#9960

A COMPARISON OF SIMULATION AND ANALYTICAL METHODS: A CASE STUDY OF THE EFFECTS OF DECOUPLING ON THE U.S. RICE INDUSTRY

1991

Lois Schertz Willett

and

Satoko Watanabe

Rice - Marketing

ABSTRACT

The specification of a dynamic national rice industry model is presented. Model coefficients using two stage least squares and model validation statistics are presented. Short run and long run elasticities are compared with other studies. Simulation and analytical methods, for testing convergence and evaluating long run values, are compared. Differences, and their implications, with regard to the effects of decoupling policies are analyzed.

PRESENTED AT AAEA MEETINGS AUG 1991

Lois Schertz Willett is an assistant professor of agricultural economics at Cornell University. Satoko Watanabe is a graduate student at the University of Texas at Austin.
The authors appreciate helpful comments from B. F. Stanton. The authors are solely responsible for the views expressed here and for any remaining errors.

A COMPARISON OF SIMULATION AND ANALYTICAL METHODS: A CASE STUDY OF THE EFFECTS OF DECOUPLING ON THE U.S. RICE INDUSTRY

INTRODUCTION

"Decoupling" is a policy proposal for agriculture designed to separate decisions in crop production from past acreage produced. Income support is provided by the government while the transition to a market economy is achieved. Under a decoupling program no acreage restrictions occur. There are price supports and government intervention at a low level in order to avert price collapse. In return for giving up target prices, the producer receives transition payments, whether he plants a crop or not. The transition payments are scaled down annually over a period of years. Decoupling was proposed initially as a means of making U.S. exports more competitive in the world market without increasing budgetary outlays. Decoupling is desirable for rice since it is one of our most export oriented crops. Rice accounts for less than one percent of the U.S. area planted to principal crops and less than one percent of the total value of farm receipts. However, more than half of the U.S. rice is exported. These exports account for about 20 percent of all the rice in international trade (Childs and Lin).

One means of evaluating the effects of decoupling on the rice industry is to develop a model of the industry, estimate that model, validate the model and use the model for policy analysis. The model's performance can be evaluated with analytical solutions of the model and known multivariate distribution theory concerning forecasting (Intrilligator). In addition, static and dynamic deterministic simulations are commonly used procedures for validating models and evaluating policy changes in econometric models. For model validation, measures of goodness of fit can be calculated to determine the model's ability to track historical values of the endogenous variables (Kost).

The objectives of this research are (1) to identify factors affecting the supply and demand for U.S. rice, (2) to assess changes in rice production brought about by a change in income support policy, (3) to estimate changes in domestic rice consumption and exports in response to changes in the market price of rice that would occur under decoupling and (4) to compare these changes using deterministic simulation techniques and analytical methods.

The theoretical model of the national rice industry is presented in the next section of the article. This model draws on the experience and results obtained by others (Brorsen, et. al.; Grant and Leath; Grant, Beach and Lin; Houck and Ryan; Kincannon; and Nakagawa). The model presented here concentrates on a more recent time period. It explicitly models the allocation of rice to the domestic and export markets. The third section of this paper discusses the data used for analysis and the estimation procedures. Coefficient estimates are presented. Elasticities, model validation statistics and model multipliers are presented in the fourth section. The model's stationary equilibrium values identified by analytical methods are compared with the values obtained using deterministic simulation techniques. The final section of this report identifies the potential impacts of decoupling on the industry. The results identified by deterministic simulation are contrasted with the results using analytical methods. Implications for model builders and policy analysis are identified.

THEORETICAL MODEL STRUCTURE

The rice industry model is a national model. Although the domestic industry is composed of three main regions: California, Texas and the remaining Gulf states, all regions were aggregated for the purpose of this paper. Hence, results reflect the impacts on the national industry and specific impacts may vary by region. The structural model is composed of three sectors, a supply sector, the allocation sector and the demand sector. Each will be discussed.

Supply Sector

The supply of rice is determined by profit maximizing producers. They maximize the net revenue they receive from their outputs subject to the technical constraints imposed by their production function. Solving the producer's problem yields first order conditions identifying the optimal level of inputs such that the value of the marginal product of the input will be equal to the price of the input. The relationships are expressed as functions of expected output prices and expected input prices. These input demand relationships can be aggregated without specification bias occurring, if and only if, each individual firm faces the same price (Debreu). Assuming all firms face the same prices the industry equation describing planted acreage is a function of the expected output price and expected cost of inputs. Once producers decide how much acreage to plant, they determine the quantity of that acreage to harvest. There is little difference between planted acreage and harvested acreage in the rice industry. Because the producer's decision about planted acreage is closely tied to harvested acreage a function for harvested acreage is specified and estimated in this model. The relationship is specified as

$$(1.0) \qquad AH_t = f_1(AH_{t-1}, PFD_t^e, COPD_t^e, u_{1t}),$$

where AH is harvested acreage, PFD^e is the expected farm price of rice, and $COPD^e$ is the expected cost of production. One would anticipate positive coefficients for lagged acreage and farm price of rice. If costs of production increased, harvested acreage would decrease.

