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ESTIMATION OF CROP ACREAGE FLEXIBILITY RESTRAINTS FOR EVALUATING ON-FARM ALCOHOL FUEL PRODUCTION IN CALIFORNIA*

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ABSTRACT

Crop acreage shifts brought about by on-farm alcohol fuel production will be constrained by factors other than the capacity of the distillery in the demand for alcohol fuel; institutional, marketing, machinery and price uncertainty also delimit the magnitude of crop acreage responses to changes in demand. This research was conducted to estimate flexibility constraints for the major crops grown in Yolo County, California for use in a linear programming optimization model constructed to evaluate the energetic and economic feasibility of on-farm alcohol fuel production.

The pertinent literature was reviewed, with respect to research in the use of energy in the agricultural sector. Two alternative estimating models were developed based upon published work undertaken on the Texas High Plains and subsequently applied to Yolo County crop production data.

Both models were formulated as simple linear regression equations in which either the current year's acreage or the previous three years' average is expressed as a function of last year's acreage or the previous three years' average acreage, respectively. The results were evaluated with conventional statistical measures, a model was selected, and acreage changes calculated.

INTRODUCTION

On-farm alcohol fuel production as an alternative source of energy both to and from the agricultural sector has been receiving a considerable amount of interest in research, development, and demonstration [1–3]. As part of a research effort to evaluate the economic and energetic feasibility of producing alcohol fuel from

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agriculture in California, a linear programming model of Yolo County was formulated to estimate the hypothetical alcohol production responses of farmers to increasing prices of purchased energy-intensive inputs. Models of this type may be designed to minimize costs of producing a given level of output of various crops [4] or to maximize net income to a given mix of activities [5]. While the former technique usually requires a fixed cropping pattern that accords with observed acreages, the latter seeks to utilize only the most profitable crop or crops in the final solution. This suggests that while cost minimization models maintain a fairly constant mix of crops, profit maximization models may drop all less profitable crops out of the solution, independent of the actual crop mix that is simulated. Therefore, major shifts among crops in the model may occur, for example, from year to year in response to price changes only. This is in sharp contrast to the observed behavior of institutional, marketing, machinery, and price factors that would serve to dampen these fluctuations and engender a more gradual adjustment.

The Yolo County on-farm alcohol fuel model seeks to maximize returns to fixed costs subject to a set of constraints. This format was followed in the belief that the decision rule for farmers planning to produce alternative farm energy sources would be primarily an economic one. Thus a key problem to be resolved was how to determine the magnitude of constrained crop acreage shifts while optimizing gross profits.

The most prevalent technique that addresses this problem is the use of flexibility restraints (constraints) that limit the year-to-year change in production activities. Day [6], who first discussed the logic and purpose of flexibility constraints in a recursive programming context, noted that

> . . . These constraints specify that in any one year only a limited change from the preceding year's production can be expected. This hypothesis is based on the conglomerate of forces which lead to caution by farmers in altering established production patterns. Primary among them are uncertainty of price and yield expectations and restrictions on the aggregate supply of production inputs . . . .

Flexibility constraints can be expressed mathematically as follows:

Upper flexibility constraints:

$$X_t \leqslant (1 + \overline{b}_t)X_{t-1}$$

Lower flexibility constraints:

$$X_t \geqslant (1 - \underline{b}_t)X_{t-1}$$

where

X_t = level of the activity to be determined in t year

X_{t-1} = level of the activity in t-1 year

$\overline{b}_t, \underline{b}_t$ = maximum allowable proportionate increase and decrease, respectively, in the level of the activity from the t-1 year to the t year; these are known as upper and lower flexibility coefficients.

Schaller discussed ten procedures for determining the flexibility coefficient (b) [7], which were grouped into four procedures by Condra and Lacewell [8]. They are:

1. the mean of absolute percentage deviations in acreage;
2. the mean of increasing (decreasing) percentage deviations in acreage;
3. the maximum percentage increase (decrease) in acreage; and
4. simple linear regression.

Sahi and Craddock compared results of three recursive linear programming models identical in every respect, except in the estimation of the flexibility coefficients [9]. The techniques were:

1. the third approach mentioned by Schaller where $\bar{b}$ and $\underline{b}$ are defined as the maximum proportionate increases and decreases over a fifteen year time series;
2. simple regression equations; and
3. a multiple linear regression equation which included exogenous variables for crop prices, inventories, exports, springtime moisture, and technological change.

For their study, which was set in Canada, the authors found the order of choice to be models three, two, and one, respectively.

