AN EXAMINATION OF MAJOR CROP ACREAGE RESPONSE

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In recent years, several studies have examined acreage response of major crops to various economic, technical, and institutional stimuli. These studies focused primarily upon the influence of government farm programs on producers' production decisions.[1] While the influence of government programs has recently diminished and market forces are more direct determinants, this less stable situation has likely increased informational needs on potential production response. Previously developed response models require updating, additional refinement, or reformulation for continued usefulness in the current situation.

This paper describes a model[2] recently assembled for the two-fold purpose of examining factors influencing acreage response and short-term prediction. Previously reported models and research results were utilized in this construct. Recent changes in major response variable values, far different from historical levels, pose serious challenges for models not reflecting them. Thus, rather pragmatic adjustments to model constructs and variables were made in an effort to enhance potential usefulness. Due to space limitations, description and discussion of the model and results can only be general.

MODEL DESCRIPTION AND RESULTS

Variables

The acreage response model is composed of seven equations, one each for 1) soybeans, 2) corn, 3) cotton, 4) grain sorghum, 5) barley, 6) oats, and 7) wheat.[3] Variables were included to represent own price or policy effects, competing uses for production resources, and factors hypothesized to uniquely affect crop acreage.

Government farm program provisions are usually assumed to be relevant supply response variables in addition to product market prices. The "expected price" variables used in this study are intended to reflect the combined influence of market prices and policy actions. For programs on corn, grain sorghum, cotton, oats, and barley, the concept of an "effective" or "weighted" price developed by Ryan and Abel [9] is used as a means of incorporating both acreage restrictions and announced price supports into a single empirical term.[4] Payments made by the government for withholding land from production (other than by direct acreage restrictions) are treated as acreage supply shifters and incorporated as a separate variable. In the past two years (1973-1974), market prices have been substantially above program rates and supply controls have not been used. For these years, lagged market prices were utilized as "expected prices" rather than the policy variable values (i.e., prices were inserted for policy variable values).

The only government program provision relating directly to soybeans is the loan rate or support price. The market price for soybeans has exceeded the support price in all but two of the 21 years considered. The one-period lagged sea-

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[1] Representative studies include [1, 3, 6, 7, 9, 10, 11, 15].

[2] The model described here is a component of a preliminary version of a production-utilization-inventory commodity system currently being developed and described in [8].

[3] While the equations have been modified to varying extents for use in this system and reestimated for different sample periods, details of original development and construction may be found as follows: equations 1-4 [6, 7], equations 4-6 [10, 11], and equation 7 from [1]. The reader is referred to these sources for more detailed information and interpretation.

[4] Values for policy variables for corn, grain sorghum, oats, and barley are found in [9, 10, 11]. The policy variable for cotton was constructed in a manner consistent with that used for the above crops. Details are in [6].

son average price received by producers was chosen as a proxy for expected price and modified to include influence, if any, of announced support rate. The constructed price series for soybeans is the larger of the weighted season average price lagged one production period (PS_{t-1}) and the announced national support rate (PSS). That is,

$$PS_t = \max\ [PSS_t, PS_{t-1}]$$

Other variables included in the model are attempts to reflect situations peculiar to the crop treated or are straight-forward constructions of trend or lagged variables. An explicit definition of all variables is contained in Table 1.

Estimation Procedure and Results

The seven-equation system, linear in defined variables, was estimated by Joint Generalized Least Squares (JGLS), since it was possible that random disturbances might be contemporaneously correlated across equations.[5] Several alternative estimators have been proposed for joint estimation of coefficients in disturbance-related equations [4]. The one utilized here was introduced by Zellner [16] and is referred to as Zellner's two-stage Aitken estimator.

Data for 1954-74 are utilized in estimating the model. Preliminary data for 1975 are used for predictive evaluation. With 21 observations, there are fourteen degrees of freedom for all equations except equation four, which has thirteen. The estimated model along with variable definitions and t-ratios are presented in Table 1. However, the t-ratios do not have the usual strict interpretation and are of limited value in testing hypotheses about structural parameters in jointly estimated systems of equations.

Space limitations do not permit a detailed discussion of coefficient estimates for each equation. However, individual equations are briefly discussed below. Overall, the model appears satisfactory as judged by conformance of coefficient signs with *a priori* expectations; coefficient magnitudes generally large relative to their standard errors; and explanation of significant amounts of variation.