The total production of rice is a function of the harvested acreage (AH) and yield. In the following relationship, changes in yield are captured by a linear time trend (T). Hence, rice production is expressed as

$$(2.0) \qquad QP_t = f_2(AH_t, T_t, u_{2t}).$$

As the quantity of harvested acreage increases the total production of rice would increase. A positive coefficient is anticipated for the trend variable since technological changes have led to increased yields.

Total quantity supplied (QS) is the sum of the quantity produced in the current year and the ending stock of the previous year (QES). Since the quantity of rice imported into the U.S. during the estimation period was negligible, it is not considered as a component of supply in this model. The relationship is

$$(3.0) \quad QS_t = QP_t + QES_{t-1}.$$

<u>Allocation Sector</u>

The domestic supply of rice is allocated to three markets: the domestic market, the export market and ending stock levels. Allocating this supply to the three markets is determined by the total supply to be allocated and the price received in each market. Rice allocation to the domestic market can be expressed as

$$(4.0) \quad QD_t = f_4(QS_t, PFD_t, PUSD_t, \varepsilon_{4t}).$$

If the total supply of rice (QS) were to increase, the domestic allocation would increase. An increase in the U.S. price received by farmers (PFD) would increase the quantity allocated to the domestic market. However, an increase in the U.S. export price (PUSD) would decrease the domestic allocation, if exports could be made.

Rice exports are a function of the total supply of rice, the domestic rice price, the U.S. export price and the Thailand export price as seen by

$$(5.0) \quad QE_t = f_5(QS_t, PFD_t, PUSD_t, PTD_t, \varepsilon_{5t}).$$

If the total supply of rice increases, exports would increase. As the price received from domestic sales (PFD) of rice increases, there would be a decrease in the quantity exported. If the U.S. export price (PUSD) increased, other things being equal, the quantity of U.S. rice demanded by importing countries will decrease. This is mainly due to a relative price change. Hence, the allocation of rice to the export market would decrease. However, if the Thai price (PTD) increased one would anticipate an increase in the quantity of U.S. exports since the Thai price is the key factor determining the quantity of U.S. exports. The

U.S. export and Thai prices are set by institutional factors and world conditions and assumed to be exogenous in this model.

Ending stocks are identified as the total supply of rice in the U.S. less the quantities allocated to the domestic market and the export market as seen by

(6.0) $QES_t = QS_t - QD_t - QE_t$.

Demand Sector

The final sector of the model identifies the demand for rice in the United States. Domestic use is the sum of direct human consumption, rice for manufacturing, especially brewing, seed required for farm production, and residual uses. The domestic demand for rice is a price dependent function of the quantity allocated to the domestic market (QD), income (YD) and the prices of substitutes - wheat (PWD) and corn (PCD). This relationship is expressed as:

(7.0) $PFD_t = f_7(QD_t, YD_t, PWD_t, \varepsilon_{7t})$.

Economic theory suggests an inverse relationship between the price and quantity of rice. If rice is a normal good the coefficient on income will be positive. Positive coefficients for the wheat and corn prices are expected.

MODEL ESTIMATION

Data for the analysis, obtained from U.S. Department of Agriculture sources, are for the period 1975 through 1989. Data are annual values and reflect the crop year (August to July). This period of analysis was chosen for two main reasons. The industry became more market oriented in the early 1970's following a tremendous increase in the price of rice and a suspension of marketing quotas in 1974. In addition, data on costs of production are available for the period 1975 through 1987. Hence, 1975 was chosen as the initial year for estimation purposes. Cost of production data for 1988 and 1989 were determined based on a fitted regression line where cost of production is a function of a linear time trend. First order serial correlation of the error term was assumed. All monetary values in the model are deflated by the gross national product deflator.

The supply sector of the model was considered independent of the allocation and the demand sector of the model because supplies available during a particular marketing year are known and fixed at the beginning of the crop year. Consequently, the coefficients of the supply sector were estimated separately from those of the demand sector. Because the variables captured by the random error terms of the harvested acreage equation and the production equation may be related, equations (1) and (2) were estimated by seemingly unrelated regression. The farm price and the cost of production from the previous period were substituted for their expectations in the harvested acreage equation based on the assumption that producers use previous prices and costs in forming their expectations.

The allocation and demand sectors of the model were estimated as a simultaneous system by two stage least squares, since it yields consistent estimators even if there is a misspecified equation in the system. In addition, two stage least squares estimates are invariant with respect to the choice of the normalized variable.

Coefficients, associated t statistics and equation statistics are presented in Table 1. Variable definitions can be found in Table 2. The domestic price of rice was dropped from equation (5) because it was not a significant variable in explaining the quantity of rice allocated to the export market. Income and the price of corn were not significant in the price dependent relationship describing the domestic demand for rice, equation (7.0). Hence, they were omitted.

