4.1558
75	72.50	82.15	80.85	81.400	5625	8.66025	75	1.0	0.00000	0	11.0268
76	72.50	80.95	81.00	81.975	5776	8.71780	76	1.0	0.00000	0	16.3473
77	73.95	83.40	83.10	82.475	5929	8.77496	77	1.0	0.00000	0	13.6040
78	70.60	84.80	84.75	81.500	6084	8.83176	78	1.0	0.00000	0	10.7482
79	71.90	81.30	80.50	81.602	6241	8.88819	79	1.0	0.00000	0	13.6029
80	66.80	86.40	87.20	83.050	6400	8.94427	80	1.0	0.00000	0	11.3333
81	75.90	83.05	83.00	82.775	6561	9.00000	81	1.0	0.00000	0	10.8984
82	68.30	83.05	82.35	81.775	6724	9.05539	82	1.0	0.00000	0	17.4033
83	71.35	83.05	82.25	82.150	6889	9.11043	83	1.0	0.00000	1	19.8655

continued--

Appendix table 2--Data for the supply section (continued)

T	P89M	P34L	P56L	P89A	SC56A	R4T	R3M
50	6.25	6.50	7.75	8.75	6.65	9.820	4.595
51	3.00	5.25	3.50	5.00	5.65	0.475	4.895
52	2.75	6.50	6.00	3.25	3.60	5.445	4.580
53	3.00	3.75	6.25	2.50	4.65	2.750	6.390
54	1.50	4.50	4.00	2.50	5.00	4.110	1.835
55	2.50	3.25	5.50	3.25	6.50	2.700	7.050
56	2.50	5.25	7.00	2.00	5.15	2.470	3.980
57	6.75	7.00	7.25	5.75	6.45	9.550	4.650
58	6.50	5.25	5.75	5.75	5.45	3.065	5.975
59	6.25	5.25	8.25	6.00	6.25	8.200	4.495
60	7.50	4.00	2.50	4.25	5.35	2.665	4.730
61	5.00	5.50	7.25	5.50	6.05	3.790	11.130
62	5.25	4.75	5.75	5.75	5.70	4.350	2.535
63	2.75	1.25	5.00	3.25	5.50	1.050	4.415
64	3.50	3.75	5.00	4.75	5.25	1.695	6.025
65	5.00	3.50	4.25	5.25	5.85	1.385	5.755
66	4.00	4.75	7.00	6.00	5.25	5.990	0.510
67	4.25	3.00	6.25	5.25	5.65	4.625	2.170
68	5.00	4.00	8.75	4.75	6.40	5.805	4.650
69	2.00	7.25	5.00	3.50	5.30	5.300	4.465
70	5.75	6.25	6.00	5.25	5.20	2.370	7.370
71	4.00	3.00	5.25	4.50	5.00	1.370	4.670
72	4.00	4.50	5.00	6.75	4.85	5.715	4.850
73	3.75	9.25	5.50	5.00	5.65	8.690	14.870
74	6.50	4.25	6.00	9.00	6.00	2.480	4.770
75	6.00	6.75	8.75	5.25	5.80	5.055	10.760
76	3.00	4.75	5.75	4.25	5.95	3.180	7.100
77	4.50	5.50	4.25	6.00	5.60	4.200	6.455
78	4.25	2.00	4.00	4.25	5.55	0.540	1.865
79	5.00	7.00	4.25	5.75	5.55	11.120	5.520
80	4.50	7.75	5.50	3.25	5.80	1.940	6.460
81	5.25	2.50	7.75	3.50	6.80	2.375	4.540
82	3.75	5.00	5.75	5.75	6.80	3.975	3.710
83	2.50	4.50	7.25	1.75	5.60	0.590	0.935

continued--

Appendix table 2--Data for supply section (continued)

