Acreage Supply Models and Forecasts: Corn, Soybeans and Wheat

by

Leonardo Green, Abner Womack, and Robert Young, III

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Government agricultural program objectives are pursued through program features aimed at controlling the acreage supplied for different crops. Agricultural income and prices are related to acreage planted and harvested over time. Hence, the efficient management of government programs requires acreage response information to determine their effect on farm income, government costs and market prices while the planning process of the service sector may be substantially improved if reliable acreage forecasts are available.

Substantial research has been done concerning farmers response to income and price stabilization programs, and in response to their attitudes towards risk. A typical supply response function includes economic relationships, weather effects and government program variables. Economic data lend themself to quantification since the theoretical relationships with acreage response is well documented. Measurement of the weather impacts on area harvested and yields has improved, but reliable weather forecasts are still non existent. Policy program variables, including program participation, have been examined via the development of effective support rate and effective diversion rate.

Several specifications were tested for alternative quantification of policy variables. Specifications must be crop specific to represent the policy program for each crop. Regional and aggregate specifications

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have also been used to examine the effects of government program variables. Further extensions to the use of policy variables (effective diversion and support rates) were derived from theoretical models that incorporate the probability distribution of price outcomes formed by the producers.

This paper presents the results of various techniques advanced by researchers for the estimation of acreage supply. Only those specifications that produced superior results are reported. No single specification produces superior results for all crops. Therefore, differentiation is made by commodity model for corn, soybeans and wheat, acreages. A short description of policy programs for each crop is presented. Secondly, a description of models employed to estimate acreage supply responses by commodity, is offered. Thirdly, a "How to Kit" for development or quantification of policy variables, using 1982, 1983, and 1984 as example years, is presented. Lastly, forecasts for 1982 to 1984 are used to evaluate the models performance.

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Discussion of Policy Variables

Government programs are intended to achieve a number of objectives. The current farm bill includes CCC loan and purchase programs to support prices, as well as provisions to increase exports and farm income. The farmer-owned reserve is extended and enhanced with a unique feature which allows non-recourse loans to farmers for a longer time period. Supply control programs including set-asides, acreage limitations, paid diversion, and allotments are continued with minor changes in the methods used to set support prices, target prices and production controls.

Corn

Effective support rate and effective voluntary diversion rate variables are developed to capture the effect of policy objectives on corn acreage supply. The functional form of this specification is consistent with the research done by Gallagher in 1978. Gallagher differentiated between producer response when facing weak market conditions versus strong market conditions. Supply shifters such as expected prices for competitive crops and a variable quantifying risk (developed by Ryan) price are also included in this specification. The basic Houck and Ryan formulation of policy variables is retained. Expected price is a combination of government policy variables and market prices in a complicated functional form.

$$PEC = CORPE1 + \gamma_1 [(CORD + 1) \cdot LN (CORD + 1) - CORD] = \text{expected price.}$$

$$PECCAC = PEC/CORVC$$

where

CORPE1 = corn effective price support

$CORD = PM_{t-1} - CORPE1$

PM_{t-1} = previous crop year market price

CORVC = corn variable cost per acre

γ_1 = the extent of producer adjustment between support and market price.

This specification employs this manufactured price expectation relative to per acre cost of production for the competitive crop, soybeans.

$$PES = SOYPE + \gamma_2 [(SOYD + 1) * lu (SOYD + 1) - SOYD] = \text{expected price.}$$

$$PECCAS = PES/SOYVC$$

where

$SOYD = SOYPF_{t-1} - SOYPE$

SOYPE = Soybeans effective price support

$SOYPF_{t-1}$ = Soybeans previous crop year market price

SOYVC = soybeans variable cost per acre.

γ_2 = the extent of producer adjustment between support and market price.

In addition to the above variables, this specification utilizes corn policy and a risk term. To quantify the government policy features an effective support rate and an effective diversion rate is constructed.

<u>Effective Support Rate</u> (CORPEI)

The effective support price for corn can be constructed as follows:

$PF = \frac{1}{n} \sum_i r_i PA$ i = 1, 2, ..., n program options

W_i = AD/AT or required percent acreage reduction, i.e. 10% RAP.
AP = acreage planted
AT = Total loan acres, i.e. AP + Acres Set Aside + Acres diverted
AD = Diverted acres.

