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MODELING SUPPLY RESPONSE FOR RICE PROGRAM ANALYSIS:

AN APPLICATION OF IMPLICIT REVENUE SWITCHING FUNCTIONS

Dean T. Chen and Shoichi Ito

Agricultural and Food Policy Center
Department of Agricultural Economics
Texas Agricultural Experiment Station
Texas Agricultural Extension Service
Texas A&M University

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ABSTRACT

A theoretical framework of implicit revenue switching functions for supply response analysis is proposed. The model develops important linkages between farm program instruments and commodity equilibrium, and allows evaluation of supply response decisions under conditions of major policy shifts. The econometric methods developed here are applied to the U.S. rice sector using 28-year (1961-88) rice program data. Simulation results of acreage response to price changes are examined under alternative policy regimes.

KEYWORDS

Implicit revenue switching functions, supply response, rice programs

MODELING SUPPLY RESPONSE FOR FARM PROGRAM ANALYSIS --AN APPLICATION OF IMPLICIT REVENUE SWITCHING FUNCTIONS--

Dean T. Chen and Shoichi Ito*

INTRODUCTION

Conventional economic theory provides little guidance in the specification of agricultural supply response models with government intervention. A pure profit maximization framework assumes perfectly competitive markets for which government policy influences generally are ignored. An empirical model, on the other hand, can be less restrictive with the use of proxy policy variables as supply shifters; however, such specification offers only limited help in identifying key program instruments and the complex process that determine producers' crop production decisions.

Policy modeling work is further complicated by frequent changes in agricultural legislation and by increasing complexities in program administration. It could be argued that a new econometric model is needed to adequately investigate supply response each time the provisions of government programs are changed. It has been suggested that a methodology for combining time-series data from time periods governed by several combinations of farm commodity programs be considered (Just).

The most critical and challenging aspects of policy modeling research involve development of: (1) a theoretical framework that encompasses key farm program instruments for policy analysis; and (2) an econometric procedure to account for major changes in model specifications across years when different farm programs are in effect. The first is a theoretical issue concerning adequate linkage between U.S. farm programs and commodity market equilibrium. The second is of an empirical nature which requires an econometric technique for incorporating alternative supply response specifications into a structural model for policy simulation.

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*Dean T. Chen and Shoichi Ito are professor and postdoctoral research associate, respectively, of the Department of Agricultural Economics, Texas A&M University. The research is supported in part by CED ERA USDA through a Cooperative Agreement (Project No. 58-3AEK-8-00019).

The purpose of this paper is to advance econometric modeling techniques in these two major directions by introducing *implicit revenue switching functions*. The *implicit revenue switching function* is composed of the *implicit revenue function* (IRF) for calculating operating returns above variable costs and the *endogenous switching system* (ESS) for combining different acreage response specifications over different farm programs. By incorporating the IRF with the ESS, acreage response equations over different farm programs are combined in the system in order to account for changes in model specifications under conditions of major policy shifts. The econometric methods developed here are applied to the U.S. rice sector to examine the sensitivity of the model to changing farm programs for policy evaluation purposes between 1961 and 1988.

A brief review of previous supply response models with government intervention is provided, followed by a description of the proposed implicit revenue function for derivation of rice acreage response equations. Special references are made with regard to the proposed endogenous switching system which helps determine producers' operating returns and costs during the three rice program periods of 1961-75, 1976-81, and 1982-88. (The key features of the program in each period are explained later and summarized in Table 1). The model is then used to show (a) acreage response elasticities in comparison with previous studies and (b) the impacts of a 1% price increase on producers' net operating returns, program participation rate, and planted acreage for program participants and nonparticipants under the different policy regimes.

PREVIOUS SUPPLY RESPONSE MODELS

The importance of government intervention in determining producers' crop production decisions has been a subject of much empirical investigation (Askari and Cummings). Among numerous econometric models estimated for major program crops, there exist three major approaches in modeling supply response for policy evaluation purposes. The first approach uses direct inclusion of key program variables such as acreage allotments, and diversion payments per acre, either as explanatory variables in the model (Garst and Miller) or as dummy intercept shifters for program years (Lidman and Bawden).