T	AA	AC	AL	AM	AT	AA_{t-1}
50	349	241	569	7	486	0
51	464	330	632	28	576	349
52	492	343	605	43	556	464
53	507	442	620	54	578	492
54	690	504	682	79	642	507
55	438	336	530	53	484	690
56	387	292	456	46	417	438
57	337	229	418	32	351	387
58	342	251	415	42	385	337
59	390	287	459	46	421	342
60	391	290	464	45	420	390
61	391	292	465	45	421	391
62	430	325	512	50	467	391
63	430	326	512	50	462	430
64	434	329	515	50	464	430
65	438	329	517	57	464	434
66	482	362	567	56	508	438
67	482	362	567	56	510	482
68	578	434	680	68	599	482
69	550	391	613	61	550	578
70	468	333	525	52	569	550
71	442	333	524	52	470	468
72	442	333	523	52	469	442
73	534	403	624	62	553	442
74	750	470	661	114	565	534
75	900	530	660	175	550	750
76	850	400	570	145	510	900
77	840	310	480	112	502	850
78	1180	500	590	220	560	840
79	1030	525	530	210	560	1180
80	1300	569	615	250	590	1030
81	1560	600	670	340	580	1300
82	1350	540	600	250	475	1560
83	925	330	390	162	320	1350

continued--

Appendix table 2--Data for supply section (continued)

T	COP_{t-1}	QCT_{t-1}	QP	QS	PF_{t-1}	FP_{t-1}	$(FP/PF)_{t-1}$	RA
50	.	3469	38820	43100	.	.	.	1.00000
51	104	4519	46089	51100	5.09	66.300	13.0255	1.00000
52	110	2040	48193	50500	4.82	66.200	13.7344	1.00000
53	110	1515	52834	54800	5.87	68.500	11.6695	1.00000
54	105	7546	64193	71800	5.19	69.800	13.4489	1.00000
55	108	26700	55902	82800	4.57	68.400	14.9672	0.28750
56	107	34618	49459	84500	4.81	67.637	14.0618	0.25583
57	107	19956	42935	63100	4.86	67.288	13.8453	0.25571
58	109	18169	44760	63100	5.11	58.950	11.5362	0.25577
59	110	15669	53647	70100	4.68	60.050	12.8312	0.25570
60	110	12144	54591	67000	4.59	58.850	12.8214	0.25580
61	110	10080	54198	64700	4.55	57.850	12.7143	0.25580
62	110	5329	66045	71400	5.14	58.350	11.3521	0.28140
63	111	7730	70269	78000	5.04	56.900	11.2897	0.28140
64	112	7539	73166	81200	5.01	52.000	10.3792	0.28140
65	111	7677	76281	84600	4.90	52.600	10.7347	0.28140
66	112	8239	85020	93300	4.93	53.200	10.7911	0.30960
67	115	8511	89379	97900	4.95	52.750	10.6566	0.30960
68	115	6784	104142	110900	4.97	54.800	11.0262	0.37150
69	115	16211	91904	108300	5.00	53.650	10.7300	0.33340
70	117	16446	83805	101700	4.95	52.550	10.6162	0.28420
71	119	18634	85768	105000	5.17	52.250	10.1064	0.28420
72	122	11434	85439	97400	5.34	51.450	9.6348	0.28420
73	126	5139	92765	98100	6.73	52.550	7.8083	0.34390
74	140	7842	112386	120300	13.80	57.350	4.1558	0.32500
75	150	7057	128437	135500	11.20	123.500	11.0268	0.27900
76	178	36875	115648	152600	8.35	136.500	16.3473	1.00000
77	173	40501	99223	139800	7.02	95.500	13.6040	1.00000
78	173	27398	133170	160600	9.49	102.000	10.7482	1.00000
79	175	31618	131947	163600	8.16	111.000	13.6029	1.00000
80	177	25679	146150	172100	10.50	119.000	11.3333	1.00000
81	208	16493	182742	199600	12.80	139.500	10.8984	1.00000
82	231	48987	154216	203800	9.05	157.500	17.4033	1.00000
83	232	66632	99720	171100	8.18	162.500	19.8655	1.00000

continued--

Appendix table 2--Data for the supply section (continued)