$r_i = 1 - W_i$

PA_i = Total government payment in planted acres

PA_i = loan + expected deficiency payment

where the deficiency payment is:

Deficiency payment = Target - loan, if loan $\leq PM_{t-1}$

= Target - PM_{t-1}, if loan < $PM_{t-1} \leq$ target

= 0 if $PM_{t-1} \geq$ target.

PM_{t-1} = Lagged market price

hypothesis that farmers will not adjust completely in the near term to large price changes.

Since no land control programs exist for soybeans, the effective support rate is the loan rate. The indirect policy effects coming from competitive crops, mainly corn, are the effective support and effective diversion rates. These are constructed as shown in the previous section.

Wheat

Wheat acreage supply functions are consistent with those developed by Houck et. al, Hoffman, Gallagher, and Bailey. Five distinct, separate, homogeneous U.S. production regions are employed to obtain regional supply equations since it is contended that producer decision processes differ by region. Therefore, the results obtained here should be superior to any single aggregate acreage supply function.

This specification, while using the basic Houck and Ryan formulation, slightly alters the way the policy variables are constructed. The supply inducing price in this equation is a weighted average of market and effective support price.

$$EP_{ji} = PRI_{ji}.PF_{ji} + PRO_{ji}.PM_{ji}$$

where

PRI_{ji} = percent of acreage complying with the farm program of commodity $_j$ in region i

PRO_{ji} = percent of acreage not complying with the farm program of commodity j in region i

PF_{ji} = effective support price for commodity j in region i

PM_{ji} = lagged season average price received by farmers for commodity j in region i

A general theoretical model is specified, with modifications in program design beginning in 1974.

1961-1973

$$PF_i = \delta\,(P_i + GPn) = \delta\,(PA_i)$$

1974-1981

$$PF_i = \delta\,(P_i + EDPn) = \delta\,(PA_i)$$

where $P_i = LR_i$ if $LR_i \geqq PM_{t-1,i}$

$= PM_{t-1,i}$ if $LR_i < PM_{t-1,i}$

LR_i = regional average loan rate

$PM_{t-1,i}$ = regional average farm price in year t-1

$PA_i = P_i + GPn$ (1961-1973), $P_i + EDPn$ (1974-1981)

PF_i = effective support rate, region i

δ = a weighting factor reflecting planting restrictions.

GPn = national government direct payments

EDPn = national deficiency payment

Finally,

$$PF = \frac{1}{n} \sum_{i=1}^{n} (\delta_i\, PA_i)$$

where $\delta_i = 1 - W_i$,

W_i = regional government acreage reduction for participation level

PA_i = total government payment on acreage planted by participants.

The δ_i (weighting factor) takes into consideration varying levels of participation in the farm program.

The effective diversion payment DP is calculated as follows:

$$DP = \frac{1}{n} \sum_{i=1}^{n} (W_i \; PR_i)$$

where

DP = effective voluntary diversion rate

PR_i = payment rate for diverted or set-aside land, for a given level of participation.

In this case, PA reflects payments on acreage planted while PR reflects payment on diverted or set-aside acreage.

This specification differs from that of Ryan and Abel in that market price is utilized in calculating the supply inducing price EP_{ij} hence, a separate variable reflecting of market price is not necessary resulting in the reduction of multicollinearity and the conservation of degrees of freedom.

Description of Results

Corn Acreage Supply Function

This model was estimated via ordinary least squares over the period 1961-1981 annual data. The statistical properties of this model are quite acceptable (Table 1). The R^2 exceeds 96 percent, indicating the capacity of the variables to explain variations in corn acreage over time. The t-statistics indicate that all independent variables are statistically related to corn acreage, hence implications concerning structure and policy effects may be drawn from the estimates. Acreage response per unit change in expected price is evaluated at the mean to be 0.13, which is consistent with other studies (Houck, Gallagher). The cross price effect with soybeans is estimated at only .08. The risk coefficient suggests that corn acreage expansions are an average of 2.88 million acres lower than if risk hadn't been a factor. The lagged dependent variable is also statistically significant in explaining historical corn acreage variation.