All equations in the model have coefficients consistent with the hypothesized signs and of reasonable magnitudes. The variable's t statistics are significant. Equation R^2's are reasonable and equation Durbin Watson statistics indicate either no autocorrelation or are inconclusive.

MODEL VALIDATION

The purpose of performing model validation is to provide the user with confidence that the model reflects results similar to actual experience even though any model is a simplification of reality. There are several ways to validate a model. Model coefficients can be evaluated and compared with hypothesized signs and magnitudes. Equation summary statistics, such as the R^2 and the Durbin Watson statistic can be analyzed as in the previous section. In this section, the elasticities and model statistics calculated from static and dynamic deterministic simulation are presented. Furthermore, multipliers and stationary equilibrium values determined by simulation and analytical means are compared.

Elasticities and Flexibilities

Demand and supply elasticities evaluated at the mean of the data set and at 1989, the last period in the data set, are presented in Table 3. The elasticities indicate that the response of rice acreage to the changes in farm price, $\varepsilon_{AH_t\,PFD_{t-1}}$, is inelastic in the short run and the long run. The response of acreage to changes in costs of production, $\varepsilon_{AH_t\,COPD_{t-1}}$, is inelastic in the short run but appears to be elastic in the long run. This suggests that as cost changes appear to be more permanent, producers will alter their acreage. Kincannon estimated the response of acreage to price to be 0.33 when evaluated for 1954. Grant and Leath found the acreage elasticity with respect to price to be 0.52 when evaluated for 1975 values. The response of acreage with respect to price was 0.125 when estimated by Grant, Beach and Lin in 1982. The short run elasticity reported here is within the range identified by other studies.

The response of the domestic allocation of rice to changes in price received by farmers, $\varepsilon_{QD_t\,PFD_t}$, and the U.S. export price, $\varepsilon_{QD_t\,PUSD_t}$, are elastic when evaluated at the mean of the data set but are inelastic when evaluated at 1989 values. Perhaps producers are less sensitive to price changes in the recent years of the data set as they become more dependent on government programs. The response of the allocation of rice to the export market with respect to the U.S. export price, $\varepsilon_{QE_t\,PUSD_t}$, and the Thai price, $\varepsilon_{QE_t\,PTD_t}$, are inelastic. Hence, change in these prices will generate a smaller percentage change in the quantity of rice that is exported.

The demand flexibility, $f_{PFD_t\,QD_t}$, is nearly unity when evaluated at the mean. However, the flexibility is large when calculated at 1989 values. These flexibilities suggest unitary elasticity when evaluated at the mean and an inelastic demand when evaluated at 1989 values. Huang found a rice elasticity of -0.147 over the period 1953-1983. Grant, Beach and Lin found an elasticity of -0.18 when evaluated at 1982 values. Demand may be less responsive to price changes as the populations' tastes and preferences change reflecting a new ethnic mix.

Static and Dynamic Simulation

To use a model for simulation each endogenous variable must appear only once on the left hand side of an equation. The right hand side variables must be exogenous variables, lagged endogenous variables or other endogenous variables that have been determined by a previous equation (Kost). In static, or one-period ahead, simulations the model computes the predicted values of current endogenous variables each period using the actual values of lagged endogenous variables. The dynamic simulation differs from the static simulation in that after the initial period, the model's predicted values of lagged endogenous variables are used to generate future values of the endogenous variables. Kost suggests evaluating simulation errors and inequality coefficients among other goodness-of-fit measures. Simulation errors, the measure of the deviation of the simulated variables from the true path of the variable, can be evaluated with various goodness of fit measures. These statistics are presented in Table 4. More error appears in the dynamic simulation than static simulation since the predicted values of lagged endogenous variables are used rather than the actual values of lagged endogenous variables. The quantity of ending stocks

(QES) has large error components because it is determined by an identity in the model.

Association between the model's predicted values and actual values for each variable can be measured by the R^2 of a linear regression of the predicted variables on the actual values (Kost). Table 5 identifies these values for each model variable where the predicted values are determined by static simulation and dynamic simulation. Perfect correlation, a R^2 equal to one, implies a linear relationship. According to Kost, if the simulations are unbiased, the intercept, β_0, should be zero and the slope, β_1, should be equal to 1. The correlation coefficients are larger for the static simulation than the dynamic simulation, since actual values of lagged endogenous variables are used in the static simulation.

Simulation is also used to determine the long run dynamic properties of a model by forecasting into the future. If the system is stable, sequential dynamic simulation will generate values of endogenous variables that approach stationary equilibrium values when all the exogenous variables are held constant. One disadvantage of this method is that interim values of the projections are sensitive to initial starting values. In the simulation presented in Table 6, all exogenous values, including population, were held at their 1989 values. Model convergence was achieved by the fifteenth period. To achieve equilibrium, there was an increase in the acreage harvested, rice produced and the total supply of rice. The increase in total supply led to more rice being allocated to the domestic and export markets. Ending stocks also increased. The price received by producers decreased from $5.82 to $5.20 because of the increased supply.