The second and perhaps most widely adopted approach uses composite policy variables as advanced by Houck and Ryan in the early 1970's. They utilized the effective support price and effective diversion payment rate as the key theoretical arguments. Several important extensions to this formulation include risk analysis (Just; Morzuch, Weaver and Helmberger; Brorsen, Chavas, and Grant), price expectations (Gardner; Romain; and Lopez), and multi-input, multi-product regional investigations (Shumway; Shumway and Alexander).

The third approach, initiated in the early 1980's, utilizes revenue and program participation rates. Examples include the feed grains program payment (FPP) model by Lee and Helmberger, the program payment and participation rate formulation of acreage response for wheat by Love, and the large-scale agricultural sector model of FAPSIM by Salathe, Price, and Gadson.

The major weakness of the two earlier supply response models reviewed above is the absence of a cohesive and broadly conceived conceptual framework for linking farm program instruments to commodity market equilibrium. The revenue and program participation rate framework partially corrects this weakness. Recently, the implicit revenue function (IRF) approach developed for cotton (Chen) and for wheat (Chen, Penson, and Teboh) offers further refinements by incorporating the price-supporting, income-supplementing, and output-restricting features of U.S. farm policies and program participation decisions into a structural model context.

Building on the IRF approach, this paper proposes an additional enhancement by establishing the endogenous switching system, which incorporates operating returns above variable costs to reflect major changes in U.S. farm programs over time. Given such a system, it is now possible to combine several alternative acreage response specifications to reflect different policy regimes. The following section discusses the derivation of producers' implicit revenue functions and specifications for acreage response equations with regard to the three rice program periods.

IMPLICIT REVENUE SWITCHING FUNCTIONS

The U.S. rice model presented here is a complete sectoral model of 34 simultaneous equations and five major blocks to determine: implicit revenue functions (or operating returns above variable costs); farm program payments and government costs; farm price and incomes; acreage, yield and production; and demand and inventory stocks. For the purpose of this paper, no detailed model description is intended. Instead, a brief description of implicit revenue switching functions and the related acreage response equations for rice are provided.

Derivation of Implicit Revenue Function

The implicit revenue function (IRF) facilitates estimation of producer's operating returns above variable costs (ORAVC) for each of the simulation periods when rice programs were substantially changed. A major benefit of using the IRF is that it is possible to avoid multicollinearity problems that frequently occur among the explanatory variables. Because the IRF reduces the number of independent variables in each equation by way of incorporating important factors into one variable, the ORAVC, this formulation also saves degrees of freedom. This is an important advantage to policy modeling work when there are only a small number of observations. Further, by focusing on the revenue and cost factors rather than specific policy instruments, it is possible to perform a policy analysis over different program periods with a single theoretical framework.

To derive ORAVC for acreage response analysis, it is useful to briefly review the historical development of previous rice programs. Three rice program periods are considered in this study. From 1961 to 1975, rice programs basically were conducted through price support and acreage allotment. The marketing quota was also proclaimed, although it was suspended in 1974 and subsequent years (Holder and Grant; Johnson et al.). During the second period (1976-81), target price and loan rate were implemented beginning with the 1976 crop. All direct benefits of the program, however, were allowed only to the allotment holders.

The third (and current period), 1982-90, regulates U.S. rice programs under the 1981 and 1985 Farm Bills. During this period, the allotment was repealed while the target price and loan rate system was continued (Johnson et al.). The base acreage concept was introduced in the 1981 Farm Bill, and the program participation became voluntary with acreage reduction required. In 1983, the PIK (payment-in-kind) program was implemented in order to reduce a large surplus (USDA, 1983). Under the 1985 Farm Bill, in particular, marketing loan and the 50/92 option were introduced to expand U.S. rice markets while cutting domestic production (Glaser).

The general formulation of IRF in terms of ORAVC (operating returns above variable costs at the farm level) can be written in matrix notations as follows:

(1) $R = P' Y^* Q^* S$

where,

R = a unit vector of returns above variable costs per acre (equivalent to ORAVC),

P = nx1 vector of prices, implicit revenues, and costs per unit,

Y = nx1 vector of yield, program payment yield, and others,

Q = nx1 vector of planted area for program payments, and

S = nx1 vector of operating function for the government program provisions,

* = indicates a diagonal matrix having the column vector elements,

' = indicates a transposed matrix.

