The Effect of Government Programs on Acreage Response over Time: The Case of Corn Production in Iowa

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Corn acreage response in Iowa is examined using a time-varying parameter regression model. Separate estimates of the permanent portion of the parameter vector are obtained for each year over the period 1957–82. The estimated elasticities are grouped into "program" and "nonprogram" periods. The results indicate corn acreage response is more own-price elastic, and the elasticity is less variable under government acreage control programs than under a "nonprogram" regime. The assumption of parameter constancy is shown to be inappropriate for modeling Iowa corn acreage response over time.

Key words: corn acreage response, government programs, time-varying parameters.

Empirical studies of acreage response for U.S. agriculture typically have been based on the assumption that the underlying structure is stable over time and that observed variations are largely transitory in nature. This is not likely to be the case for most commercially produced field crops. Changes in production techniques, plant varieties, and government programs are but a few of the factors that could contribute to permanent changes in production relationships. These shifts in structure over time often are incorporated in the analysis through the inclusion of a linear trend variable. In many cases the inclusion of a trend variable is justified as "capturing the effects of omitted variables that may have exerted systematic effects over time" (Morzuch, Weaver, and Helmberger). While the trend variable may account for systematic change over time, this again assumes that such change takes place according to a stationary process. In many applications it would be more reasonable to assume that production relationships vary over time in a nonstationary manner. This is particularly true for commodities produced under government programs.

The problem of parameter variation in response to changing government programs has been specifically addressed by disaggregating the time series into two or more subsamples corresponding to "program" and "free market" periods (Morzuch, Weaver, and Helmberger; Lee and Helmberger). While temporal disaggregation is able to account for structural change between the two regimes, it assumes that relationships within a regime are stable. Temporal disaggregation also creates a serious empirical problem by reducing the number of observations available for analysis. In addition, as Rausser and Just point out, some policy instruments were used for a very short period, and it is not likely that much information on their impact can be gained through historical observations. It also could be argued that even during the so-called "free-market" years when market factors are thought to be of dominant importance relative to government program provisions, some producers are still influenced by the level of program payments (Romain; Duffy, Richardson, and Wohlgenant).

An alternative to temporal disaggregation is to employ the adaptive regression model developed by Cooley and Prescott (1973b). This

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model allows for parameter variation over time based on the assumption that the parameters are the sum of transitory disturbances which have an effect in the current period and a permanent component whose effects persist into the future. In the adaptive regression model, the transitory disturbance in the intercept can be thought of as the usual additive error term. The permanent components are allowed to vary systematically over time with no inherent tendency to return to a mean value (Cooley and Prescott 1973a).

The purpose of this paper is to examine the relative magnitudes of parameter estimates and elasticities obtained from an acreage response model for Iowa and to draw inferences regarding supply response under "program" and "nonprogram" regimes. Corn acreage response is examined over the period 1957–82 using a time-varying parameter model to trace the paths of the parameter estimates. Estimates of the permanent components of the acreage response parameters for each year and elasticities based on these annual parameter estimates are reported. The results are summarized for "program" and "nonprogram" regimes. The "program" regime is defined as the subset of years in which feed grain acreage control programs were in effect and the "nonprogram" regime as those years in which market forces were thought to be dominant.

A Time-Varying Parameter Model

The assumed structure for the time-varying parameter model is:

(1) $$y_t = X_t'\beta_t \qquad t = 1, 2, \ldots, T$$

where X_t is a k component vector of explanatory variables, y_t is the t^{th} observation on the dependent variable, and β_t is a k component vector of parameters subject to variation. The parameters are assumed to be adaptive in nature and subject to both permanent and transitory changes, where the hypothesized variations are:

(2) $$\beta_t = \beta_t^p + \upsilon_t, \quad \beta_t^p = \beta_{t-1}^p + \nu_t$$

where the p superscript denotes the permanent component of the parameters. The υ_t and ν_t are identically and independently distributed with mean vectors 0 and covariances

(3) $$\text{cov}(\upsilon_t) = (1 - \tau)\sigma^2\Sigma_\upsilon \quad \text{and} \quad \text{cov}(\nu_t) = \tau\sigma^2\Sigma_\nu \quad \text{with } 0 \le \tau \le 1,$$

where Σ_υ and Σ_ν give information regarding the relative variability of the parameters and are assumed known up to scale factors. The unknown parameter, τ, measures the relative importance of the permanent component of parameter variation. The larger the value of τ, the greater the importance of permanent changes. The unknown parameters are the β, σ^2, and τ. The objective of the estimation is to obtain estimates for σ^2, τ, and the permanent components of β_t.

