An Evaluation of the Forecasting Accuracy of Alternative Acreage Supply Response Models

by

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Agricultural economists have devoted considerable attention in the past to the specification and estimation of econometric models of crop acreage supply. The impetus for this continuing effort in modeling acreage supply response has stemmed from several sources, including the use of acreage supply models in private decision-making and in the analysis of the effects of agricultural policies. Despite this attention, however, and despite the often-cited use of acreage supply models for forecasting purposes, most analyses have been largely concerned with modeling historic acreage supply trends, and have devoted relatively little attention to the forecasting ability of estimated models. An explicit comparison of the forecasting ability of three different acreage supply models is the principal objective of this paper.

A primary reason for the attention given to the modeling of crop acreage supply has been the attempt to improve on prior specifications of models incorporating structural change in acreage supply response. For many economic relationships, understanding structural change has been hampered by a lack of knowledge regarding the causes, timing, and effects of these changes, leading to a variety of proposed approaches, including the use of switching regression models (Goldfeld and Quandt), random coefficient regression models (Swamy), and spline functions (Poirier).

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In examining changes in crop acreage supply response, however, particularly for those crops which are the object of government price support and acreage control programs, it is apparent that the most important structural changes in crop supply response have often been those caused by the introduction, termination, or changes in those government programs. Given continual changes in wheat and feed grain programs, for example, researchers have often been led to devote particular attention to the impact of changing program provisions on crop acreage. The models evaluated below represent three different methods for forecasting crop acreage supply based on alternative methods for integrating government farm program variables in supply response models.

In what follows, we first review these three different types of acreage response models. Two of the models, the "effective price" approach and the Food and Agricultural Policy Simulator (FAPSIM) model developed by the Economic Research Service of the U.S.D.A., have been described extensively elsewhere and are reviewed only briefly here. The third, "disaggregated" approach to supply response modeling has appeared less frequently in the literature and is described in somewhat more detail. Following review of the three models, their ability to forecast annual U.S. planted crop acreages is evaluated over the five year period, 1978-1982, for three principal grain crops, corn, soybeans, and wheat. The forecasting abilities of the three models are then compared, and finally, the advantages and disadvantages of each approach are reviewed.

Government Farm Programs and Crop Acreage Supply

Numerous crop acreage response models have been formulated and estimated for a wide variety of crops, regions, and time periods, and using a variety of estimation procedures. While a review of these studies is beyond the scope of this paper, crop acreage forecasts have generally been derived from two types of models. First, and most common, are the relatively small scale econometric models which have often been developed for analytic purposes, for example, in analyzing the effects of farm programs. These models generally involve the direct estimation of reduced form acreage supply equations, using single or multiple equation estimation procedures. These small scale reduced form models have been used in modeling acreage supply response for corn (Houck and Ryan; Whittaker and Bancroft), wheat (Garst and Miller; Lidman and Bawden), soybeans (Heady and Rao; Houck and Subotnik), and other crops. The "effective price" and "disaggregated" models reviewed below are examples of this type of model.

A second category of models attempts to explain crop acreage supply in the broader context of a simultaneous equation system, often with an explicit forecasting aim. These estimated models have been both small scale (Penn and Irwin) and large scale, the latter group including the agricultural sector models which have been developed by private econometric forecasting firms (see Chen, for example), USDA, and others. While the development of these models involves a considerably more complex modeling effort and greater expense in model estimation and maintenance, they have the potential for more accurate forecasting because of their greater detail and completeness. The FAPSIM model evaluated here is representative of the large scale simultaneous equation models.

The "Effective Price" Model

The effective price model was initially developed by Houck and Subotnick in an analysis of U.S. soybean acreage response. The approach is based on the argument that in years in which acreage controls are required for producers to receive crop price supports, announced support levels must be weighted by the accompanying planting restrictions to reflect the limited availability of program benefits. Specifically, if P_a is the announced price support level, then the effective price support P_f is calculated as (Houck, et al.):

$$(1)\ P_f = r(P_a) = 1/2 \left[\frac{A_{min}}{A_{base}} + \frac{A_{max}}{A_{base}}\right] P_a$$

where r is an "adjustment factor;" A_{min} and A_{max} are, respectively, the minimum and maximum levels of planted acreage permitted under the program; and A_{base} is the historically determined crop acreage base. Parameter r decreases in magnitude as the acreage limitation becomes more and more restrictive. Conversely, for years in which no acreage limitations are required of participating producers, r = 1, and $P_f = P_a$. Houck, et al. suggest an analogous procedure for weighting acreage diversion payments to reflect the actual availability of those payments.

Through use of the above weighting procedures, announced price supports and diversion payments associated with the feed grain and wheat programs of the past three decades are adjusted to reflect their "effective" impact on grain producers, and are then included, along with other determinants of crop acreage supply, as independent variables in acreage supply equations. This procedure has been used extensively to integrate farm program benefit and constraint levels in supply response models. Studies using the procedure have included analyses of corn acreage response (Houck and Ryan; Ryan and Abel; Reed and Riggins), soybean acreage supply (Houck and Subotnik; Kenyon and Evans), and multiple commodity supply analyses (Penn; Walker and Penn; Houck, et al.).