T	RC	RL	RM	RT	AC_{t-1}	AL_{t-1}	AM_{t-1}	AT_{t-1}
50	1.00000	1.0000	1.0000	1.0000	0	0	0	.
51	1.00000	1.0000	1.0000	1.0000	241	569	7	486
52	1.00000	1.0000	1.0000	1.0000	330	632	28	576
53	1.00000	1.0000	1.0000	1.0000	343	605	43	556
54	1.00000	1.0000	1.0000	1.0000	442	620	54	578
55	0.58367	0.8173	0.1424	0.7729	504	682	79	642
56	0.49967	0.6966	0.1374	0.6579	336	530	53	484
57	0.49950	0.6963	0.1374	0.6576	292	456	46	417
58	0.49967	0.6965	0.1374	0.6578	229	418	32	351
59	0.49930	0.6963	0.1374	0.6575	251	415	42	385
60	0.49970	0.6965	0.1374	0.6578	287	459	46	421
61	0.49970	0.6965	0.1374	0.6578	290	464	45	420
62	0.54950	0.7661	0.1509	0.7237	292	465	45	421
63	0.54970	0.7663	0.1512	0.7238	325	512	50	467
64	0.54970	0.7663	0.1512	0.7238	326	512	50	462
65	0.54970	0.7663	0.1512	0.7238	329	515	50	464
66	0.60470	0.8430	0.1662	0.7961	329	517	57	464
67	0.60470	0.8430	0.1662	0.7961	362	567	56	508
68	0.72570	1.0000	0.1994	0.9553	362	567	56	510
69	0.65300	0.9091	0.1794	0.8598	434	680	68	599
70	0.55500	0.7739	0.1527	0.7308	391	613	61	550
71	0.55500	0.7739	0.1527	0.7308	333	525	52	569
72	0.55500	0.7739	0.1527	0.7308	333	524	52	470
73	0.67170	0.9364	0.1844	0.8843	333	523	52	469
74	0.63480	0.8850	0.1744	0.8358	403	624	62	553
75	0.54500	0.7600	0.1497	0.7176	470	661	114	565
76	1.00000	1.0000	1.0000	1.0000	530	660	175	550
77	1.00000	1.0000	1.0000	1.0000	400	570	145	510
78	1.00000	1.0000	1.0000	1.0000	310	480	112	502
79	1.00000	1.0000	1.0000	1.0000	500	590	220	560
80	1.00000	1.0000	1.0000	1.0000	525	530	210	560
81	1.00000	1.0000	1.0000	1.0000	569	615	250	590
82	1.00000	1.0000	1.0000	1.0000	600	670	340	580
83	1.00000	1.0000	1.0000	1.0000	540	600	250	475

Appendix Table 3--Acreage equations using net income variable

1. Mississippi

$$AM_t = 19.9790 + \underset{(5.37)}{0.7499}(RM_t{*}RNETM_{t-1}) + \underset{(4.57)}{0.4947}AM_{t-1} - \underset{(-2.05)}{60.2718}D83$$

$R^2 = 0.91$ D.W. = 2.24

2. Texas

$$AT_t = 251.9376 + \underset{(2.71)}{0.3664}(RT_t{*}RNETT_{t-1}) + \underset{(2.98)}{0.4209}AT_{t-1} - \underset{(-3.86)}{177.7250}D83$$

$R^2 = 0.66$ D.W. = 1.47

3. Louisiana

$$AL_t = 281.66 + \underset{(2.96)}{0.5455}(RL_t{*}RNETL_{t-1}) + \underset{(2.84)}{0.4066}AL_{t-1} - \underset{(-3.49)}{187.7206}D83$$

$R^2 = 0.61$ D.W. = 1.72

4. Arkansas

$$AA_t = 124.9613 + \underset{(5.61)}{2.6495}(RA_t{*}RNETA_{t-1}) + \underset{(5.57)}{0.5492}AA_{t-1} - \underset{(-2.51)}{269.0905}D83$$

$R^2 = 0.94$ D.W. = 2.44

5. California

$$AC_t = 130.5992 + \underset{(5.85)}{0.7236}(RC_t{*}RNETC_{t-1}) + \underset{(3.55)}{0.3863}AC_{t-1} - \underset{(-3.52)}{166.2680}D83$$

$R^2 = 0.82$ D.W. = 1.92

where:

$$RNETM_{t-1} = (((PF_{t-1}{*}YM_{t-1}) - COP_{t-1})/GNP_{t-1})$$
$$RNETT_{t-1} = (((PF_{t-1}{*}YT_{t-1}) - COP_{t-1})/GNP_{t-1})$$
$$RNETL_{t-1} = (((PF_{t-1}{*}YL_{t-1}) - COP_{t-1})/GNP_{t-1})$$
$$RNETA_{t-1} = (((PF_{t-1}{*}YA_{t-1}) - COP_{t-1})/GNP_{t-1})$$
$$RNETC_{t-1} = (((PF_{t-1}{*}YC_{t-1}) - COP_{t-1})/GNP_{t-1})$$