The elements of P, Y, Q, and S matrices used in Equation (1)[1] for program participants during three rice programs periods of 1961-75, 1976-81 and 1982-90 are summarized in Tables 1A, 1B, and 1C. The ORAVC for the earlier rice programs can be estimated fairly simply as shown in Tables 1A and 1B. The rice programs for the 1982-90 period governed by the 1981 and 1985 Farm Bills are the most sophisticated (Table 1C). The connotations of variables in Tables 1A, 1B, and 1C are:

ALLOT = allotment acreage,

BASE = base acreage (the greater of planted acreage or total allotment acres for years prior to 1982),

k = insurance value coefficient,

KARP = rate of acreage reduction,

KPLD = rate of paid land diversion,

KPIK = 0.3 in 1983 indicating the PIK program in 1983, otherwise 0 (assuming producers cut back additional 30% under the PIK),

[1]Equation (1) can be also rewritten as: $R = \Sigma_{i=1} p_i y_i q_i s_i$, where p_i, y_i, q_i, and s_i are elements of P, Y, Q, and S, respectively.

PAW	= USDA-announced world adjusted price (U.S. annual average, $/cwt),	
PDVG	= U.S. average paid land diversion payment rate ($/cwt),	
PF	= U.S. average producer price, crop year average ($/cwt),	
PF5	= U.S. average producer price during August through December for payment calculation ($/cwt),	
PGZ	= revenue from grazing on diverted land ($/acre),	
PL	= U.S. average loan rate ($/cwt),	
PMC	= maintenance cost ($/acre),	
PS	= U.S. average government support price ($/cwt),	
PT	= U.S. average target price ($/cwt),	
PVC	= U.S. average variable cost ($/acre),	
SY	= U.S. average yield (cwt/acre),	
SYG	= U.S. average program payment yield (cwt/acre),	
A1	= 0.99 if marketing quotas are imposed, otherwise 1 (Marketing quotas were suspended in 1974 and subsequent years),	
B1	= 1 if PF5 > PT indicating the allotment system is practically not a restricting factor for rice production,	
C1	= 1 if PF5 > PT, otherwise 0,	
C2	= 1 if year is earlier than 1982 and if PF5 > PVC/SY indicating no participation in the 50/92 option, otherwise 0,	
C3	= participation coefficient for the 50/92 option, and	
C4	= 0 if disaster payments are declared, otherwise 1.	

Because the rice programs during 1982-90 period is the most complicated, the process of calculating the ORAVC during this period is explained below.

The top row of Table 1C for period 1982-90 indicates cash receipt per one base acre for the program participants when PF under the P matrix is multiplied by SY of Y matrix, 1-KARP-KPLD-C3*0.3 of Q matrix, and 1 of S matrix. For example, in 1983, a 15% acreage reduction (ARP) was imposed on the participants. In addition, a 5% paid land diversion (PLD) and the PIK program were optional participation choices after the ARP. To calculate the ORAVC per one base acre for the participants, it is assumed in this study that the participants enrolled in all of the options. Thus, the planted acreage rate is one base acre subtracted by the rates of ARP, PLD, and the rate of PIK in which an additional 10% to 30% reduction was required.[1]

The second row of Table 1C is for calculating the deficiency payments. First, the deficiency payment rate is defined under the **P** matrix. The deficiency payment rate is the difference of the target price and the higher of the loan rate or the 5-month average farm price.[2] Deficiency payments are paid on government program yield (SYG). Planted acreage under the **Q** matrix is the same as that for cash receipts. The value of C1 for the policy option operator under the **S** matrix will be 0 if PF5 > PT indicating deficiency payments are paid, or 1 if PF5 < PT indicating no deficiency payments. Accordingly, the deficiency payments per one base acre would result by multiplying each item in P, Y, Q, and S matrices, i.e.:

(PT - MAX(PL,PF5))*SYG*(1 - KARP - KPLD - KPIK)*(1 - C1)*(C2 + C3*(1 -C2)*0.92).

Following the same manner, a value in each row is calculated, then added (or subtracted for the cost items) and estimated for the ORAVC per one base acre for the program participants.

For nonparticipants, the calculation of ORAVC is straightforward. The corresponding unit values under individual P, Y, Q, and S matrices for cash receipts would be PF, SY, 1, and 1, respectively. Because nonparticipants do not have to set aside any area, their planted acreage would be the whole base acre with a unit of 1. Variable costs are also applied for the whole one base acre. Of course, no government payments are applied for nonparticipants. Thus, the ORAVC for nonparticipants are calculated with cash receipts subtracted by variable costs.