For forecasting purposes here, the crop supply equations developed by Houck, et al. for the U.S. through 1974, are updated, estimated, and used to evaluate, ex post, the forecasting accuracy of the "effective price" approach for the period 1978-1982. This procedure involved the estimation of five equations for each of the three crops, corn, soybeans, and wheat; 1978 acreage forecasts were derived from the regression equation using 1950-77 data; 1979 forecasts were derived from an estimated equation using 1950-1978 data; etc. Equations were estimated, following Houck, et al., by ordinary least squares.

Although the large number of individual supply equations estimated prevents the listing of all estimation results,[1] in general form, the "effective price" equations estimated were as follows:

(2) Corn: $$A_{ct} = A_{ct}(\frac{PIC_t}{PS_{t-1}}, DPC_t, PSS_t, AGM_t, DV_t, T)$$

(3) Soybeans: $$A_{st} = A_{st}(\frac{PS_{t-1}}{PC_{t-1}}, DPC_t, PSS_t, PIC_t, AS_{t-1})$$

(4) Wheat: $$A_{wt} = A_{wt}(PW_{t-1}, PFW_t, DPW_t, RNC_t)$$

where: A_{ct}, A_{st}, A_{wt} = corn, soybean, and wheat planted acreage in year t (1,000 acres)

PIC_t = effective corn price support in year t (1950-1971); corn market price in year t-1 (1972-82) (cents per bushel)

PS_{t-1} = soybean market price in year t-1 (cents per bushel)

DPC_t = effective corn diversion payment in year t (cents per bushel)

PSS_t = effective soybean price support in year t (cents per bushel)

AGM_t = sorghum planted acreage in year t (1950-1960); 1948-1959 average sorghum acreage (1961-1982)

DV_t = dummy variable representing change in form of diversion payment (= 0: 1950-1965 and 1974-1982; = 1: 1965-73)

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[1]Estimation results are available from the senior author.

T	= trend (1 = 1950; 2 = 1951; etc.)
PC_{t-1}	= corn market price in year t-1 (cents per bushel)
PW_{t-1}	= wheat market price in year t-1 (cents per bushel)
PFW_t	= effective wheat support price in year t (cents per bushel)
DPW_t	= effective wheat diversion payment in year t (cents per bushel)
RNC_t	= range condition in year t, index value.

Estimation of the updated corn and wheat equations yielded generally acceptable statistical results. In most cases, the coefficients of the independent program variables were statistically significant and possessed the expected signs; coefficients of determination were in the .88-.94 range for the corn equations and in a lower .63-.78 range for the wheat equations. Coefficients of determination for the soybean equations were high, in the .98-.99 range, although both corn and soybean program variables proved to be almost uniformly not statistically significant determinants of soybean acreage. These variables were nonetheless included in the forecasting equations given their inclusion in effective price models previously estimated (see Houck, et al.).

Disaggregated Acreage Supply Models

An alternative procedure which avoids some of the problems often encountered in estimation of the effective price model (Burnstein), is a temporally disaggregated approach to supply estimation. This approach is based on explicit recognition of the fact that, from both a theoretical standpoint as well as empirical observation, crop acreage response under farm programs is fundamentally different than under competitive market conditions. This suggests the usefulness of separately modeling crop acreage supply response under "free market" and "farm program" regimes. Such an approach avoids many of the problems encountered by models which attempt to model both regimes simultaneously, including the likelihood of bias in estimated coefficients resulting from the assumption of coefficient stability when, in fact, structural change has occured. Different versions of such a disaggregated approach have been used in modeling acreage supply response for wheat (Lidman and Bawden; Morzuch, Weaver and Helmberger), corn (Weaver and Krainick), and corn and soybeans together (Lee and Helmberger).

Importantly, the disaggregated approach permits consideration of the program participation decision and its consequences for aggregate crop supply response. To illustrate, in the second quandrant of Figure 1, $\pi^*(P_c)$ and $\pi'(P_c)$ are expected profit functions for a representative corn producer given nonparticipation and participation, respectively, in a voluntary feedgrain program. P_c, P_{ci}, and P_{ca} are respectively defined as the price of corn, the "indifference price" at which a producer is indifferent between program nonparticipation and participation, and the "allotment" price, at which the participating producer encounters a binding corn acreage allotment. Subject to assumptions concerning the curvature properties of π^* and π' and the characteristics of the feedgrain program (see Lee and Helmberger), it can be shown that at low corn prices the profit-maximizing producer will elect participation and at high prices will choose nonparticipation, as expected a priori. As corn prices decline to indifference price P_{ci}, the producer becomes a program participant, with the resulting discontinuous corn acreage supply curve S_c' in the first quandrant.[2] If $P_{ca} < P_{ci}$, the inelastic portion of L_c, the participator's