Approximate long run multipliers for the model can be obtained using simulation techniques. These multipliers, seen in Table 7, are computed by varying each exogenous variable one at a time and comparing the new stationary equilibrium values with the base run values. Each exogenous variable was assumed to increase ten percent over its 1989 value. The approximate long run multiplier for each endogenous variable in the model is equal to the change in the endogenous variable divided by the change in the exogenous variable using the base run as a comparison. Multipliers may vary as a function of the level of the exogenous variables and the presence or absence of disturbances. Hence, those presented are approximations appropriate only for the level of exogenous variables.

Analytical Methods

Another method of validating a model is to obtain the reduced form of the model and use analytical methods to determine the model's properties. Because of the simplicity of this model of the rice industry, analytical methods can be used to evaluate the model. If the model were nonlinear or contained discontinuities, analytical techniques would be more difficult. Following Intrilligator, the structural model can be expressed as

$$H_1 Y_t = H_2 Y_{t-1} + H_3 Z_t, \quad (8.0)$$

where

$$H_1 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.044 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -0.267 & 1 & 0 & 0 & -7.612 \\ 0 & 0 & -0.257 & 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0.148 & 0 & 0 & 1 \end{bmatrix}$$

$$H_2 = \begin{bmatrix} 0.458 & 0 & 0 & 0 & 0 & 0 & 93.789 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$H_3 = \begin{bmatrix} 3745.415 & -12.326 & 0 & 0 & 0 & 0 \\ -16.1307 & 0 & 2.492 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 42.071 & 0 & 0 & -4.693 & 0 & 0 \\ 21.351 & 0 & 0 & -2.756 & 3.986 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 11.682 & 0 & 0 & 0 & 0 & 1.834 \end{bmatrix}$$

$$Y_t = \begin{bmatrix} AH_t \\ QP_t \\ QS_t \\ QD_t \\ QE_t \\ QES_t \\ PFD_t \end{bmatrix}$$

$$Y_{t-1} = \begin{bmatrix} AH_{t-1} \\ QP_{t-1} \\ QS_{t-1} \\ QD_{t-1} \\ QE_{t-1} \\ QES_{t-1} \\ PFD_{t-1} \end{bmatrix}, \text{ and}$$

$$Z_t = \begin{bmatrix} C_t \\ COPD_{t-1} \\ T_t \\ PUSD_t \\ PTD_t \\ PWD_t \end{bmatrix}.$$

The reduced form is

$$(9.0) \qquad Y_t = A\,Y_{t-1} + B\,Z_t,$$

where $A = H_1^{-1}H_2$ and $B = H_1^{-1}H_3$. The matrices A and B are the model's impact multipliers. These values identify the impact of a change in the current value of a predetermined variable or an exogenous variable on the current value of an endogenous variable. The final form of the model is

$$(10.0) \qquad Y_t = A^t\,Y_0 + \sum_{i=1}^{t} A^{t-i}\,BZ_i.$$

For stability to occur A^t must converge to 0 as t increases. According to Reutlinger, the conditions for convergence are that the characteristic roots of the matrix must be less than one. If complex roots exist the modulus, M, must be less than 1. The roots of this matrix for the rice model indicate convergence. If t is allowed to increase indefinitely, then

(11.0) $\lim_{t \to \infty} A^t = 0$ and

$$\lim_{t \to \infty} \sum_{i=1}^{t} A^{t-i} = (I-A)^{-1} .$$

Hence, the stationary equilibrium values can be expressed as

(12.0) $Y_t = (I-A)^{-1} B Z_t^*$

where Z_t^* is set equal to Z_{1989} in this case. The long run multipliers are equivalent to

(13.0) $(I-A)^{-1} B$.

Impact multipliers, stationary equilibrium values and long run multipliers for the rice industry model are presented in Table 8.

A comparison of the values in Tables 6 and 8 indicate discrepancies do exist between those stationary equilibrium values identified by simulation methods and the stationary equilibrium values identified by the analytical solutions. Analytical solutions suggest the stationary equilibrium value of harvested acreage will increase over eleven percent as compared to the 1989 values. The dynamic simulation suggests a sixteen percent increase in harvested acreage. An increase in harvested acreage leads to an increase in the quantity produced and the total supply. However, the increase in these quantities, suggested by the analytical methods, is only six percent for the quantity produced and fourteen percent for the quantity supplied. These values can be compared with nine percent and twenty-one percent increases suggested by the dynamic simulations. According to the analytical solutions the quantity of rice allocated to the domestic market increases by two percent over the 1989 values. The quantity of rice allocated to the export market increases by nine percent. Dynamic simulation suggests a larger increase in the quantity allocated to the domestic market - over four percent - and a larger increase in the quantity allocated to the export market - over thirteen percent. Dynamic simulation indicates ending stocks nearly doubled in order to achieve stationary equilibrium. However, the analytical solutions suggest a much smaller increase in these stock levels. Both the analytical solution method and the dynamic simulation indicate the price received by producers would fall. Dynamic simulation suggests an eleven percent reduction in price. Analytical methods indicate a six percent reduction. All of these percentages are in a range of relatively modest proportion reflecting the general past and present of the industry.