Note that the IRF incorporates the expectation term. Under the 1981 and 1985 Farm Bills, in particular, the government announces target prices, loan rates, and other program provisions in

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[1]In this research, the PIK participants are assumed to set aside the largest 30% of the base acreage, which is close to the actual situation.

[2]If the average farm price of the first 5 months (August-December) of the marketing year is equal to or higher than the target price, then there are no deficiency payments. Accordingly, C1 and (1 -C1) under the S matrix are one and zero, respectively, indicating no deficiency payments.

advance so that producers can formulate their expectation of ORAVC. It is critical for producers to formulate expectations in order to decide whether or not to participate in the program.

Acreage Response Prior to 1981 Farm Bill

The rice programs under farm bills prior to the 1981 and 1985 Farm Bills were less complicated. Based on the IRF formulation, the ORAVC for the allotment holders and nonholders are calculated. Data for acreage planted by the allotment holders and nonholders are not available, however. Interestingly, planted acreage during 1961-73 was always slightly lower than allotment acreage.[3] The allotment system essentially was suspended between 1974 and 1981 due to supply shortages and high market prices. Therefore, it may not be too far off from the real situation even if it is assumed that all rice producers were under some government protection during 1961 and 1981. Under this assumption and applying the Nerlovian partial adjustment model (Nerlove),[4] a stochastic equation for acreage planted during 1961-81 may be estimated as a function of lagged one period planted acreage, SA_{-1}, and expected ORAVC;

(2) $SA = f(SA_{-1}, E(ORAVCAD)),$

where ORAVCAD equals ORAVC for producers under the government programs. This specification with the simple formulation of the IRF should sufficiently capture the key program instruments implemented in the rice programs prior to the 1981 Farm Bill.

Acreage Response under Recent Farm Bills

Modeling acreage response under the 1981 and 1985 farm programs is much more

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[3]During this period, marketing quotas were implemented. The penalty for violating quotas was quite detrimental to producers (Holder and Grant). This may be why planted acreages did not exceed the allotment acreages during this period.

[4]In the Nerlovian partial adjustment model, expected market price is used. In this research, however, expected price term is replaced by expected operating return above variable costs (ORAVC).

complicated, requiring a step-by-step procedure employing several equations. Once the ORAVC per one base acre for both program participants and nonparticipants are calculated, it is possible to estimate the participation rate for the rice program in a stochastic equation. The participation rate is calculated in terms of base acreage of the participants to the total base acreage at the national level and regressed in a manner specified as follows:

(3) RPRM = f(E(ORAVCAD - ORAVCNO)/ORAVCAD)

where RPRM is the participation rate in the program, and ORAVCAD and ORAVCNO are the operating returns above variable costs for the program participants and nonparticipants, respectively. This relative profitability measurement is expressed in an expectation term for the coming year. To take into account the participation rate as the key planting decision variable, an equation for acreage planted by the participants would be specified:

(4) SAAD = f(SB*RPRM, KARP+KPLD, KPIK)

where SAAD is acreage planted by the participants, SB is total base acreage, and KARP, KPLD, and KPIK are the percentages of acreage set-aside under ARP, PLD, and PIK programs.

Acreage planted by the nonparticipants, on the other hand, can be specified:

(5) SANO = f(SB*(1-RPRM), E(ORAVCNO/ORAVCOT)

where SANO and SB*(1-RPRM) are planted acreage and base acreage, respectively, of the nonparticipants, and ORAVCOT is the operating returns above variable costs of competitive crops. Nonparticipants have flexibility to switch a portion of rice land to other crops which may be more profitable than rice. The specification of Equation (5) is also in expectation terms. Accordingly, using identity equations, total acreage planted (SA) can be defined as a sum of the planted acreages of participants and nonparticipants:

(6) SA = SAAD + SANO.