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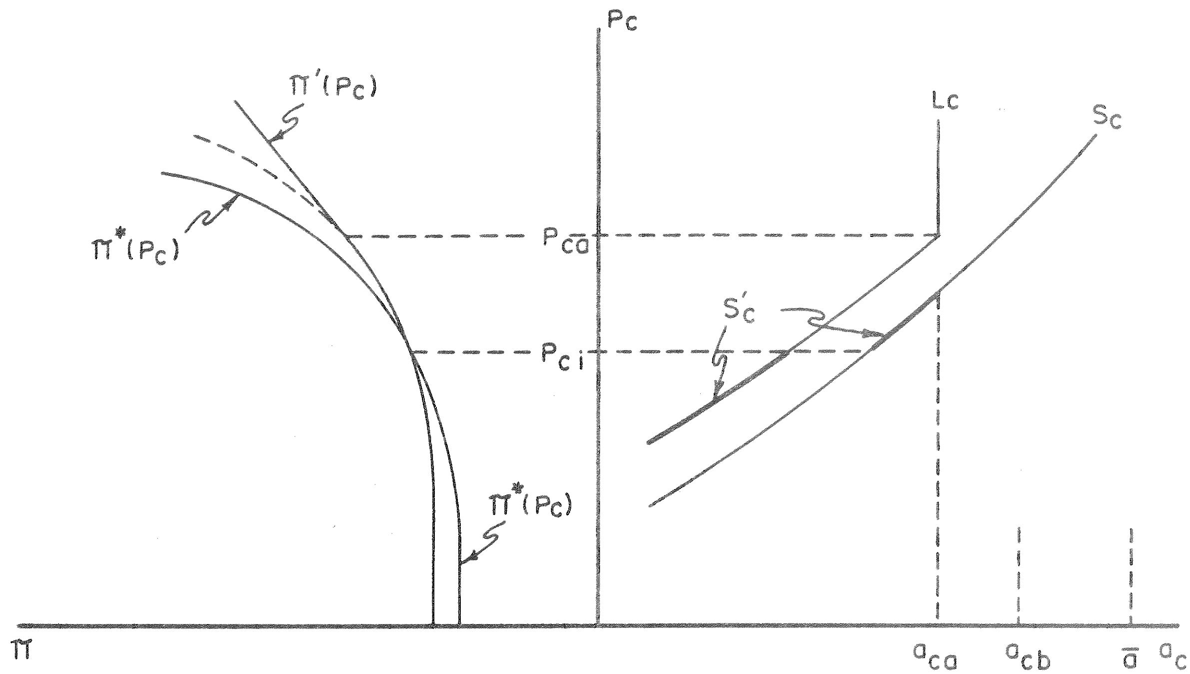
[2]Note that from Hotelling's lemma, the first derivative of the expected profit function with respect to output price is the output supply function.

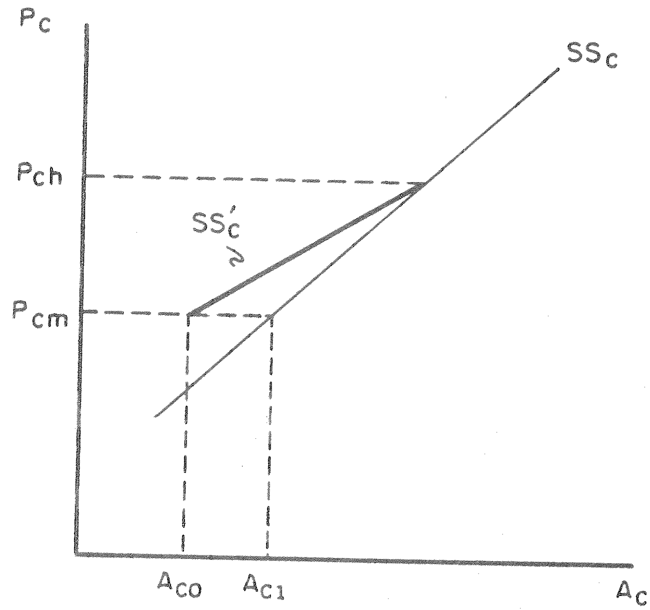
FIGURE I. EXPECTED PROFIT FUNCTIONS AND CORN ACREAGE WITH NON-BINDING ALLOTMENT



acreage supply function, would also comprise part of S_c', which would again be discontinuous.

The consequences of the above argument for aggregate corn acreage response can be seen in Figure 2, which shows the aggregate supply function SS_c', between the highest (P_{ch}) and lowest (P_{cm}) indifference prices encountered among producers in a given geographic area. Above P_{ch}, all producers are non-participants, a situation existing in all "free market" years, when acreage limitations were not required to receive program benefits. Between P_{ch} and P_{cm}, some, but less than 100 percent program participation exists, reflecting actual program experience. Horizontal summation of individual producer acreage supply functions yields SS_c',

FIGURE 2. AGGREGATE CORN ACREAGE SUPPLY CURVE



which may be shown to be more elastic under farm programs than in their absence. Results for Midwestern states show the corn acreage supply elasticity under feedgrain programs to be more than twice the magnitude of the supply elasticity under free market conditions (Lee and Helmberger). This and related results point to the potential usefulness in a forecasting context of disaggregated models of crop acreage response estimated under alternative "free market" and "farm program" regimes.