As indicated in Tables 7 and 8, the long run multipliers identified by the analytical solution and dynamic simulation are similar. All signs and magnitudes are similar. Hence, the long run impacts of changes in exogenous variables on the endogenous variables of the system are consistent no matter which method of analysis is used.

POLICY APPLICATIONS AND INTERPRETATIONS

Decoupling is an idea or policy proposal intended to move farmers toward a market oriented decision process where prices direct the use of resources through time. Income payments would be used in a transition period to assist in the move toward a free market system. For this study, it is assumed that: (1) the size of transition payments will not be determined by current production, prices, or acres planted and (2) the decisions by individual farmers about what and how much to plant will be guided by market prices and costs of production rather than past acreage history.

In this analysis, unilateral decoupling is analyzed. It is assumed the U.S. export price of rice (PUSD) becomes the same as the Thai export price (PTD) as a result of the decoupling policy. All other exogenous variables are held at their 1989 values. This analysis is not a projection of what is to happen if decoupling is adopted. Rather the analysis provides a comparison with a base run, if the only variable that were to change were the value of U.S. exports.

Results of the analysis using dynamic deterministic simulation are presented in Table 9. These values can be compared with the base run stationary equilibrium values identified by dynamic deterministic simulation presented in Table 6. According to the simulation an eleven percent decrease in the U.S. export price in 1990, results in a lower stationary equilibrium value of harvested acreage. The quantity produced and the total supply are less when unilateral decoupling is adopted. There is a decrease in the quantity of rice exported of over one million hundredweight, yet the quantity of rice allocated to the domestic market increases by six hundred thousand hundredweight. The stationary equilibrium value of ending stocks is nearly seventeen million hundredweight lower when decoupling is assumed. These changes in supply and demand for rice generate an equilibrium price of only $5.13 per hundredweight, seven cents less than the stationary equilibrium price when no decoupling is assumed.

Analytical methods suggest that the effects of unilateral decoupling are similar in the direction of change. However, the magnitude of the impacts vary. As in the dynamic simulation analysis, all comparisons are made with respect to the stationary equilibrium values under the base case scenario identified in Table 8. Analytical solutions indicate there is a decrease of eight and one half percent in the stationary equilibrium value of the total supply of rice. The allocation of rice to the domestic market increased slightly, but the quantity exported decreased. The stock level fell by nearly forty percent. The dynamic simulation indicated a decrease in stock levels of only thirty-three percent. Analytical solutions indicated decoupling leads to an eight cent decrease in the price of rice.

The analytical solutions and dynamic simulations are consistent in identifying the directions of change resulting from decoupling policies. However, the magnitudes of the effects are uncertain. Analytical solutions are more accurate than dynamic simulation since the analytical solutions are derived from the model's reduced form and final form. The dynamic simulation is sensitive to initial starting values. Furthermore, a discrepancy exists between the stationary equilibrium values suggested by each method. Dynamic simulation is easy to use especially if the model is nonlinear or discontinuities exist. However, interpretation of the results must be used with caution. Whenever possible, analytical solutions should be used to validate a model and to analyze policy impacts with the model.

According to the dynamic simulation and the analytical solutions, unilateral decoupling is likely to have negative effects on the U.S. rice industry. There is a decline in rice production and a loss of export markets. Furthermore, there is a decrease in the price received by rice producers. Hence, it is unlikely the United States will undertake decoupling unilaterally unless some concessions are made by other countries. As evidenced by the recent GATT negotiations, it is unlikely many concessions will be made by other countries. Hence, bilateral negotiations may occur with specific countries. The national rice industry may become more oriented toward a domestic market in response to growth in domestic consumption and the concentration of production in areas that are relatively unsuited for other crops of similar value.

REFERENCES

Brorsen, B. W., J. P. Chavas, and W. R. Grant. " A Market Equilibrium Analysis of the Impact of Risk on the U.S. Rice Industry." Amer. J. of Agr. Econ. 69 (1987): 733-739.

Childs, N. W. and W. Lin. Rice: Background for 1990 Farm Legislation. Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture, Staff Report No. AGES 89-49. November 1989.

Debreu, G. Theory of Value. New Haven: Yale University Press, 1959.

Grant, W. R., J. Beach and W. Lin. Factors Affecting Supply, Demand, and Prices of U.S. Rice. National Economics Division, Economic Research Service, U.S. Department of Agriculture, ERS Staff Report No. AGES 840803. October 1984.