These four equations for acreage response under 1981 and 1985 Farm Bills allow us to evaluate program participation rate, acreages planted by participants and nonparticipants, and total acreage planted.[5]

Switching Procedure

To combine alternative acreage response equations for the whole period from 1961 through 1988, an endogenous switching procedure is employed in this study using S1 and S2 to combine Equations (2), (4), and (5):

$$(7) \quad SA = S1*(f_1(SA_{-1}, E(ORAVCAD/ORAVCOT)) + S2*(f_2(SB*RPRM, KARP+KPLD, KPIK) + f_3(SB*(1-RPRM), E(ORAVCNO/ORAVCOT))$$

where S1 is 1 during 1961-81, otherwise 0; S2 is 1 during 1982-88, otherwise 0. The function f_1 represents acreage responses by all producers during the early rice program period (1961-81), while functions f_2 and f_3 represent acreage responses by the program participants and nonparticipants during the recent farm programs (1982-88), respectively.

In this study, the endogenous switching system is designed to describe two different policy regimes within which either the simple specifications (1 equation) of IRF for acreage allotment/price support programs or the complex formulation (4 equations) of program participation/acreage set-aside programs can be evaluated. A single theoretical framework of IRF, which has a capability to jointly estimate both types of programs over time, is crucial to this modeling approach. In the context of simultaneous equation systems, this switching mechanism is a more straightforward

[5]Further, the whole system with these specific program equations also allows us to evaluate government costs.

estimation procedure than the approach designed for dairy program study by Liu et al.

Data

Data used in this study were collected from various publications of the U.S. Department of Agriculture. They are *Rice Situation and Outlook Report, Crop Production Report, Agricultural Outlook, World Supply and Demand Estimates, Economic Indicators of the Farm Sector: Costs of Production* and *Agricultural Statistics*. Missing data were generated by regressing the available data against individual correlated variables. Production costs data prior to 1975, for example, are not available; therefore, costs data during 1961-74 were estimated by regressing costs against price index of all fertilizers based on data during 1975-88. Crop year annual data between 1961 and 1988 were used in this study.

EMPIRICAL RESULTS

The 34 equations of the whole system were simultaneously solved using the Gauss-Seidel method. The simulation performance of the model provides significant results in tracing the effects of government rice programs, and allows evaluation of major policy shifts over time. Due to the purpose and brevity of this paper, only the acreage response-related equations are discussed. The estimated equations for acreage planted for the earlier farm program period, program participation rate, and acreage planted by the participants and nonparticipants under 1981 and 1985 Farm Bills during 1982 and 1988, are as follows (connotations of variable names are the same as explained above, and t-values are in parentheses):

(8)
$$SA = \underset{(2.26)}{513} + \underset{(5.75)}{0.655}*SA_{-1} - \underset{(3.57)}{2.11}*ORAVCAD_{-1} - \underset{(3.35)}{3082}*KPIK$$

$R^2 = 0.851$ $\quad$ $R^2adj. = 0.862$ $\quad$ $DW = 1.93$ $\quad$ Durbin h. = 0.17

(9)
$$RPRM = \underset{(27.5)}{0.742} + \underset{(5.11)}{0.458}*KPIK + \underset{(5.84)}{0.159}*((ORAVCAD - ORAVCNO)/ORAVCAD + (ORAVCAD_{-1} - ORAVCNO_{-1})/ORAVCAD_{-1})$$

$R^2 = 0.920$ $\quad$ $R^2.adj. = 0.880$ $\quad$ $DW = 2.29$

(10) $SAAD = 104 + 1.04*(SB*RPRM) - 4806*(KARP+KPLD) - 3560*KPIK$
(0.344) (9.25) (10.1) (15.6)

$R^2 = 0.989$ $R^2adj. = 0.978$ $DW = 1.68$

(11) $SANO = -325 + 0.640*SB*(1-RPRM) + 394*(ORAVCNO + ORAVCNO_{-1})$
(2.97) (3.53) (3.38)