In forecasting crop acreage supply using the disaggregated approach, the models estimated by Morzuch, Weaver, and Helmberger for Plains and Western wheat producing states, and by Lee and Helmberger for Midwestern corn and soybean producing states were expanded to the national level. Wheat acreage forecasts were derived from estimation of a model containing the non-quota years of 1948-49, 1951-59, and 1965 on. The years in which restrictive wheat acreage allotments were in effect were excluded from the analysis due to the fundamentally different nature of wheat acreage response in those years.

Corn and soybean acreage forecasts were derived in a similar manner. Forecasts for 1980 and 1981 were based on estimation of "free market" models comprised of the earlier years 1948-49, 1951-53, 1959-60 and 1973-77, when producers responded primarily to market-oriented factors in allocating crop acreage. Forecasts for 1979, 1980, and 1982 were derived from acreage supply models relevant to "farm program" regime years when restrictive feed grain program provisions were in effect, including the earlier period, 1961-1973. While the linkage between feedgrain programs and planted corn acreage is straightforward, justification for the extension of this approach in deriving soybean acreage forecasts lies not in the actual provisions of feed grain programs but in their important cross-commodity effects on soybean acreage.

Based on the above, the following equations were estimated prior to forecasting corn, soybean, and wheat acreage for the years 1978-1982:

(5) Corn: 1978, 1979, and 1982 forecasts:

$$AC_t = AC_t\left(\frac{PC_{t-1}}{IDX_t}, \frac{PS_{t-1}}{IDX_t}, \frac{FPP_t}{IDX_t}, MXDIV_t, TREND\right)$$

(6) Corn: 1980 and 1981 forecasts:

$$AC_t = AC_t\left(\frac{PC_{t-1}}{IDX_t}, \frac{PS_{t-1}}{IDX_t}, TREND\right)$$

(7) Soybeans: 1978, 1979, and 1982 forecasts:

$$AS_t = AS_t\left(\frac{PS_{t-1}}{IDX_t}, \frac{PC_{t-1}}{IDX_t}, \frac{FPP_t}{IDX_t}, MSDIV_t, TREND\right)$$

(8) Soybeans: 1980 and 1981 forecasts:

$$AS_t = AS_t(\frac{PS_{t-1}}{IDX_t}, \frac{PC_{t-1}}{IDX_t}, TREND)$$

(9) Wheat: 1978-1982 forecasts:

$$AW_t = AW_t(\frac{PW_{t-1}}{CPRF_{t-1}}, \frac{RUDC_t}{CPRF_{t-1}}, MAXD_t, TREND)$$

where: IDX_t = index of prices of inputs used in crop production in year t (1967 = 100)

FPP_t = farm program payments in year t (dollars per required idled acre)

$MXDIV_t$ = maximum acreage diverted in year t (1,000 acres)

$CPRF_{t-1}$ = index of crop prices received by farmers in year t-1 (1967 = 100)

$RUDC_t$ = diversion payment in year t (cents per bushel)

$MAXD_t$ = maximum wheat acreage diversion in year t (1,000 acres)

and all other variables are defined as previously. Equations (6) and (8) were estimated in log-linear functional form based given its superiority in explaining acreage response for both corn and soybean crops over the "free market" period. All other equations were estimated in linear form. Given uncertainty, based on the results of previous research (see Lee and Helmberger), over the extent to which the secondary effects of feedgrain programs have caused measurable structural changes in soybean acreage response, an alternative (contrained) forecasting equation was estimated for soybean acreage only, using data from the entire sample period, and a log-linear functional form:

(10) Soybeans: 1978-1982 forecasts:

$$AS_t = AS_t(\frac{PS_{t-1}}{IDX_t}, \frac{PC_{t-1}}{IDX_t}, AS_{t-1}, TREND)$$

In the estimation of equations (5)-(10) most coefficient estimates had the expected signs and were statistically significant. A major problem encountered in estimating equations (5)-(8) concerned the relatively short time-series in each model, although all estimated equations did prove to have coefficients of determination of .80 or better. This factor had been less of a problem in multiple equation state acreage supply equations estimated previously, given the use in these cases of multiple equation generalized least squares estimation procedures (Lee and Helmberger).

Food and Agricultural Policy Simulator (FAPSIM)

The FAPSIM model developed by U.S.D.A. is a large scale econometric model of the U.S. agricultural sector used primarily for policy analysis (Gadson, Price, and Salathe). The FAPSIM model contains 360 endogenous and 265 exogenous variables, and links together a number of crop and livestock submodels. Crop subsectors included are corn, oats, barley, grain sorghum, wheat, soybeans, and cotton; livestock subsectors include beef, pork, dairy, chickens, turkeys, and eggs. FAPSIM simultaneously solves for all endogenous variables in the system given specified exogenous variable data on population, disposable income, production input prices, consumer prices, and a wide variety of government policy variables.