Soybean Equation. It has been suggested that soybeans have served the function of a "safety valve" in structuring production policies in recent years. That is, controls were applied as needed to feed grains and cotton with the knowledge that, as a substitute, soybean production would absorb much of the loss to individuals from limiting main crop enterprise. Estimates of this equation seem to support the contention for corn, but not as strongly for cotton. Coefficients of corn policy variables and that of own soybean price indicate that soybean acreage was more responsive to feed grain program changes than own price changes, but not very responsive to cotton programs. Thus, depending upon the magnitude of acreage change desired by policymakers, soybean acreage changes may be more effectively brought about by feed grain program provision adjustments than by soybean support rate adjustments.

Corn Equation. Feed grain program provisions applicable to corn have provided policymakers with alternative means of effecting annual acreage adjustments. Diversion provisions provided the most direct means of obtaining short-term acreage changes. Support rate provisions provided an alternate method but are not as influential in acreage changes as diversion provisions. The competitive relationship of corn with soybeans and grain sorghum is evidenced by this equation, but competition is not strong. In terms of relative profitability, it appears that soybeans do not strongly compete with corn, especially in the major corn-producing areas. Also, program changes since 1961 have altered the substitution relationship between corn and grain sorghum. Thus, program provision changes to encourage changes in corn acreage may affect competing crop acreage significantly, but changes in other crop acreages do not significantly affect corn acreage.

Cotton Equation. Cotton is produced across the entire southern United States. Crops grown in conjunction with cotton across this rather wide geographic area vary by region. Variables included in this equation are an attempt to reflect these regional situations. Signs on all coefficients were expected *a priori,* with the exception of the corn acreage variable. Results of the cotton equation reveal a general situation which is plausible. Cotton acreage has been largely influenced by government policies relating to cotton. Some substitution with other crops, namely soybeans and grain sorghum, does occur but competition among them is not strong, i.e., not over a large portion of production given past price ranges. The relationship with corn

[5] In situations such as this, coefficients may be estimated by ordinary least squares (OLS) procedures applied to each equation separately. Such estimates are unbiased and consistent but it cannot be generally asserted that they possess other optimal properties as well. For a discussion of this technique, see [14].

Table 1. JGLS ESTIMATED AGGREGATE RESPONSE MODEL, 1954-74

Equation 1 - Soybeans								
Variable	Constant	PV1C[1/]	PV2C	DVC	PS	ACT(T-1)	TIME	
B	-46,696.0	-8,218.7	-16,221.0	3,371.2	7,371.2	-0.17073	1,144.1	
B/SD	-6.65	-2.90	-2.28	4.05	5.43	-1.75	9.37	
Equation 2 - Corn								
Variable	Constant	PV1C	PV2C	DVC	PS	AGSM	TIME	
B	100,350.0	20,232.0	-32,584.0	7,361.9	-7,943.7	-0.41853	-294.95	
B/SD	12.06	5.86	-3.75	6.87	-5.04	-2.62	-2.28	
Equation 3 - Cotton								
Variable	Constant	PV1CT	AS(T-1)	AGS(T-1)	ACS(T-1)	DDIV	PYDCT	
B	10,750.0	15,854.0	-.090427	-.12145	0.31903	-2,285.8	-31.256	
B/SD	2.43	3.78	-1.06	-.81	1.44	-1.90	-1.09	
Equation 4 - Grain Sorghum								
Variable	Constant	PV1GS	PV2GS	DVC	AWHM	ACTS(T-1)	PS	TIME
B	35,477.0	1,667.2	-13,575.0	3,184.4	-0.89655	-0.010855	-2,125.2	154.58
B/SD	6.32	1.54	-4.90	5.72	-10.87	-.0749	-2.81	1.53
Equation 5 - Barley								
Variable	Constant	PFB	PFO	AW	AWD	DVB	TIME	
B	43,452.0	5,638.9	-11,969.0	-0.20596	-0.035495	-663.31	-243.58	
B/SD	14.36	6.64	-5.59	-4.06	-0.86	-1.36	-5.90	
Equation 6 - Oats								
Variable	Constant	PFO	AW	AWD	DV68	TIME	T SQ	
B	38,9730.0	1,693.9	-0.099135	0.036621	4,365.0	-9,523.8	61.013	
B/SD	8.11	0.74	-1.15	0.49	4.09	-6.50	5.06	
Equation 7 - Wheat								
Variable	Constant	PW(T-1)	RNC	CONACS	EDPRW	ESW	WALLOT	
B	-2,067.6	1,755.4	235.77	-85.30	-2,705.2	2,823.6	0.6410	
B/SD	-0.304	1.12	4.20	-1.53	-1.50	1.62	7.26	

[1/] Variable descriptions:

Endogenous Variables

AS_t = acres of soybeans planted (thousand acres) in year t,
AC_t = acres of corn planted (thousand acres) in year t,
ACT_t = acres of cotton planted (thousand acres) in year t,
AGS_t = acres of grain sorghum planted (thousand acres) in year t,
AB_t = acres of barley planted (thousand acres) in year t,
AO_t = acres of oats planted (thousand acres) in year t,
AW_t = acres of wheat planted (thousand acres) in year t.