Soybeans Acreage Supply Function

The impact of government policy on soybeans acreage supply stems from price support loans and for soybeans and from the indirect effects of price support and acreage control programs for competitive crops. The model given in Table 2 emphasizes the relationship between soybeans and corn, cotton, and the strong trend observed in soybeans acreage through time. This model was also estimated using ordinary least squares for the sample period 1961 and 1981.

The market relationship of soybeans with corn and cotton are captured by the first two variables in the model. In addition, the indirect effect of policy programs for alternative crops is reflected in the ratio of the corn effective diversion rate to corn price. Lagged soybeans acreage accounts for the trend behavior in soybeans acreage.

The lagged dependent variable dominate the remaining variables when explaining soybeans acreage. The support price for soybeans has a positive effect on soybean acreage even though the market price relationship of soybeans with corn and cotton are also included in the model's specification.

Table 1. CORN PLANTED AREA (CORSA), OLS 1961 - 1981

Variable	Coefficient	t-Statistic	R_2	MSE	DW
Intercept	52.168	8.538	0.965	2.73	2.447
PECCAC	500.328	2.124			
PECCAS	-62.568	-1.271			
CORPDI/					
$CORPF_{t-1}$	-68.919	-8.251			
RISK	- 2.88	-1.842			
$CORSA_{t-1}$	0.326	5.374			
Dummy 66-72	4.913	4.570			

DUMMY 66-72 = 1 if year == 1966 and ≤ 1972, included to account for a change in the method of calculating direct support payments between 1966 and 1972.

Table 2. SOYBEAN PLANTED AREA, (OLS 1961 - 1981)

Variable	Coefficient	t-Statistic	R^2	MSE	DW
Intercept	-18.819	5.046	0.992	2.30	1.851
$SOYPF_{t-1}/CORPF_{t-1}$	9.186	8.051			
$SOYPF_{t-1}/COLPF_{t-1}$	0.462	2.848			
SOYPE/CORPE1	1.912	1.911			
$CORPD1/CORPF_{t-1}$	-20.544	-2.420			
$SOYSA_{t-1}$	0.821	21.057			
DUMMY 1974	- 4.555048	-2.7040			

SOYSA - soybeans acreage planted
SOYPF - soybeans average price received by farmers
CORPF - corn average price received by farmers
COLPF - cotton average price received by farmers
SOYPE - soybeans effective support rate
CORPE - corn effective support rate
CORPD1 - corn effective diversion rate

All coefficients have large t-statistic confirming the postulated relationships and over 99 percent of the variability in the historical series for soybeans acreage is explained by this set of variables.

Conclusions made by Houck are supported by this model. Both the corn program and corn price have a substantial impact on soybean acreage since both crops compete for planted acreage. Furthermore, due to the absence of acreage controls or marketing controls for soybeans, market forces have a direct and strong influence on planted acreage.

Wheat Acreage Supply Function

The wheat equations are presented in Table 3. Specifications are developed by Bailey. The OLS results for all regions suggest the included explanatory variables indeed relate to planted wheat acreage. The only exception was variable costs of production. According to Bailey, the variable cost of wheat production increased at a greater rate over time than wheat prices creating downward pressure on the deflated price variable yielding a negative relationship with acreage planted.

The expected price of wheat, constructed as previously discussed, was statistically significant in all regions with the magnitude of its coefficient varying according to region. The effective voluntary diversion rate was significant in only region 2, the northern plains. The competitive crops included in each regional specification differed according to the region being analyzed. As such, cotton was used as a substitute crop in the southern plains while oats reflected the primary substitute in the northern plains. Weather variables were also statistically related to acreage planted, and yielded different results for each region. As such, above normal precipitation in the arid southern plain would increase wheat acreage, while above average precipitation reduced wheat acreage in the northern plains. The statistically significant lagged dependent variables for most regions suggest that producers do not adjust wheat acreage instantaneously to changes in price and technology.

Calculated elasticities from this research are given in Table 4. The price elasticities suggest that the southeast and northwest regions have become relatively more price responsive, the cornbelt price responsiveness has remained stable, and the northern and southern plains have become less price responsive over time.