Like the disaggregated model described above, the FAPSIM model explicitly attempts to capture the effects of varying program participation rates in voluntary farm programs. Independent acreage response equations are specified for acreages planted by program participants and nonparticipants, and the net returns from both participation and nonparticipation options are explicitly included as explanatory variables in crop acreage supply equations. The size and complexity of the FAPSIM model does not permit further elaboration here (see Gadson, Price, and Salathe for an extensive discussion, description of the structural equations, and estimation results).

Forecasting Results and Evaluation

The forecasting ability of the effective price, disaggregated, and FAPSIM models was evaluated, ex post over the five year period 1978-1982.[3] Annual crop forecasts derived from the effective price and disaggregated models were generated by reestimating each model using data series updated through the previous year, and using the resulting coefficient estimates and current (forecast) year exogenous variable data to forecast current year acreage. FAPSIM acreage forecasts were based on estimated coefficients derived from estimation of the relevant submodels over the 1950-1979 period and given forecast year exogenous variable data. The results are evaluated in turn below for each of the three crops.

Corn Acreage Forecasts

The corn acreage forecasts derived from the three alternative models are presented in Figure 3 and compared with actual U.S. planted corn acreage in recent years. Acreage set-aside programs in 1978, 1979, and 1982 caused actual corn acreage to be the lowest in these three years of the 1976-1982 period. In 1980 and 1981, U.S. corn acreage was between 84 and 85 million acres, as had been previously the case in 1976 and 1977; in all four of these years, no acreage control programs were in effect.

As can be seen in Figure 3 and from the summary statistics presented in Table 1, the FAPSIM model yielded the most accurate forecasts of U.S. corn acreage over the forecast interval. The FAPSIM corn acreage forecasts

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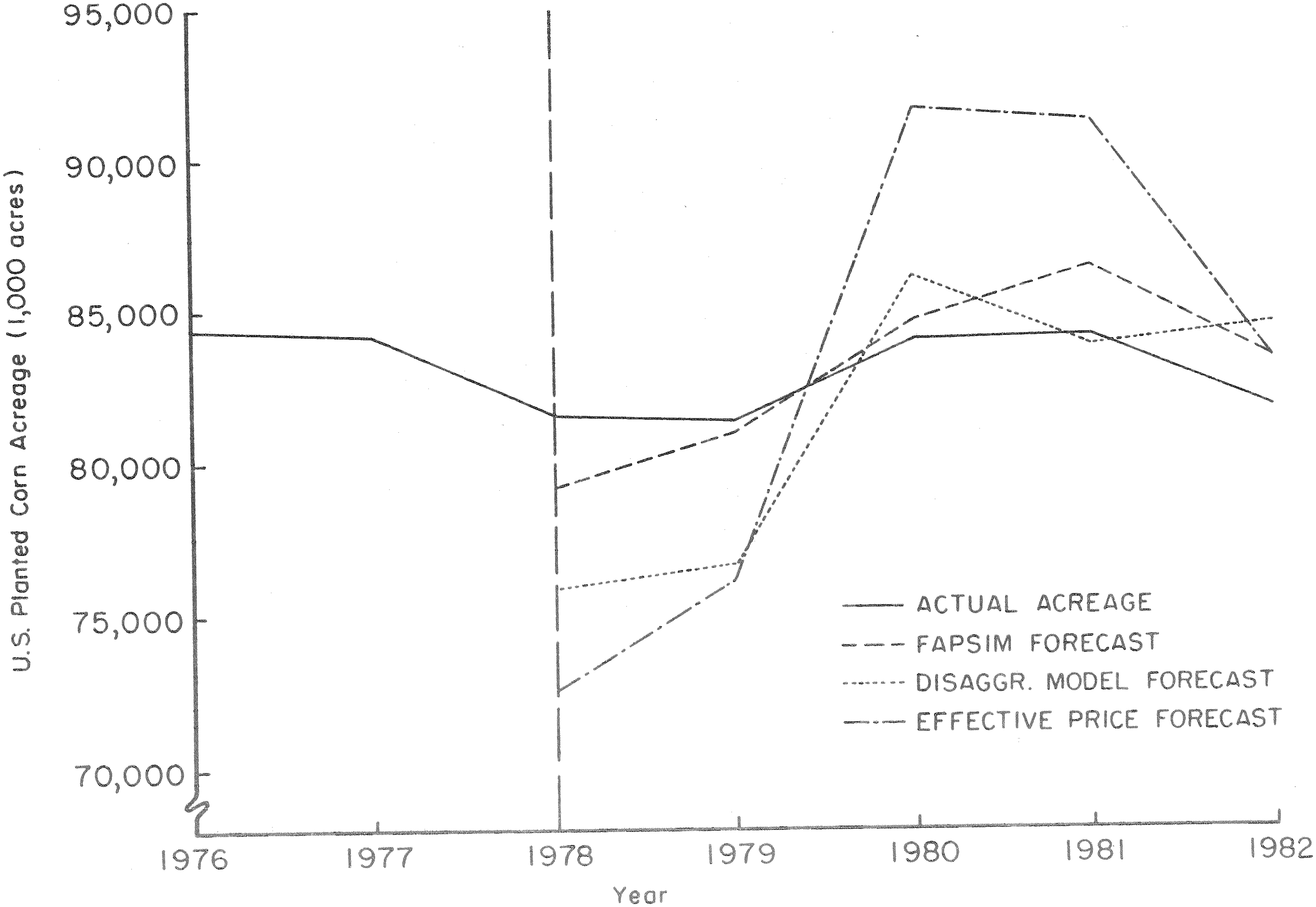
[3]FAPSIM model forecasts and the associated summary statistics in Table 1 are for 1980-1982 only. Estimates for 1978-79 are within-sample predicted values.