The process generating the parameters is nonstationary, therefore, it is impossible to specify the likelihood function. In our application, however, we are interested in specific realizations of the parameter process. Since the likelihood function conditional on the value of the parameter process at some point in time is well defined, we can "stop" the process at a particular realization (e.g., period $T + 1$) and obtain estimates of the unknown parameters. In this case:

(4) $$\beta_{T+1}^p = \beta_t^p + \nu_T, \quad = \beta_t^p + \sum_{s=t+1}^{T+1} \nu_s,$$

from which it follows

$$\beta_t = \beta_{T+1}^p - \sum_{s=+1}^{T+1} \nu_s + \upsilon_t.$$

Equation (1) can be rewritten as:

(5) $$y_t = X_t'\beta + \mu_t,$$

where $\beta = \beta_{T+1}^p$, and

(6) $$\mu_t = x_t'\upsilon_t - x_t' \sum_{s=t+1}^{T+1} \nu_s.$$

It can be shown (Cooley and Prescott 1973a) that μ is distributed normally with mean zero and covariance matrix:

(7) $$\text{cov}(\mu) = \sigma^2[(1 - \tau)R + \tau Q] \equiv \sigma^2\Omega_{(\tau)},$$

where R is a diagonal matrix with

(8) $$r_{ii} = (x_i'\Sigma_\upsilon x_i),$$

and Q is a $T \times T$ matrix such that

(9) $$q_{ij} = \min\{|t - i|, |t - j|\}(x_i'\Sigma_\nu x_j),$$

for all $i, j \neq t$, otherwise $q_{ij} = 0$. From equation (5) it follows that Y, the t component vector of the y_t, is distributed as:

Table 1. Estimates of the Permanent Components of the β Vector for Corn Acreage Response in Iowa 1957–82[a]