Exogenous Variables

PV1C = weighted support rate (\$/bu.) for corn,
PV2C = weighted diversion payment rate (\$/bu.) for corn,
PV1CT = weighted support (\$/lb.) for cotton,
PV1GS = weighted support (\$/cwt.) for grain sorghum,
PV2GS = weighted diversion payment rate (\$/cwt.) for grain sorghum,
PS = larger of national support rate and season average price (\$/bu.) lagged one period for soybeans,
PFB = weighted support rate (\$/bu.) for barley,
PFO = weighted support rate (\$/bu.) for oats,
DVC = zero-one variable to account for changes beginning in 1966 when corn and grain sorghum payments were shifted from inclusion in the calculations of PV1C to PV2C and PV2GS, i.e., 0 in 1954-65, 1.0 in 1966-73, and 0 in 1974,
AGSM = acreage of grain sorghum planted (thousand acres) in 1954-60 and mean of 1950-60 acreage for 1961-74,
ACS_{t-1} = acreage of corn planted (thousand acres) in 15 Southern states, lagged one period,
$PYDCT_{t-1}$ = percent deviation of cotton yield per acre (pounds lint) from "normal" (trend) yield, lagged one period,
DDIV = zero-one variable for Acreage Reserve Program and Conservation Reserve Program-- 0 for all years except 1956-58 when the value is 1.0 (years in which the programs were operational),
AWHM = acreage of winter wheat harvested (thousand acres) in eight states (Texas, New Mexico, Oklahoma, Colorado, Kansas, Nebraska, Missouri and California) for 1954-60 and mean of 1950-60 acreage for 1961-74,
$ACTS_{t-1}$ = acreage of cotton planted (thousand acres) in five states (Texas, New Mexico, Oklahoma, Missouri and California), lagged one period,
Time = 54, 55, ..., 74,
AWD = acreage of wheat diverted (thousand acres),
DVB = 0 in 1957-65, 1 in 1967-71, and 0 in 1972-74 to account for a change beginning in 1966 when support payments for barley were shifted from support prices to diversion payments,
DV68 = 0 in 1956-67, 1 in 1968-71, and 0 in 1972-74,
PW_{t-1} = market price of wheat (\$/bu.), lagged one period,
CONACS = acres of land in Conservation Reserve (million acres),
EDPRW = effective diversion payment rate for wheat (\$/bu.),
ESW = effective support rate for wheat (\$/bu.),
WALLOT = acres of wheat allotment (thousand acres),
TSQ = time square (i.e., t = 54, t^2 = 2916),
RNC = index of range and pasture (moisture) conditions in Western states on the previous October 1.

is less definite but results suggest that cotton acreage is not greatly influenced by corn acreage changes. Thus, policy actions directed toward cotton are most effective in obtaining acreage changes, policies affecting acreage of other crops having little indirect influence on cotton acreage.

Grain Sorghum Equation. The feed grain policy variables for grain sorghum are central in explaining acreage. Winter wheat was strongly competitive prior to cross-compliance program restrictions instituted in 1961. Cotton and soybeans, as represented here, are revealed to have little competitive influence. This suggests that major alterations in grain sorghum acreage are more responsive to changes in programs or, as in recent years, to own price. As with corn, the diversion payment rate variable is a larger determinant of acreage than the weighted support rate. A ten cent per bushel change in the diversion payment rate produces a 1.4 million acre change in the opposite direction, *ceteris paribus,* while a like change in the support rate produces a much smaller change of 167 thousand acres in the same direction.

Barley Equation. A strong competitive relationship is indicated between barley and oats and wheat, but only a moderately competitive relationship with wheat acreage diversion. The decline in barley acreage over time is reflected in the trend variable.

Oats Equation. The acreage of oats is influenced by the effective support price for oats and, to a lesser extent, by wheat acreage. Wheat acreage diversion has only a minimal influence. The decline in oat acreage over time is also reflected in the variables representing trend.

Wheat Equation. Variables included in this equation relate primarily to wheat acreage only. They indicate the influence of programs, market price, and planting conditions. Support and diversion payment rates have substantial impacts on acreage as does market price.

Overall, the estimated model generally tends to support major hypothesized relationships such as degrees in competitiveness among certain crops, varying influences of program provisions on specific crops, etc. A detailed examination of estimated equations reveals the cotton equation to be the least satisfactory. Also, certain variable specifications in selected other equations need additional review. Efforts toward effecting such improvements are continuing.