FIGURE 3. U.S. CORN ACREAGE AND ACREAGE FORECASTS



had an associated root mean squared percentage error (RMSPE) of just over two percent, less than half the magnitude of the next most accurate set of forecasts derived from the disaggregated model. Forecasts from the disaggregated model were considerably more accurate than those derived from the effective price model, despite their derivation from two separate equations.

Table 1: Summary Statistics for Crop Acreage Forecasts

Crop, Summary Statistic	Forecasting Model		
	FAPSIM	Disaggregated	Effective Price
Corn:			
Mean Absolute Deviation	1,529	3,056	6,111
Root Mean Squared Percentage Error	2.01%	4.40%	8.02%
Soybeans:			
Mean Absolute Deviation	2,138	I: 5,364 II: 2,051	3,110
Root Mean Squared Percentage Error	3.32%	I:10.25% II: 4.37%	5.17%
Wheat:			
Mean Absolute Deviation	16,021	6,619	9,625
Root Mean Squared Percentage Error	19.83%	9.21%	18.85%

Given the shift in feedgrain program provisions back to acreage set-aside requirements in 1978, the elimination of this requirement in 1980, and finally a return to set-asides and planted acreage constraints in 1982, accurately forecast corn acreage might be open to question. The FAPSIM model, then, appears to have performed particularly well over the forecast interval. The relatively large forecast errors associated with the effective price model are not wholly unexpected given the frequent shifts in feedgrain program provisions over the five year period, and the apparent sensitivity of the resulting forecasts to changes in program variables.

Soybean Acreage Forecasts

The forecasts of U.S. soybean acreage given by the three models are presented in Figure 4 and are also summarized in Table 1. Soybean acreage was more volatile than corn acreage over the 1978-1982 period, and was generally negatively correlated with trends in corn acreage due largely to the impact of feedgrain program changes. Soybean acreage increased significantly between 1977 and 1979 with corn acreage restrictions in effect, decreased in 1980-81, and increased again in 1982 when corn set-aside requirements were reintroduced.

As was the case for the corn acreage forecasts, the FAPSIM forecasts prove more accurate than those derived from the small scale models, with an overall RMSPE of only slightly over about three percent. The root mean squared percentage errors associated with the effective price and basic disaggregated models were 5.17 and 10.25 percent, respectively. The disaggregated model forecast errors were particularly large in the "free market" years, 1980-81. However, the simpler constrained version of the disaggregated model performed best of all, with a RMSPE of 4.37%, slightly less than that associated with the FAPSIM forecasts.

Wheat Acreage Forecasts

The wheat acreage forecasts and summary statistics for the three models are presented in Figure 5 and Table 1, respectively. As was the