Appendix Table 4--Demand model assuming Government exports (QEG) determined exogenously

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18. $$QFE_t = -47.6459 - \underset{(-2.55)^*}{10.7367}PBR_t + \underset{(69.09)^*}{0.1086}QM_t + \underset{(4.09)^*}{5.1186}PI_t$$

19. $$QSE_t = -1833.18 + \underset{(4.41)^*}{17900.06}(R^*PF)_t + \underset{(4.20)^*}{0.5074}ACRE_t + \underset{(6.14)^*}{44.7559}T_t$$

20. $$QFD_t = (7.3983 - \underset{(-2.82)^*}{0.03453}PR_t + \underset{(10.22)^*}{0.02674}YI_t + \underset{(1.02)}{0.1483}D59)POP_t$$

21. $$QB_t = (1.2630 - \underset{(-5.01)^*}{0.1511}(PB/PC)_t + \underset{(3.74)^*}{0.003328}YI_t + \underset{(8.80)^*}{0.6329}(QB/POP)_{t-1})POP_t$$

22. $$QEC_t = -15503.5 - \underset{(-6.14)^*}{16570}(PE/PT)_t - \underset{(-9.59)^*}{0.5333}QEG_t + \underset{(16.01)^*}{0.2671}QS_t + \underset{(5.26)^*}{33534.65}SDR_t$$

24. $$QER_t = 9453.29 - \underset{(-0.23)}{18.7632}(PF/SDR)_t + \underset{(3.10)^*}{0.2859}QER_{t-1} + \underset{(2.62)^*}{12.2110}POL_t - \underset{(-5.52)^*}{13.0247}IQP_t$$

25. $$QCP_t = -3586.3 - \underset{(-2.16)^*}{4460.94}(PF/PG)_t + \underset{(2.23)^*}{0.1462}QCG_t + \underset{(12.63)^*}{0.1851}QS_t$$

26. $$QCG_t = -4762.69 - \underset{(-5.83)^*}{14113.7}(PF/PG)_t + \underset{(7.04)^*}{27498.18}(PE/PT)_t - \underset{(-4.60)^*}{8412.91}GP1 - \underset{(-4.73)^*}{7874.6}GP$$

27. $$QH_t = 731.5308 + \underset{(11.34)^*}{0.1256}QM_t + \underset{(3.39)^*}{0.2285}QH_{t-1}$$

28. $$QM_t = QFD_t + QB_t + QFE_t + QH_t + QEC_t + QEG_t$$

29. $$QD_t = QM_t + QCP_t + QCG_t + QER_t + QSE_t$$

30. $$PR_t = -9.7346 + \underset{(21.35)^*}{0.9516}PW_t + \underset{(4.26)^*}{0.1574}T_t + \underset{(19.82)^*}{0.5436}PR_{t-1}$$

31. $$PB_t = 1.3862 + \underset{(7.37)^*}{0.1948}PW_t + \underset{(5.00)^*}{0.3670}PB_{t-1}$$

32. $$PBR_t = -.6672 + \underset{(5.31)^*}{1.0164}PW_t + \underset{(.41)}{0.08814}LU_t + \underset{(9.88)^*}{0.1922}PI_t$$

33. $$PF_t = -.6642 + \underset{(36.48)^*}{0.4267}PW_t + \underset{(3.13)^*}{0.01946}T_t$$

34. $$PE_t = -38.8281 + \underset{(.37)}{0.03373}(QWR/POPW)_t - \underset{(-1.87)^*}{0.5707}QWE_t - \underset{(-.50)}{0.03596}(QWW/POPW)_t$$
$$+ \underset{(9.92)^*}{1.08304}(PG-PS)_t + \underset{(7.56)^*}{46.0174}SDR_t$$

35. $$PT_t = -35.5126 - \underset{(-.11)}{0.008724}(QWR/POPW)_t - \underset{(-2.44)^*}{0.6513}QWE_t + \underset{(.26)}{0.01661}(QWW/POPW)_t$$

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$$+ \underset{(7.79)^*}{0.3585}PT_{t-1} + \underset{(7.99)^*}{43.6829}SDR_t$$

36. $PW_t = PE_t + PS_t$