Table 3. WHEAT AREA PLANTED EQUATION BY REGION, (OLS 1962 - 1981)

Variable	Coefficient	t-statistic	R^2	SSE	DW
SOUTHERN PLAINS					
Constant	13215.760	3.025	0.882	40040475	1.977
WTBEP1	3267.104	3.697			
WHEEDRR1	-4378.970	-0.831			
CTBEP1	-14.485	-0.303			
DFN1	286.065	0.983			
RISK1	-1142.470	-1.557			
WHLRPTR1	0.357	2.083			
NORTHERN PLAINS					
Constant	20277.110	3.965	0.934	26691485	2.317
WTBEP2	980.481	1.601			
WHEEDRR2	-7244.610	-1.857			
OATRPTR2	-1.278	-2.927			
RISK2	-19.090	-0.056			
DFN2	-338.195	-1.609			
WHLRPTR2	0.332	2.556			
NORTHWEST					
Constant	1958.894	2.198	0.860	4607962	1.961
WTBEP3	456.080	1.801			
WHEEDRR3	-1220.500	-0.787			
RISK3	-50.443	-0.349			
WHLRPTR3	0.550	2.899			
CORNBELT					
Constant	7218.692	3.792	0.788	9218074	1.866
WTBEP4	1791.692	5.338			
WHEEDRR4	-567.406	-0.266			
SOYRPTR4	-0.1824	-3.511			
RISK4	-386.554	-1.021			
WHLRPTR4	0.1159	0.703			
SOUTHEAST					
Constant	-1080.570	-1.098	0.663	11560451	1.112
WTBEP5	748.258	2.323			
WHEEDRR5	-550.190	-0.228			
RISK5	-514.374	-0.918			
WHLRPTR5	0.9687	2.545			

(continued)

Table 3. WHEAT AREA PLANTED EQUATION BY REGION, (OLS 1962 - 1981) (continued)

VARIABLE DESCRIPTION LIST:

Southern Plains

WHERPTR1	Wheat, all types, acreage planted, region 1, 1,000 acres.
WTBEP1	Wheat, all types, expected price, region 1, $/bu.
WHEEDRR1	Wheat, all types, effective voluntary diversion rate, region 1, $/bu.
CTBEP1	Cotton, upland, expected price, region 1, $/cwt.
DFN1	Weather departures from normal precipitation, region 1, inches.
RISK1	Regional price risk variable, region 1.
WHLRPTR1	Wheat, all types, lagged acreage planted, region 1, 1,000 acres.

Northern Plains

WHERPTR2	Wheat, all types, acreage planted, region 2, 1,000 acres.
WTBEP2	Wheat, all types, expected price, region 2, $/bu.
WHEEDRR2	Wheat, all types, effective voluntary diversion rate, region 2, $/bu.
OATRPTR2	Oats, acreage planted, region 2, 1,000 acres.
RISK2	Regional price risk variable, region 2.
DFN2	Weather, departures from normal precipitation, region 2, inches.
WHLRPTR2	Wheat, all types, lagged acreage planted, region 2, 1,000 acres.

Northwest

WHERPTR3	Wheat, all types, acreage planted, region 3, 1,000 acres.
WTBEP3	Wheat, all types, expected price, region 3, $/bu.
WHEEDRR3	Wheat, all types, effective voluntary diversion rate, region 3, $/bu.
RISK3	Regional price risk variable, region 3.
WHLRPTR3	Wheat, all types, lagged acreage planted, region 3, 1,000 acres.

Cornbelt

WHERPTR4	Wheat, all types, acreage planted, region 4, 1,000 acres.
WTBEP4	Wheat, all types, expected price, region 4, $/bu.
WHEEDRR4	Wheat, all types, effective voluntary diversion rate, region 4, $/bu.
SOYRPTR4	Soybeans, acreage planted, region 4, 1,000 acres.
RISK4	Regional price risk variable, region 4.
WHLRPTR4	Wheat, all types, lagged acreage planted, region 4, 1,000 acres.