FIGURE 4. U.S. SOYBEAN ACREAGE AND ACREAGE FORECASTS

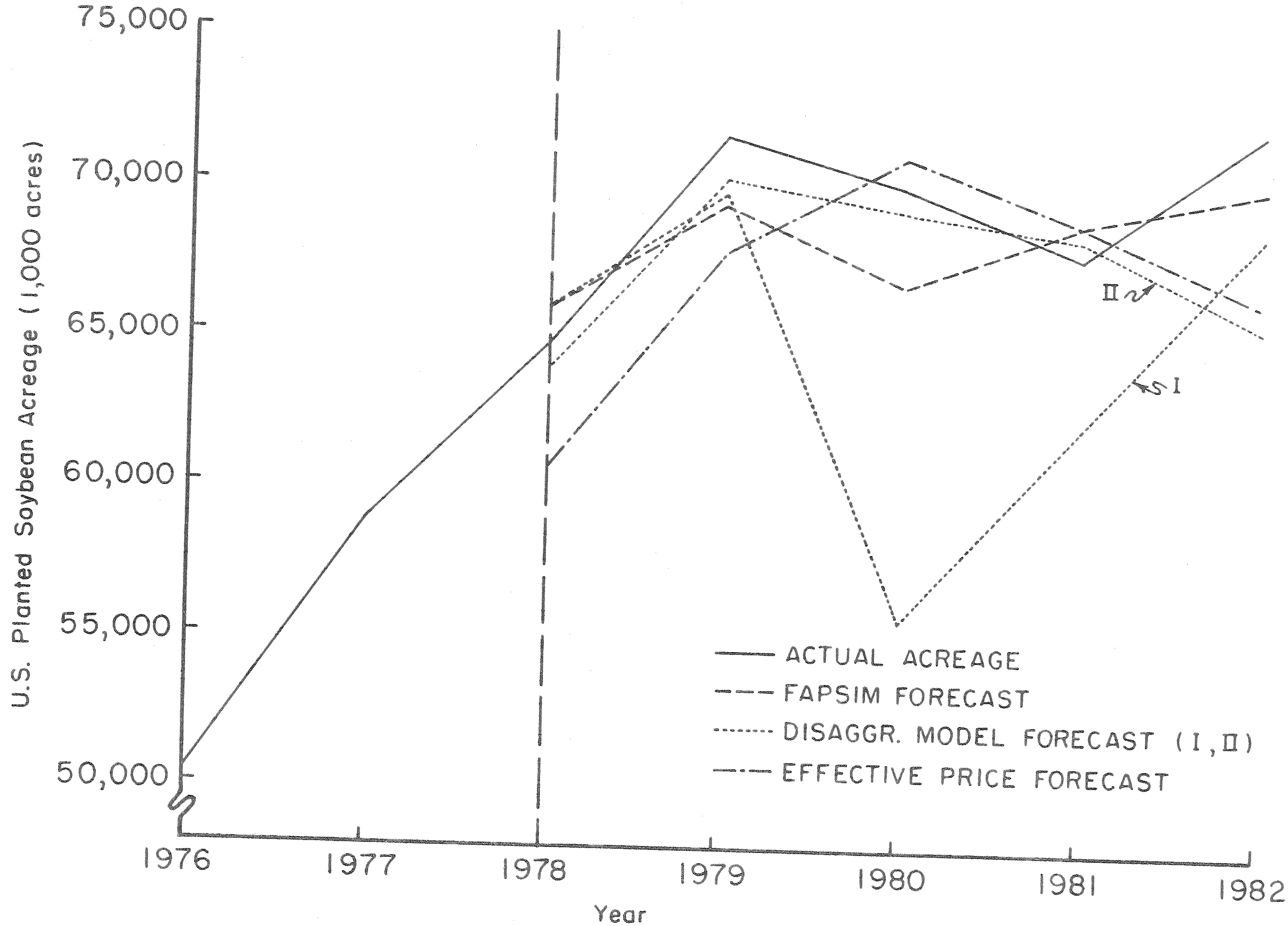
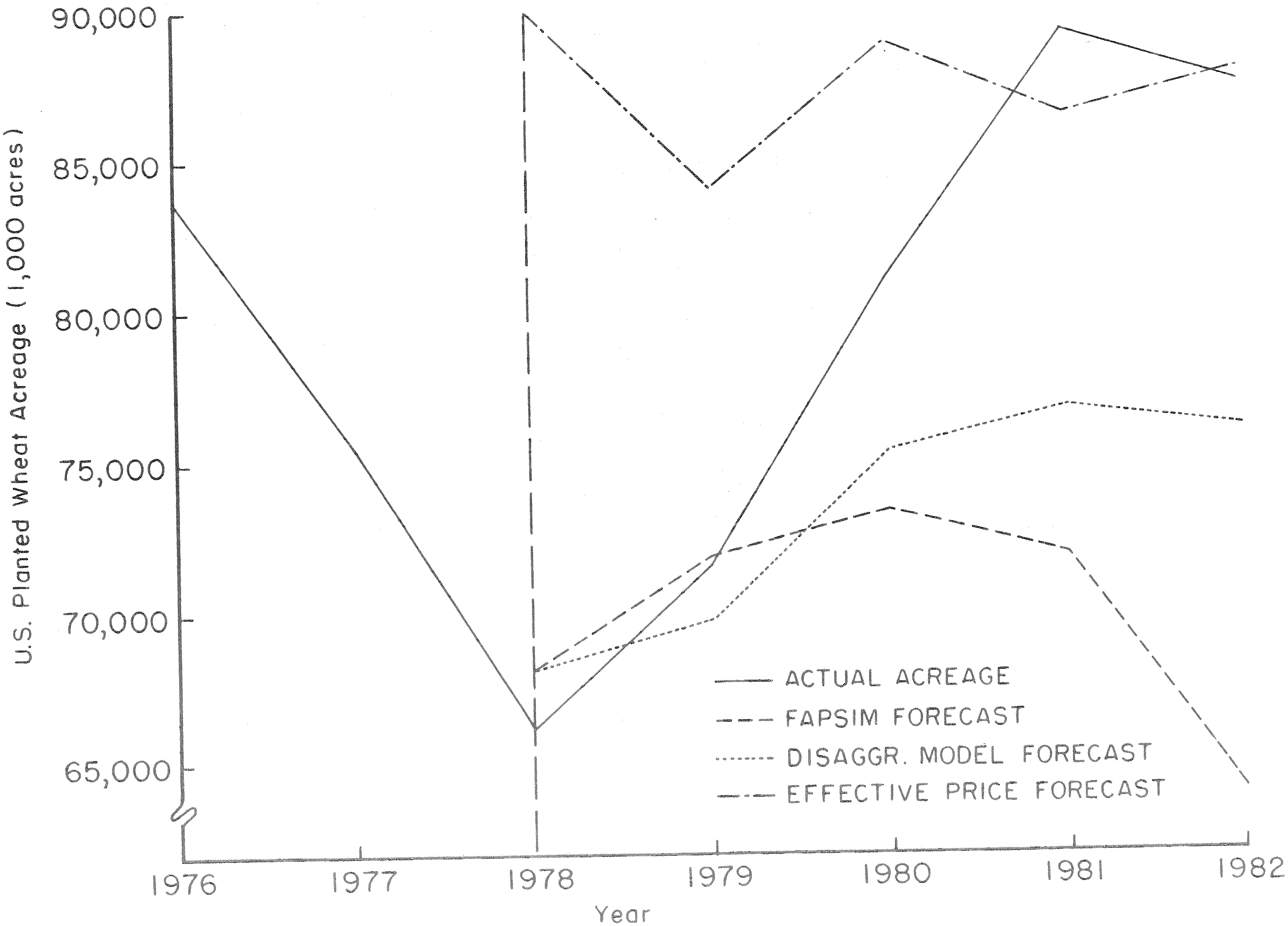