EVALUATION OF MODEL PREDICTIVE ABILITY

Development of a device capable of generating reliable short-term prediction was an objective of this study. Ideally, to evaluate predictive ability, several of the most recent observations (in this case, annual) would be excluded from use in parameter estimation and used in ex-post forecast evaluation. However, the recent period of significantly changed (and changing) commodity price levels along with cessation of government supply controls precluded this. Variable values for this recent period were far outside the range of historical values. It was deemed necessary to use all observations available for parameter estimation. This, of course, severely limits evaluation of the model's predictive ability, but some notion may be gained from sample period performance. One such measure is provided by Theil's inequality coefficient [13], which may take values from zero to infinity.[6] When U is zero the model forecasts perfectly, whereas at unity it gives the same results as a naive no-change model (i.e., $p_{t+1} = a_t$, where p_{t+1} is the predicted value in t+1 and a_t the actual value in t).

A naive no-change model provides a useful standard for comparison. It is the simplest and cheapest possible method of forecasting, representing a minimal standard against which to judge alternative methods. Also, it indicates inter-period movement of the series and thus the inherent difficulty of forecasting the variable under consideration.

Actual and predicted acreage values from the JGLS estimated equations for 1974 and conditional predictions for 1975 are shown in Table 2. Inequality coefficient (U) values for the period of fit (1954-74) were calculated for forecasts from each of the estimated equations and are shown in Table 3.

The corn, soybean, grain sorghum, oat, and wheat equations produced forecasts substantially improved over no-change forecasts. Forecasts from the cotton equation are only slightly better than no-change forecasts, and are amenable to improvement.

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[6] The definition of the inequality coefficient used here is

$$U = \frac{\sqrt{\Sigma(P_i - A_i)^2}}{\sqrt{\Sigma(A_i - A_{i-1})^2}}$$

which is a conversion of Theil's U_2, applicable to *change* models, to one applicable for variables expressed in *levels.*

Table 2. ACTUAL AND PREDICTED PLANTED ACRES, BY COMMODITY, U.S. 1974-75*

Commodity/year	Actual*	Predicted**	Deviation	% Deviation
	(1,000 acres)			
Soybeans				
1974	53580.	54791.	1,211.	2.26
1975	56632.	58911.	2,279	4.02
Corn				
1974	77353.	78251.	898.	1.16
1975	75290.	78741.	3,451.	4.58
Cotton				
1974	14278.	13496.	782.	5.48
1975	9884.	13099.	3,215	32.53
Grain Sorghum				
1974	17684.	18649.	965.	5.46
1975	18855.	18788.	67.	0.36
Barley				
1974	9203.	9144.	58.	.64
1975	10184	9517.	667.	6.55
Oats				
1974	18310.	18093.	217.	1.18
1975	18189	17788	401.	2.21
Wheat				
1974	69963.	71543.	1,580.	2.26
1975	73218.	72773.	445.	0.61

*Prospective plantings, SRS-USDA, March 1975.

**These predictions are for model validation only and do not represent official predictions of the U.S. Department of Agriculture.

Several additional methods might be used for forecast evaluation, but the inherent difficulty of small sample size due to use of annual data poses problems, as most data years are needed in parameter estimation. Since only one preliminary observation (1975) is available outside the range of data used for estimation (for comparison with forecast values), little would be gained from employing additional forecast evaluation tests.

On balance, however, the U coefficient criterion and an examination of the magnitude of forecast errors for 1974-75, provide some assessment of the model's potential predictive capabilities. The results suggest that it could prove useful as a short-run predictive device if caution is exercised. The estimation should be updated annually as new data become available, and used to extend forecasts only one period into the future.

Table 3. INEQUALITY COEFFICIENTS, BY EQUATION, 1954-74

Equation	Inequality coefficient (U)
Equation (1) soybeans	.36
Equation (2) corn	.26
Equation (3) cotton	.76
Equation (4) grain sorghum	.27
Equation (5) barley	.56
Equation (6) oats	.39
Equation (7) wheat	.38

CONCLUSION

The recent dramatic changes in production, price levels, and influence of government production programs are outside the historical range of observation. This poses serious difficulties for models based upon time series data, as both periods of strong farm program influence and periods of practically no farm program influence must be utilized. Rather than waiting for passage of time sufficient to produce enough usable observations, attempts must be made, utilizing existing data, to develop constructs capable of generating useful information. The model presented here is an attempt to bridge the so-called "controlled" and "free market" periods. While any assessment of overall usefulness is tentative and caution must be exercised in use, preliminary evaluation suggests useful information may be obtained.

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