Grant, W. R. and M. W. Leath. Factors Affecting Supply, Demand and Prices of U.S. Rice. Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture, Report No. ESCS-47. March 1979.

Houck, J. P. and M. E. Ryan. "Supply Analysis for Corn in the United States: The Impact of Changing Government Programs." Amer. J. of Agr. Econ. 54 (1972): 184-191.

Howrey, P. and H. H. Kelejian. "Simulation Versus Analytical Solutions." The Design of Computer Simulation Experiments. Ed. Thomas H. Naylor. Durham: Duke University Press, 1969, 207-231.

---. "Simulation Versus Analytical Solutions: The Case of Econometric Models." Computer Simulation Experiments with Models of Economic Systems. Ed. Thomas H. Naylor. New York: John Wiley and Sons, 1971, 299-319.

Huang, Kuo S. U.S. Demand for Food: A Complete System of Price and Income Effects. National Economics Division, Economic Research Service, U.S. Department of Agriculture, Technical Bulletin No. 1714. December 1985.

Intrilligator, M. D. Econometric Models, Techniques, and Application. Englewood Cliffs:

Prentice-Hall. 1978.

Kincannon, J. A. Statistical Analysis of Rice Supply and Demand Before and During Government Programs, Texas Agricultural Experiment Station Miscellaneous Publication 273, April 1958.

Kost, W. E. " Model Validation and the Net Trade Model." Agr. Econ. Res. 32 (1980):1-16.

Livezey, Janet. Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture. Personal Communication. January 16, 1991.

McElroy, R. M. Ali, R. Dismukes and A. Clauson, Costs of Production for Major U.S. Crops 1975-87. Agriculture and Rural Economy Division. Economic Research Service. United States Department of Agriculture. May 1989.

Nakagawa, M. "Amerika no Kome Jukyu (Demand and Supply of U.S. Rice)." Kome no Kokusai Jukyu to Yunyu Jiyuka Mondai (International Demand and Supply of Rice and Its Import Liberalization). Ed. K. Tsuchiya and K. Oga. Tokyo: Norin Tokei Kyokai, 1986. 75-119. (In Japanese).

Reutlinger, S. "Analysis of a Dynamic Model, with Particular Emphasis on Long-Run Projections." J. of Farm Econ. 48 (1966):88-106.

United States Department of Agriculture. Rice Outlook and Situation Report. Economic Research Service. Selected Issues.

Watanabe, S., B. F. Stanton, L. S. Willett. Potential Effect of Decoupling on the U.S. Rice Industry. Department of Agricultural Economics, Cornell University, A. E. Res. 90-5. March 1990.

Table 1

U.S. Rice Industry Model

Supply Sector

(1.1) $AH_t = 3745.415 + 0.458 * AH_{t-1} + 93.789 * PFD_{t-1} - 12.326 * COPD_{t-1}$
(4.526) (2.727) (4.119) (-3.335)
$R^2 = 0.60$ Durbin h = 1.132

(2.1) $QP_t = -16.131 + 0.044 * AH_t + 2.492 * T_t$
(-1.490) (13.099) (7.366)
$R^2 = 0.93$ D. W. = 1.281

(3.1) $QS_t = QP_t + QES_{t-1}$

Allocation Sector

(4.0) $QD_t = 42.071 + 0.267 * QS_t + 7.612 * PFD_t - 4.693 * PUSD_t$
(1.118) (1.702) (1.401) (-1.646)
$R^2 = 0.69$ D. W. = 1.578

(5.0) $QE_t = 21.351 + 0.257 * QS_t - 2.756 * PUSD_t + 3.986 * PTD_t$
(0.772) (2.190) (-3.430) (4.851)
$R^2 = 0.73$ D. W. = 1.013

(6.0) $QES_t = QS_t - QD_t - QE_t$

Demand Sector

(7.0) $PFD_t = 11.682 - 0.148\ QD_t + 1.834 * PWD_t$
(1.914)(-2.306) (2.565)
$R^2 = 0.78$ D. W. = 1.313

Table 2

Definitions for U.S. Rice Industry Model

AH	U.S. Acres Harvested	(thousands)
COPD	U.S. Rice Variable Cash Expenses	(1982$/planted acre)
PFD	U.S. Farm Price of Rice	(1982$/cwt)
PTD	Thailand Milled Rice Price, f.o.b. Bangkok, 100% 2nd grade, Board of Trade Quote	(1982$/cwt)
PUSD	U.S. Milled Rice Price f.o.b. Houston, Long	(1982$/cwt)
PWD	U.S. Farm Price of Wheat	(1982$/bushel)
QD	U.S. Rice Disappearance	(million cwt)
QE	U.S. Rice Exports	(million cwt)
QES	U.S. Ending Stocks of Rice	(million cwt)
QP	U.S. Rice Production	(million cwt)
QS	U.S. Total Rice Supply	(million cwt)
T	Time Trend	(1975 = 5)