FIGURE 5. U.S. WHEAT ACREAGE AND ACREAGE FORECASTS



case with the feedgrain program, wheat acreage constraints were introduced in 1978, 1979, and 1982, but were not present in 1980 and 1981. Actual planted wheat acreage dropped nearly 10 million acres between 1977 and 1978 with the introduction of the program constraints, but then increased steadily between 1978 and 1981. Reintroduction of acreage constraints caused wheat acreage to turn downward again in 1982, to a level of nearly 87.3 million acres. Both the steady increase in wheat acreage over the 1978-1981 period, and the lack of a significant negative response to the acreage control program in 1982 may be at least partially due to the recent increase in doublecropping of wheat acreage in some areas of the U.S.

Unlike the corn and soybean models, the wheat acreage forecasts of the FAPSIM model are characterized by a relatively high forecast error (FMSPE of 19.83 percent), as were, to a lesser extent, the forecasts from the effective price and disaggregated models. A likely reason for the magnitudes of these forecast errors is the recent increase in the doublecropping of wheat acreage (Price), a development which may not be adequately accounted for in all three models. The disaggregated model performs best in forecasting U.S. wheat acreage with a RMSPE of 9.21 percent, although the forecast errors increase significantly toward the end of the forecast interval.

General Model Evaluation and Conclusions

In evaluating the overall performance of the three models in forecasting planted crop acreage, the mean absolute deviations and root mean squared percentage errors associated with each crop forecast for each model have been weighted by the proportion of average annual total acreage planted to each crop. These weighted measurements are listed in Table 2. The results show that the disaggregated model (using either of the soybean forecasting models) had the lowest forecast errors of the three models. However, individual year forecasts derived from the FAPSIM model were within a five percent error range 67 percent of the time, compared with figures of 60 percent and 40 percent for the disaggregated and effective price models. Given the low number of annual crop forecasts analyzed, overall forecast errors for all three models are especially sensitive to large errors for particular crops or years.

Table 2: Evaluation of Three Acreage Forecasting Models

Criterion	Forecasting Model		
	FAPSIM	Disaggregated Model*	Effective Price Model
Weighted Mean Absolute Deviation	6,668	3,973 (4,967)	6,412
Weighted Root Mean Squared Percentage Error	8.50%	6.04% (7.80%)	10.87%

*Includes forecasts from soybean models II and I, respectively.

The problems encountered by individual models in particular crop acreage forecasts are explainable, to a large extent. The FAPSIM model has an excellent ability to forecast corn and soybean acreage, and its significant underforecasting of wheat acreage may be largely due to the doublecropping factor. The disaggregated model also performed well in forecasting corn and soybean acreage, and best of the three in forecasting wheat acreage. Previous studies using the disaggregated model have been at the state level; the expansion of this model to the national level may have accounted for a part of its forecast error. The effective price forecasting model performed poorest overall, despite an apparent ability to successfully explain historical acreage trends. Its usefulness for forecasting applications would appear most in doubt of the three models evaluated.

These results suggest several conclusions regarding the strengths, weaknesses, and tradeoffs involved in the development and use of acreage supply models. The detail and forecasting ability of the FAPSIM model would appear to warrant its use over more small scale models were it not for the much higher costs of maintenance, updating, and estimation of FAPSIM and other large scale sector models.

Given these costs, as well as the multiplicity of uses for which acreage response models have been constructed, smaller scale models, such as the two evaluated here, have often been estimated. These smaller scale models, as has been shown here, may have very good forecasting abilities, though they are likely to be particularly sensitive to problems encountered in specification and estimation. In the case of the disaggregated model, the main problem encountered is the relative lack of time series observations in forecasting equations for corn and soybeans. The principal problems with the effective price model are its relatively poor forecasting ability and questions regarding model specification (Burnstein). Despite these problems, however, small scale econometric models of crop acreage response continue to be a frequent focus of applied research. The results from this analysis suggest that recognition of the tradeoffs involved in model specification, estimation, and forecasting is important to the constructive use of these models.

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