$/(ORAVCSY + ORAVCSY_{-1})$

$R^2 = 0.941$ $R^2adj. = 0.902$ $DW = 1.53$

The estimated coefficients for independent variables are all significantly different from zero at the 5% significance level. The Durbin-Watson or Durbin h statistic in each equation indicates no serious serial correlations in an error term. The estimation period for acreage planted prior to the 1981 Farm Bill (Equation (8)) was extended to 1983 in order to improve reliability of estimation. In this equation, a dummy for the 1983 PIK program is included as an explanatory variable. For the acreage equation for the period prior to the 1981 Farm Bill, incorporation of the current ORAVC deteriorated the level of goodness of fit. On the other hand, Equation (9) for the rate of program participation was improved by incorporating the current ORAVC. These may be because producer behaviors prior to the 1981 Farm Bill tended to depend heavily on the results of the previous crop year. Acreages planted to rice were constrained by allotment systems and marketing quotas up to 1973. During 1974-81, market prices were higher than support/target prices. Although government payments were available only for allotment holders, farm prices higher than the target prices tended to upstage dependence on government prices during this period. Accordingly, during the period up to 1981, the performance of the previous year appeared to be the better source than government prices when producers estimated revenue and decided how much acreage to plant. After 1981 (under the 1981 and 1985 Farm Bills), farm prices have been substantially lower than target prices. Most rice producers have been eligible for government prices, which are set up four to five years in advance; therefore, producers tend to depend on current expected operating returns under the government programs while being influenced by the results in the previous year. This is particularly observed in estimating program participation rate (Equation (9)) and acreage planted by nonparticipants (Equation (11)) during the 1982-88 period.

Program participation rate (Equation (9)) was regressed by a dummy for the PIK program (KPIK) and a relative level of benefit of participation in government programs. The relative benefit is expressed as a difference of operating returns above variable costs for program participants (ORAVCAD) and nonparticipants (ORAVCNO) divided by ORAVCAD during current and previous years. Once participation rate is estimated, planted acreage by the program participants (Equation (10)) is expressed by the national total base acreage multiplied by the participation rate, a sum of acreage reduction rate and paid diversion rate, and a dummy for the 1983 PIK program. Acreage planted by the nonparticipants (Equation (11)) is regressed by the base acreage of the nonparticipants and the relative benefit of ORAVC of rice to soybeans, which is the major competitive crop for rice, during the current and previous years. Using the switch procedure in Equation (7), the estimated Equations (8), (10), and (11) are combined into one equation in the system for the whole period from 1961 through 1988.

Price Elasticities and Impacts

Impacts of a 1% increase in farm price were simulated throughout the system in order to evaluate magnitudes of effects of a price increase at various points. Because the estimated impacts are through a shock of 1% increase in farm price, the impacts are regarded as elasticities with respect to farm price. These impacts, which are estimated through the whole system, should be more realistic values than elasticities calculated from individual single equations. The magnitudes of estimated impacts are reported in Tables 2 and 3. Impacts with respect to farm prices are estimated during different rice programs.

The estimated impact of this study on acreage response for the 1981 crop is slightly larger at 0.23 than elasticities estimated by Grant, Beach, and Lin (0.13) and Jolly, Fielder, and Traylor (0.16) for the 1982 and 1979 crops, respectively (Table 2). The difference between the results of this study and others may be due to the means of calculating elasticities. The impact (or elasticity) of this research is mathematically derived using the chain rule:

$$(12) \quad E_{p,SA1} = \frac{\partial SA}{\partial R} \frac{\partial R}{\partial PF} \frac{PF}{SA}$$

where $E_{p,SA1}$ is own-price elasticity (or impact) of acreage response in the IRF method, and R is operating return above variable cost (ORAVC). A change in farm price (PF) affects the ORAVC initially. Then, the change in ORAVC affects acreage planted. Meanwhile, a method employed by Grant et al. and Jolly et al. is a direct estimation:

$$(13) \quad E_p = \frac{\partial SA}{\partial PF} \frac{PF}{SA}$$

where E_p is an own-price elasticity with respect to farm prices. Because producer behaviors are rational and affected by not only farm price but the entire operating returns above costs, the acreage response elasticity (or impact) estimated in this research appears to be more realistic. The impacts of a 1% increase in farm price for operating returns (ORAVC) to the allotment holders and nonholders for the 1981 crops were estimated to be 2.20 and 2.36, respectively. This implies that as farm price increased by 10%, ORAVC increased by 22% and 23.6% for allotment holders and nonholders, respectively.