Table 3

Elasticities and Flexibilities for U.S. Rice Industry Model

	Mean	1989 Values
Supply Sector		
$\varepsilon_{AH_t\,PFD_{t-1}}$		
Short Run	0.35	0.20
Long Run	0.64	0.36
$\varepsilon_{AH_t\,COPD_{t-1}}$		
Short Run	-0.31	-0.27
Long Run	-2.14	-1.81
Allocation Sector		
$\varepsilon_{QD_t\,PFD_t}$	1.15	0.57
$\varepsilon_{QD_t\,PUSD_t}$	-1.61	-0.77
$\varepsilon_{QE_t\,PUSD_t}$	-0.79	-0.46
$\varepsilon_{QE_t\,PTD_t}$	0.88	0.60
Demand Sector		
$f_{PFD_t\,QD_t}$	-0.98	-1.99

Table 4

Validation Statistics for U.S. Rice Industry Model[1]

	AH	QP	QS	QD	QE	QES	PFD
Static Simulation							
Mean	2766.33	136.11	351.24	61.14	73.69	41.54	9.27
Predicted Mean	2766.33	136.11	351.47	61.13	73.69	41.54	9.27
ME	-0.0009	-0.0001	0.2320	-0.0053	0.0016	0.0037	0.0012
MAE	219.59	9.83	27.74	7.38	4.52	12.49	0.50
RMSE	274.56	13.19	5.87	8.75	5.36	14.62	0.68
MPE	0.0091	0.0103	0.0503	0.0102	0.0068	0.1138	0.0174
MARE	0.0786	0.0752	0.0636	0.1267	0.0659	0.3604	0.0543
RMSPE	0.0992	0.1079	0.1616	0.1498	0.0833	0.4834	0.0694
U	0.0491	0.0480	0.5106	0.0702	0.0361	0.1639	0.0345
U1	0.3078	0.2934	1.1054	0.5391	0.2411	0.4690	0.1229
U2	0.5633	0.5202	3.7337	1.3501	0.4854	0.8076	0.2305
Dynamic Simulation							
Mean	2766.33	136.11	176.37	61.14	73.69	41.54	9.27
Predicted Mean	2764.97	136.05	174.46	60.89	73.20	40.36	9.30
ME	-1.3593	-0.0601	-1.9106	-0.2451	-0.4890	-1.1765	0.0367
MAE	252.24	10.11	11.65	6.34	4.90	13.27	0.53
RMSE	317.35	13.92	12.78	8.02	5.94	15.87	0.74
MPE	0.0121	0.0121	-0.0078	0.0041	-0.0031	0.1371	0.0258
MARE	0.0879	0.0740	0.0658	0.1122	0.0713	0.3977	0.0627
RMSPE	0.1024	0.0979	0.0712	0.1412	0.0877	0.5796	0.0903
U	0.0569	0.0507	0.0362	0.0644	0.0400	0.1834	0.0375
U1	0.3240	0.2907	0.3280	0.4994	0.2648	0.4363	0.1322
U2	0.6510	0.5489	0.7360	1.2369	0.5377	0.8770	0.2507

[1] ME = Mean Error, MAE = Mean Absolute Error, RMSE = Root Mean Square Error, MPE = Mean Percentage Error, MARE = Mean Absolute Relative Error, RMSPE = Root Mean Square Percentage Error, U = Theil's U Statistic, U1 = Theil's U1 Statistic, U2 = Theil's U2 Statistic.

Table 5

Correlation Statistics for U.S. Rice Industry Model

	AH	QP	QS	QD	QE	QES	PFD
Static Simulation							
β_0	1112.777	55.93	36.49	24.43	16.10	20.76	0.91
β_1	0.598	0.589	0.793	0.668	0.737	0.500	0.902
R^2	0.60	0.61	0.67	0.71	0.56	0.31	0.97
Dynamic Simulation							
β_0	1589.48	71.72	37.90	11.00	13.17	30.45	1.09
β_1	0.425	0.473	0.774	0.844	0.781	0.239	0.886
R^2	0.47	0.59	0.69	0.68	0.62	0.20	0.96

Table 6

Dynamic Simulation of the U.S. Rice Industry Model

	AH	QP	QS	QD	QE	QES	PFD
Period 0*	2687.0	154.5	181.2	76.8	78.1	26.3	5.82
1	2870.4	158.2	184.5	75.7	79.6	29.1	5.86
2	3060.1	166.6	195.7	77.2	82.5	36.1	5.65
3	3128.7	169.6	205.7	78.4	85.0	42.2	5.46
4	3142.3	170.2	212.4	79.2	86.8	46.4	5.34
5	3136.8	169.9	216.3	79.7	87.8	48.8	5.26
6	3127.4	169.5	218.4	80.0	88.3	50.1	5.23
7	3119.6	169.2	219.3	80.1	88.5	50.6	5.21
8	3114.4	168.9	219.6	80.1	88.6	50.8	5.20
9	3111.5	168.8	219.7	80.2	88.6	50.9	5.20
10	3110.0	168.8	219.6	80.2	88.6	50.9	5.20
11	3109.4	168.7	219.6	80.1	88.6	50.8	5.20
12	3109.2	168.7	219.6	80.1	88.6	50.8	5.20
13	3109.1	168.7	219.5	80.1	88.6	50.8	5.20
14	3109.2	168.7	219.5	80.1	88.6	50.8	5.20
15	3109.2	168.7	219.5	80.1	88.6	50.8	5.20

* Period 0 is the initial period. All variables are set to 1989 values.