Condra and Lacewell applied the latter two approaches to estimation of flexibility restraints for subregions of the Texas High Plains [8]. They formulated four models; three linear regression models patterned after Day [6], Henderson [10], and a multiple linear regression model incorporating several exogenous variables after Sahi and Craddock [9]. In the Texas case, models one and three were superior to the other two formulations. For purposes of consistency of choice for all crops, model three was the ultimate selection, in part by subjective evaluation.

Objectives

The general objective of this study was to develop flexibility constraints for acreages of selected crops in Yolo County for the on-farm alcohol fuel production linear programming model. Due to the infancy of the industry, alcohol fuel production levels ought to be small relative to the levels of cash crop production, and therefore ought not to change crop acreages drastically in the near term. Thus, crop acreage responses are believed to be compatible with the assumptions stated in previous research. Given this, the specific objectives were:

1. estimate flexibility coefficients for major cash crops in Yolo County using two alternative models;
2. evaluate the models by conventional statistical tests; and
3. select the appropriate model for estimation of flexibility coefficients and apply the model for the cash crops included in the alcohol fuel programming model.

Procedures

Yearly acreages for six conventional crops grown in Yolo County were transcribed from the Yolo County Agricultural Crop Reports for a twenty-one year time period extending from 1959 through 1980. Starch or sugar-rich crops with the potential for contributing to alcohol fuel production included field corn, wheat, barley, grain sorghum, and sugar beets. In addition, tomatoes, which are an important cash crop grown in the Sacramento Valley, were included in the model. The data sets generated from the Crop Reports for all six crops were continuous and complete; there were no interruptions or missing entries.

Following Condra and Lacewell two alternative linear regression models were specified [8]:

Model I – This model is a simple one-year lag model in which this year's acreage is expressed as a function of last year's acreage. Although this model is based upon Sahi and Craddock's simple regression equation, Condra and Lacewell combined the changes for both increasing and decreasing years in a single equation by the use of a dummy variable. The model is specified as follows:

$$AC = b_1 ACLAG + b_2 ACDOWN + e$$

where

AC	=	Acreage of a given crop in the current year
ACLAG	=	Acreage of a given crop in the previous year
ACDOWN	=	A dummy variable which distinguishes years of increase from years of decrease[1]

If AC > ACLAG than ACDOWN = 0
If AC < ACLAG then ACDOWN = ACLAG

Thus:

$$1 + \bar{b} = b_1 \text{ and } 1 - \underline{b} = b_1 + b_2$$

Model II – Model II modifies Model I by changing the base acreage from the previous year's acreage to a moving average of the past three years' acreage. This alteration dampens some of the effects of extremely high and low acreages in the previous year while allowing trends in acreage to change their sign.

Specified as:

$$AC = b_1 AVLAG + b_2 AVDOWN + e$$

[1] Explanation of the model formulation is as follows: Since $1 + \bar{b} = b_1$ and $1 - \underline{b} = b_1 + b_2$ then $b_2 = -\bar{b} - \underline{b}$ so $AC = (1 + \bar{b})\,ACLAG + (-\bar{b} - \underline{b})\,ACDOWN$. If AC > ACLAG then ACDOWN = 0 and drops out of the equation such that $AC = (1 + \bar{b})\,ACLAG$. If AC < ACLAG then ACDOWN = ACLAG, and $AC = (1 + \bar{b})ACLAG + (-\bar{b} - \underline{b})\,ACLAG$ or $AC = (1 + \bar{b} - \bar{b} - \underline{b})ACLAG$ and $AC = (1 - \bar{b})ACLAG$.

where

AC	=	Acreage of a given crop in the current year
AVLAG	=	Previous three years' average acreage of a given crop
AVDOWN	=	A dummy variable which distinguishes between above and below average acreage years

Thus:

$$1 + \overline{b} = b_1 \quad \text{and} \quad 1 - \underline{b} = b_1 + b_2$$

Both models were initially specified by Condra and Lacewell without an intercept term. To test whether the intercept term was significant in this analysis, Models I and II were reformulated with an intercept term and statistically evaluated.[2]

Estimation of the models – Acreage data transcribed from the crop reports was coded onto computer accessed disc files and fitted into linear regression equations with the Minitab statistical software package [11]. Routine statistical analyses were performed and residual plots of all runs were made to check for the presence of serial correlation.