Under the recent programs, on the other hand, those impacts on participation rate, acreages planted by the program participants and nonparticipants, and total acreage planted with respect to a 1% increase in farm price are theoretically derived as follows:

$$(14) \quad E_{p,SAAD} = \frac{\partial SAAD}{\partial RPRM} \frac{\partial RPRM}{\partial R_{AD}} \frac{\partial R_{AD}}{\partial PF} \frac{PF}{SAAD}$$

$$(15) \quad E_{p,SANO} = \frac{\partial SANO}{\partial (1-RPRM)} \frac{\partial (1-RPRM)}{\partial R_{NO}} \frac{\partial R_{NO}}{\partial PF} \frac{PF}{SANO}$$

$$(16) \quad E_{p,SA2} = RPRM^{*}E_{p,SAAD} + (1-RPRM)^{*}E_{p,SANO}$$
$$(0 \leq RPRM \leq 1)$$

where connotations of the variables are the same as explained above except for : $E_{p,SAAD}$ and $E_{p,SANO}$ are impacts on acreages planted by the program participants and nonparticipants, respectively; R_{AD} and R_{NO} are operating returns above variable costs for the participants and nonparticipants, respectively; and $E_{p,SA}$ is impacts on the total acreage. Equations (14) and (15) indicate that a change in farm price affects operating returns above variable costs, which then affects the participation rate. Finally, a change in participation rate affects acreages planted by the participants and nonparticipants. The two impacts on the participants and nonparticipants are weighted proportionately by the participation rate and added to derive the total impacts (or elasticity) of national acreage planted (Equation (16)). The estimated impacts on acreage response (Table 3) clearly illustrate the differences between program participants and nonparticipants and also between the two recent Farm Bills. First, the price impacts on ORAVC for nonparticipants are much greater than those for participants. This may be because revenues of nonparticipants are directly affected by the market prices, while revenues of the program participants are protected to a certain extent by government subsidies such as target prices.

Impacts on program participation rate are almost identical between the 1981 and 1985 Farm Bills at -0.13 for the 1984 crop and -0.12 for the 1987 crop, respectively, indicating that a 10% increase in farm price would lead to a 1.2% to 1.3% decrease in participation rate. The magnitude of the price impacts are not strong; however, the statistically significant coefficient in Equation (11) suggests that producers tend to get out of the program and cultivate more acreage without being restricted if that is more profitable.

Finally, impacts of acreage planted are very different between the program participants and nonparticipants. The estimated impacts for the participants are negative -0.20 and -0.21 for 1984 and 1987 crops, respectively, while those for nonparticipants are positive 1.55 and 40.83 in the two crop years, respectively. This also implies that producers tend to get out of the program as market price increases, rendering a decrease in acreage planted by participants. Accordingly, acreage planted by nonparticipants tends to increase through transfer from participating to nonparticipating as farm prices increase. The large impacts estimated for acreage planted by nonparticipants for the 1987 crop may be reflecting the small acreage base of nonparticipants due to introduction of the marketing loan under the 1985 Farm Bill. Since reactions by the participants and nonparticipants regarding acreage planted are opposite, the impact of total acreage planted reflects the net effect of these two; impacts are estimated to be 0.07 and 0.13 for the 1984 and 1987 crops, respectively. Comparing the magnitude of impacts of acreage planted under the circumstances to earlier and recent farm bills, the impact during the earlier farm bills appears to be greater. This may reflect a situation of high farm prices and freedom to expand acreage, particularly during 1973-81.[6] On the other hand, the situation after 1981 has been under government intervention due to low farm prices, and producers are apt to be inflexible and restricted within the program provisions.

CONCLUSION

The implicit revenue function approach applied for this supply response study shows promise in providing a comprehensive set of program instruments for agricultural policy analysis. This study also demonstrates the utility of an endogenous switching procedure that allows evaluation of supply response behaviors for time periods governed by several different farm programs in a system of equations. Empirical results from this research compare well with those of the previous studies. In addition, the model provides significant results and valuable insights on producers' acreage response behavior through the program participation decisions.

[6] During the 1973-81 period, farm prices were higher than support/target prices, and there were no governmental restrictions to acreage planted.

Table 1. F parameters for three rice program simulation periods.

A: From 1961 through 1975

Revenue/cost components	Price, cost, and payment rate (P)	Yield unit (Y)	Acreage unit (Q)	**Policy option operators (S)**
Cash receipts	PF	SY	1	**A1**
Loan payments	MAX(PS,PF) - PF	SY	ALLOT/BASE	**1**
Variable costs	PVC	-1	1	**A1**

B: From 1976 through 1981

Revenue/cost components	Price, cost, and payment rate (P)	Yield unit (Y)	Acreage unit (Q)	**Policy Option Operators (S)**
Cash receipts	PF	SY	1	**1**
Def. payments	PT - MAX(PL,PF5)	SYG	ALLOT/BASE	**1 - B1**
Loan payments	MAX(PL,PF) - PF	SY	ALLOT/BASE	**1 - B1**
Disaster payments	k * PT/3	SYG * .75	ALLOT/BASE	**1 - B1**
Variable costs	PVC	-1	1	**1**