(continued)

Table 3. WHEAT AREA PLANTED EQUATION BY REGION, (OLS 1962 - 1981) (continued)

Southeast

WHERPTR5	Wheat, all types, acreage planted, region 5, 1,000 acres.
WTBEP5	Wheat, all types, expected price, region 5, \$/bu.
WHEEDRR5	Wheat, all types, effective voluntary diversion rate, region 5, \$/bu.
RISK5	Regional price risk variable, region 5.
WHLRPTR5	Wheat, all types, lagged acreage planted, region 5, 1,000 acres.

Southern Plains: Wyoming, Colorado, Nebraska, Kansas, Oklahoma, Texas, New Mexico.
Northern Plains: Montana, Minnesota, North Dakota, South Dakota.
Northwest: Washington, Oregon, California, Nevada, Utah, Arizona.
Cornbelt: Wisconsin, Iowa, Missouri, Ohio, Illinois, Indiana, Michigan, and 11 other northeast states.
Southeast: Arkansas, Louisiana, Mississippi, Alabama, Kentucky, Tennessee, West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida.

$$MAC_{ij} = .33\left(\sum_{K=2}^{4} PM_{ij-K}\right)$$

$$RISK_{ij} = (PM_{ij-1} - MAC_{if})^2/MAC_{ij}$$

where PM_{ij} = season average farm price for commodity i in region j.

Table 4. Summary of Response Elasticity, Market Price

	Mean	1981
S. Plains	0.246	0.333
N. Plains	0.128	0.167
Northwest	0.172	0.226
Cornbelt	0.547	0.698
Southeast	0.620	0.374

Development of Policy Variables For 1982, 1983, and 1984

Assuming the effective support rate and the effective voluntary diversion payments are estimated appropriately, the models presented above appear to capture the essence of the various control programs for the crops sector. That is, it is possible to combine, in a few quantitative variables, the price and income supporting features of annual commodity programs and their acreage controlling aspects. Hence, in the absence of a satisfactory theory on acreage response, continuous and improved research is needed to quantify the policy variables properly. On the other hand, research is also needed to develop these measures for new types of farm programs, such as PIK, if proper analysis of these programs are to be conducted. In this section attention is focused on the construction of these quantitative policy variables.

Corn and Soybeans

Two policy variables will be constructed - the effective support price and the effective diversion rate.

Effective Support Rate

In 1982 the corn program consisted of a 10% RAP, with the loan rate set at $2.55 and the target price set at $2.70. The effective support price for 1982 can be calculated applying the formula above given in the policy sections.

$PF = \gamma$ [loan + deficiency payment]

$w = 10\%$ i.e. $\gamma = 90\% = .90$

$PF = .90\ [2.55 + .15] = \$2.43$

Since the corn program offered only one option in 1982, no averaging over a number of options is necessary.

In 1983, three basic options were announced for corn. These were: (1) 10% set aside with a 10% paid diversion, (2) 10% set aside, 10% paid diversion, and a 30% maximum PIK, and (3) 10% set aside with up to 90% PIK. Additionally, the loan rate was set at \$2.65, target price at \$2.86, and \$1.50 as the diversion payment.

In option 1, 80% is planted, i.e., $r = .80$. For option 2, $r = .50$, the amount planted, and $r = 0.0$ for the third option.

$$PF = \frac{PF_1 + PF_2 + PF_3}{3}, \text{ where}$$

$$PF_1 = .80\ [2.65 + .21] = \$2.288$$

$$PF_2 = .50\ [2.65 + .21] = \$1.43$$

$$PF_3 = 0\ [2.65 + .21] = \$0.0$$

The average PF for the three options yields the effective support rate for 1983.

$$PF_{83} = 1/3\ [2.288 + 1.43 + 0.0] = \$1.24$$

For 1984, three possible options are examined. They are 0%, 10%, or 15% RAP. The loan price is \$2.55 with the target price set at \$3.03. PM_{t-1} is estimated at 3.30. The effective support rate is calculated as follows:

0% RAP
$$PF_1 = 1.0\ [2.55 + 0] = \$2.55$$

10% RAP
$$PF_2 = 0.90\ [2.55 + 0] = 2.29$$

15% RAP
$$PF_3 = 0.85\ [2.55 + 0] = 2.17$$

10% RAP - 10% PIK $PF_4 = 0.80\ [2.55 + 0] = 2.04$

Effective Diversion Rate

In 1982, no diversion program was announced, consequently the DP is zero.