Results

The regression coefficients of the two models run both with and without an intercept term are presented in Table 1, along with their R^2 values and standard deviations. It should be noted that the normal interpretation of R^2 does not apply when the intercept is constrained to zero. Consequently, residuals were plotted against time for Models I and II and compared for pattern and proximity to zero. The intercept term is significant for grain sorghum only, the remaining crop intercept terms being statistically insignificant. Therefore, the null hypothesis that there is no difference between the intercept terms and zero was not rejected, and the regression equations specified with an intercept were not accepted. This result is in agreement with models estimated in the literature.

Without an intercept term, Model I has a higher R^2 value and lower standard deviation for all crops except grain sorghum. This result is in contrast with Condra and Lacewell who found Model II (their model 3) to be superior. Inspection of residual plots for Model I were also more closely clustered to zero than for Model II, adding further evidence of improved estimation [12].

[2] Since sugar beets and tomatoes are both contract crops their acreages will likely respond more readily to exogenous factors such as price setting, support payments, and processing capacity. Sahi and Craddock addressed these issues and developed a model that included similar exogenous variables. In their work on the High Plains, however, Condra and Lacewell got weak results with this approach and eliminated it from further consideration. Hence, it was not tested in this research.

Table 1. Alternative Estimating Equations for Flexibility Coefficients, Yolo County, California

Crop	*Model No.*	*Intercept*	*ACLAG*	*AVLAG*	*ACDOWN*	*AVDOWN*	R^2	*Standard Deviation*
Corn	I[c]	3785	0.983		-0.258		0.832	3798
	I		1.12[b]		-0.255		0.979	3899
	II[c]	2146		1.11		-0.361	0.757	4568
	II			1.20[b]		-0.363[b]	0.973	4474
Wheat	I[c]	2925	1.10		-0.284		0.946	7360
	I		1.15[b]		-0.272[a]		0.982	7350
	II[c]	8319		1.16		-0.653	0.958	6507
	II			1.31[b]		-0.524[b]	0.979	7808
Barley	I[c]	9142	1.06		-0.343		0.897	12541
	I		1.15[b]		-0.329[a]		0.975	12885
	II[c]	8043		1.17		-0.504	0.825	16337
	II			1.27[b]		-0.539[b]	0.961	16340
Tomato	I[c]	-3257	1.24		-0.323		0.909	3996
	I		1.16[b]		-0.303[b]		0.993	3966
	II[c]	2276		1.12		-0.323	0.903	4124
	II			1.18[b]		-0.328[b]	0.993	4046
Grain Sorghum	I[c]	2977	1.06		-0.316		0.738	7645
	I		1.14[b]		-0.324[b]		0.957	7506
	II[c]	-1232		1.24		-0.400	0.750	7473
	II			1.20		-0.401	0.959	7260
Sugar Beet	I[c]	-850	1.18		-0.270		0.807	3289
	I		1.15[b]		-0.272[b]		0.987	3198
	II[c]	-2409		1.15		-0.222	0.784	3478
	II			1.06[b]		-0.219[b]	0.985	3410

[a] Significant at the 0.05 level.
[b] Highly significant at the 0.01 level.
[c] With intercept.

Table 2 presents the flexibility coefficients estimated by Model I, and the resulting upper and lower constraints when multiplied by the 1979-1980, two year average acreage for each of the six crops. A long fun flexibility constraint is also calculated and shown. A three year time period is felt by Condra and Lacewell to be a satisfactory interval for short run changes to make adjustments to the long run. This flexibility coefficient is calculated as $(1 \pm b)^3$. The long

Table 2.

Crop	Acres 1979-1980 Average	$1+\bar{b}$	$1-\underline{b}$	Flexibility Constraints Short Run Upper	Short Run Lower	Long Run Upper	Long Run Lower
Corn	38,000	1.123	0.868	42,663	32,973	53,774	24,825
Wheat	96,800	1.155	0.883	111,765	85,436	148,994	66,553
Barley	34,250	1.148	0.819	39,326	28,061	51,846	18,836
Tomato	58,755	1.161	0.859	68,232	50,447	92,019	37,189
Grain Sorghum	8,500	1.142	0.818	9,907	6,953	12,659	4,652
Sugar Beet	15,400	1.146	0.874	17,650	13,463	12,184	10,289

NOTE: $(1 \pm b)$(1979-1980 Av.) = Short Run Flexibility Constraint
$(1 \pm b)^3$ (1979-1980 Av.) = Long Run Flexibility Constraint

run flexibility constraint is important in recursive programming models where one year's acreage changes affect a subsequent year's. They were not used in the Yolo County model, and are shown for comparison only.

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