Table 1. -- ...tinued...
C: From 1982 through 1990

Revenue/cost components	Price, cost, and payment rate (P)	Yield unit (Y)	Acreage unit (Q)	Policy option operations (S)
Cash receipts	PF	SY	1-KARP-KPLD-KPIK	(1-C1){C2+C3*(1-C2)*0.92}
Def. payments	PT-MAX(PL,PF5)	SYG	1-KARP-KPLD-KPIK	(1-C1){C2+C3*(1-C2)*0.92}
Loan payments	MAX(PL,PF)-PF	SY	1-KARP-KLPD-KPIK	C2+C3*(1-C2)*0.50
Marketing loan premium	PF-PAW	SY	1-KARP-KPLD-KPIK	C2+C3*(1-C2)*0.50
Diversion payments	PDVG	SYG	KPLD	1
PIK payments	PF	SYG*0.8	KPIK	1
Disaster payments	k * PT *0.33	SYG*.75	1-KARP-KPLD-KPIK	1-C4
Variable costs	PVC	-1	1-KARP-KPLD-KPIK	C1+(1-C1){C2+C3*(1-C2)*0.50}
Maintenance costs for diverted land	PMC	-1	KARP+KPLD+KPIK	1
Maintenance costs for 50/92	PMC	-1	1-KARP-KPLD	C2*(1-C2)*0.50
Revenue from grazing on diverted land	PGZ	1	KARP+KPLD+KPIK	1

These tables show matrices to calculate operating returns above variable costs per one base acre under the different farm programs during 1961 and 1990. Connotations of the variable names are: ALLOT = allotment acreage, BASE = base acreage (the greater of planted acreage or total allotment acres for years prior to 1982) k = insurance value coefficient, KARP = rate of general acreage reduction (non-paid), KPLD = rate of paid land diversion, KPIK = 0.3 in 1983 indicating the PIK program in 1983, KPLD = rate of paid land diversion, PAW = USDA announced world adjusted price, PDVG = paid diversion payment rate, PF = annual average producer price, PF5 = producer price during August through December, PT = target price, PVC = variable cost, SY = yield, and SYG = program yield.

The policy option operators are as follows: A1 = 0.99 if marketing quotas are imposed, otherwise 1 (Marketing quotas were suspended in 1974 and subsequent years); B1 = 1 if PF5≥PT indicating the allotment system is practically not a restricting factor for rice production; C1 = 1 if PF5 ≥PT, otherwise 0; C2 = 1 if year is earlier than 1982 and if PF5≥PVC(SY/100) indicating no participation in the 50/92 option, otherwise 0; C3 = participation coefficient for the 50/92 option; and C4 = 0 if disaster payments are declared, otherwise 0.

If PL≤PAW, the PL-PAW = 0. Prior to 1986, PAW = PL. The PIK program was implemented in 1983. The features were to encourage producers to cut production acreage by another 10% to 30% (or whole base under bidding) in addition to the regular 15% of ARP and 5% of paid diversion. The acreage diverted due to the PIK was paid in-kind with 80% of the established program yield.

Table 2. Comparison of Elasticities with Respect to Own-Price.

	Chen and Ito (1981 crop)	Grant, Beach, and Lin (1982 crop)	Jolly, Fielder, and Traylor (1979 crop)[1]
Acreage planted	0.23	0.13	0.16

Table 3. Impacts of 1% Price Increase on Revenue and Planted Acreage for Three Rice Program Periods.

	Earlier programs (1981 crop)	1981 Farm Bill (1984 crop)	1985 Farm Bill (1987 Crop)
		(%)	
Operating returns			
Participants[2]	2.20	1.22	0.88
Nonparticipants[2]	2.36	2.78	2.76
Participation rate	NA	-0.13	-0.12
Acreage planted			
Participants	NA	-0.20	0.21
Nonparticipants	NA	1.55	40.83
Total	0.23	0.07	0.13

[1] Jolly et al. did not report elasticities; therefore, the elasticity was calculated based on their estimated farm price coefficients and 1979 data.

[2] Participants and nonparticipants for the 1981 crop imply allotment holders and nonallotment holders, respectively.

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