Table 7

Approximate Long Run Multipliers of the U.S. Rice Industry Model From Dynamic Simulation

Exogenous Variables	AH	QP	QS	QD	QE	QES	PFD
$COPD_{t-1}$	-16.572	-0.732	-1.918	-0.241	-0.492	-1.185	0.036
T_t	-15.306	1.820	4.747	0.596	1.219	2.933	-0.088
$PUSD_t$	10.748	0.483	14.223	-0.419	0.896	13.747	0.062
PTD_t	24.489	1.092	-7.594	-0.953	2.036	-8.677	0.141
PWD_t	148.888	6.618	0.078	6.566	0.020	-6.509	0.860

Table 8

Impact Multipliers, Stationary Equilibrium Values and Long Run Multipliers of the U.S. Rice Industry Model From Analytical Solutions

Impact Multipliers

	AH	QP	QS	QD	QE	QES	PFD
Lagged Endogenous Variables							
AH_{t-1}	0.458	0.020	0.020	0.003	0.005	0.013	0
QP_{t-1}	0	0	0	0	0	0	0
QS_{t-1}	0	0	0	0	0	0	0
QD_{t-1}	0	0	0	0	0	0	0
QE_{t-1}	0	0	0	0	0	0	0
QES_{t-1}	0	0	1	0.126	0.257	0.618	-0.186
PFD_{t-1}	93.789	4.148	4.148	0.521	1.065	2.562	-0.077
Exogenous Variables							
C_t	3745.410	149.514	149.514	80.296	59.739	9.480	-0.227
$COPD_{t-1}$	-12.326	-0.545	-0.545	-0.068	-0.140	-0.337	0.010
T_t	0	2.492	2.492	0.313	0.640	1.539	-0.046
$PUSD_t$	0	0	0	-2.204	-2.756	4.961	0.327
PTD_t	0	0	0	0	3.986	-3.986	0
PWD_t	0	0	0	6.556	0	-6.556	0.861

Stationary Equilibrium Values

AH	QP	QS	QD	QE	QES	PFD
2996.2	163.7	206.4	78.5	85.2	42.7	5.45

Long Run Multipliers

	AH	QP	QS	QD	QE	QES	PFD
Exogenous Variables							
C_t							
$COPD_{t-1}$	5967.090	247.770	431.354	115.670	132.101	183.583	-5.474
T_t	-16.575	-0.733	-1.918	-0.241	-0.492	-1.185	0.036
$PUSD_t$	10.769	0.476	14.223	-0.419	0.896	13.747	0.062
PTD_t	24.481	1.083	-7.595	-0.953	2.036	-8.677	0.141
PWD_t	148.898	6.585	0.075	6.566	0.019	-6.510	0.860

Table 9

Effect of Unilateral Decoupling on the U.S. Rice Industry Model

Dynamic Simulation

	AH	QP	QS	QD	QE	QES	PFD
Period 0*	2687.0	154.5	181.2	76.8	78.1	26.3	5.82
1	2870.4	158.2	188.0	78.5	83.0	23.0	5.46
2	3023.3	164.9	192.9	78.9	83.9	25.2	5.39
3	3087.2	167.7	196.9	79.5	85.1	28.3	5.30
4	3107.8	168.7	199.5	80.0	86.2	30.7	5.22
5	3110.3	168.8	200.9	80.3	86.8	32.3	5.18
6	3106.9	168.6	201.7	80.5	87.2	33.2	5.15
7	3102.9	168.4	202.0	80.6	87.4	33.7	5.14
8	3099.8	168.3	202.1	80.6	87.5	33.8	5.13
9	3097.8	168.2	202.1	80.7	87.5	33.9	5.13
10	3096.8	168.2	202.1	80.7	87.5	33.9	5.13
11	3096.2	168.1	202.0	80.7	87.5	33.9	5.13
12	3096.0	168.1	202.0	80.7	87.5	33.9	5.13
13	3096.0	168.1	202.0	80.7	87.5	33.9	5.13
14	3096.0	168.1	202.0	80.7	87.5	33.9	5.13
15	3096.0	168.1	202.0	80.7	87.5	33.9	5.13

Analytical Solutions-Stationary Equilibrium Values

	AH	QP	QS	QD	QE	QES	PFD
	2983.0	163.1	188.9	79.0	84.1	25.8	5.37