Table 5

Summary Table for Corn Policy Options

	LOAN	TARGET	DIV PAY	PIK PAY	EFFECT SUPPORT	EFFECTIVE DIV PAY
82/83	2.55	2.77	-	-	2.43	-
83/84	2.65	2.86	1.50	80% base	1.24	1.00
84/85	2.55	3.03	-	-	-	-
0% RAP	2.55	3.03	-	-	2.55	-
10% RAP	2.55	3.03	-	-	2.29	-
10% RAP - 5% P.D.	2.55	3.03	1.50	-	2.17	.075
15% RAP - 5% P.D.	2.55	3.03	1.50	-	2.04	.075
10% RAP - 10% PIK	2.55	3.03	1.50	-	2.04	.150
10% RAP - 10% PIK	2.55	3.03	-	70% base	2.05	.18
15% RAP	2.55	3.03	-	-	2.17	-
10% RAP-10% P.D.- 10% PIK	2.55	3.03	1.5	70% base	2.04	.24

Wheat

The wheat acreage function does not separate effects of government prices and market prices. Rather, by using the percentage of acreage within or outside the program it is possible to obtain a weighted price, the expected price.

In 1982 the program in place was a 15 RAP, with a loan rate of \$3.55 and a target price of \$4.05. Therefore,

$$PF = .85\ (3.55 + .50) = \$3.44$$

In 1983 the wheat program consisted of a 15% RAP, 5% DIV and a 10-30% PIK. The loan rate was set at \$3.65 and the target price at \$4.30. Diversion payment was \$2.70 on 95% base yield payback. For 1984, the announced program consist of a 30% RAP and a 10-20% PIK, with the

In 1983 three options were available: (1) 10% set aside with a 10% paid diversion, (2) 10% set aside, 10% paid diversion, and a maximum of 30% PIK, (3) 10% set aside - paid diversion, 90% PIK. The payment rate on diverted acres is $1.50. In the case of the PIK program, this option is treated the same as a paid diversion. This formulation values the PIK grain at the loan rate for the 80 percent payment in kind of base acreage yield. The effective diversion payment in 1983 is constructed as follows:

$$PD_1 = .10\ (1.5) = .15$$

$$PD_2 = .10\ (1.5) + .30\ (.8)\ (2.65) = .786$$

$$PD_3 = .10\ (1.5) + .9\ (.8)\ (2.65) = 2.058$$

$$PD_{1983} = \frac{PD_1 + PD_2 + PD_3}{3} = \$1.00$$

The 0.8 refers to a PIK payment at 80% of base yield.

In 1984 the program options considered are:

1. 5% paid diversion $= .05\ (1.5) = .075$
2. 10% paid diversion $= .10\ (1.5) = .150$
3. 10% PIK at 70% base yield payback = $= .10(.70 * 2.55) = .18$
4. 10% paid diversion plus option of 10% PIK at 70% base yield payback = $= \frac{1}{2}\ [.10(1.5)] + [.10(1.5) + .10(.7)(2.55)]\ \frac{1}{2}$ $= \frac{1}{2}\ (.15 + 33) = .24$

Table 5, a summary table, contains the effective support rate and effective diversion payments for 1982 and 1983. It also contains several program options for 1984.

In the case of soybeans, the effective support rate becomes the loan rate since no acreage control program exists.

loan rate at $3.30 and target price at $4.45. PIK payment is on a 75% base yield. Additionally, several options which have been suggested is examined. The results for these options are shown on Table 7, a summary table for wheat programs.

Model Forecasts

To gauge the performance of the acreage supply functions and their ability to produce reliable forecasts, values will be estimated for 1982, 1983, and for the various options in 1984.

Comparing the results obtained from these models in the forecast mode (1982 through 1984) to the actual values in addition to the performance of these models over the historical acreage series, imply the value of these models for outlook and policy analysis. Barring any major structural changes in farm policy, these models should continue to forecast well with minor adaptations for the effective diversion rate and effective support rate.

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