$\hat{\tau}$[b]	Intercept[c]	LAC	EPCO	EPSY	WSPCO	WDPCO	T
.98	8.39000 (1.523)**	0.05950 (0.077)	0.624664 (0.276)**	−0.24420 (0.157)	1.23166 (0.372)**	−1.97367 (0.730)**	0.09209 (0.080)
.98	7.91947 (1.633)**	0.07702 (0.078)	0.746608 (0.279)**	−0.24347 (0.154)	1.30303 (0.366)**	−1.83986 (0.746)**	0.09219 (0.075)
.98	8.48227 (1.376)**	0.02629 (0.069)	0.701266 (0.283)**	−0.24269 (0.150)	1.25709 (0.359)**	−1.71735 (0.741)**	0.06934 (0.056)
.98	11.30150 (1.012)**	0.03863 (0.067)	0.112454 (0.239)	−0.18122 (0.168)	0.52577 (0.288)*	−3.30668 (0.554)**	0.04817 (0.035)
.98	10.91240 (0.947)**	0.09890 (0.047)**	0.320447 (0.250)	−0.21181 (0.169)	0.23461 (0.252)	−3.70932 (0.529)**	0.05414 (0.031)*
.98	10.15290 (1.026)**	0.01853 (0.051)	0.747596 (0.234)**	−0.27377 (0.154)*	0.62256 (0.326)*	−3.22982 (0.584)**	0.05416 (0.030)*
.98	11.10710 (0.865)**	0.03457 (0.037)	0.372594 (0.248)	−0.13082 (0.141)*	0.44010 (0.225)	−3.48498 (0.411)**	0.01264 (0.030)
.50	8.33389 (1.590)**	0.08356 (0.085)	0.326103 (0.299)	−0.16797 (0.141)	1.40885 (0.377)**	−2.11734 (0.722)**	0.05442 (0.028)*
.56	6.05300 (1.294)**	0.10214 (0.070)	0.680152 (0.281)**	−0.18517 (0.139)	1.77224 (0.355)**	−0.87371 (0.621)	0.09718 (0.028)**
.28	7.21971 (1.411)**	0.00882 (0.081)	0.584755 (0.308)*	−0.10651 (0.141)	1.52065 (0.412)**	−1.27529 (0.777)	0.10484 (0.029)**
.22	7.68808 (1.440)**	0.03334 (0.081)	0.438717 (0.292)	−0.06319 (0.133)	1.21071 (0.410)**	−1.94836 (0.803)**	0.09726 (0.028)**
.48	7.79219 (1.451)**	0.03448 (0.082)	0.507507 (0.281)*	−0.14903 (0.123)	1.14707 (0.370)**	−2.27780 (0.690)**	0.10622 (0.027)**
.82	8.11007 (1.359)**	−0.00719 (0.067)	0.594117 (0.265)**	−0.35451 (0.117)**	1.06743 (0.364)**	−1.72377 (0.609)**	0.16363 (0.027)**
.00	5.80318 (1.716)**	0.20620 (0.082)**	0.701061 (0.364)*	−0.11584 (0.157)	1.24461 (0.493)**	−2.04346 (0.924)**	0.09886 (0.029)**
.00	5.80318 (1.716)**	0.20620 (0.082)**	0.701061 (0.364)*	−0.11584 (0.157)	1.24461 (0.493)**	−2.04346 (0.924)**	0.09886 (0.029)**
.70	4.83869 (1.328)**	0.16007 (0.094)*	1.069450 (0.278)**	−0.18413 (0.123)	1.46404 (0.438)**	−1.74304 (0.791)**	0.17441 (0.037)**
.00	5.80318 (1.716)**	0.20620 (0.082)**	0.701061 (0.364)*	−0.11584 (0.157)	1.24461 (0.493)**	−2.04346 (0.924)**	0.09886 (0.029)**
.00	5.80318 (1.716)**	0.20620 (0.082)**	0.701061 (0.364)*	−0.11584 (0.157)	1.24461 (0.493)**	−2.04346 (0.924)**	0.09886 (0.029)**
.76	6.46240 (1.277)**	0.07725 (0.074)	0.786505 (0.286)**	−0.26994 (0.121)**	1.31373 (0.367)**	−1.77760 (0.704)**	0.18246 (0.035)**
.68	7.66672 (1.399)**	0.08435 (0.081)	0.482088 (0.265)*	−0.20382 (0.136)	1.37138 (0.396)**	−1.67474 (0.754)**	0.13742 (0.038)**
.96	8.57185 (1.113)**	0.05268 (0.086)	0.431002 (0.165)**	−0.25267 (0.070)**	1.69995 (0.401)**	−0.94643 (0.667)	0.09353 (0.042)**
.98	9.94510 (1.523)**	0.01083 (0.077)	0.826632 (0.223)**	−0.33752 (0.079)**	0.89599 (0.235)**	−2.28216 (0.657)**	0.13377 (0.048)**
.98	7.51212 (1.633)**	0.12341 (0.095)	1.083090 (0.211)**	−0.17023 (0.088)*	1.28178 (0.462)**	−1.13104 (0.787)	0.07775 (0.038)**
.98	10.20180 (1.552)**	0.15195 (0.105)	0.475595 (0.216)**	0.04165 (0.125)	1.16299 (0.406)**	−1.95319 (0.749)**	−0.05412 (0.052)
.60	8.51541 (1.610)**	0.07353 (0.088)	0.540994 (0.295)*	−0.15159 (0.144)	1.22964 (0.427)**	−1.95556 (0.803)**	0.8692 (0.049)*
.98	8.39000 (1.589)**	0.04870 (0.095)	0.657878 (0.277)**	−0.24220 (0.138)*	1.23371 (0.404)**	−1.91261 (0.751)**	0.09800 (0.063)

[a] The actual data used in this study, as well as a program for estimating the time-varying parameter model, are available from the authors.

[b] The $\hat{\tau}$ are the estimates of the fraction of parameter variation due to permanent changes. The closer $\hat{\tau}$ is to one, the more important

(10) $$Y \sim [X\beta, \sigma^2\Omega_{(\tau)}].$$

The log likelihood function at a particular realization can be written as:

(11)
$$L(Y; \beta,\sigma^2,\tau,X) = -T/2(\ln 2\pi + \ln \sigma^2 + 1/T \ln|\Omega_{(\tau)}|) - \tfrac{1}{2}\sigma^2(Y - X\beta_{(\tau)})' \Omega_{(\tau)}^{-1}(Y - X\beta)_{(\tau)}).$$

Maximizing partially for β and σ^2 and substituting into (11), we obtain the concentrated likelihood function:

(12) $$L_c(Y; \tau) = -T/2(\ln 2\pi + 1) - T/2 \ln \sigma^2_{(\tau)} - \tfrac{1}{2} \ln|\Omega_{(\tau)}|.$$

Maximizing the concentrated likelihood function (12) is equivalent to globally maximizing the log likelihood function (11). Since $0 \leq \tau \leq 1$, equation (12) can be estimated for a number of points within the range and an estimate of τ, say g, chosen such that:

(13) $$L_c(Y; g,X) \geq L_c(Y; \tau_i,X) \text{ for all } i.$$

This procedure obtains a consistent estimator of τ which implies that the estimates of β and σ^2 are asymptotically efficient (Cooley and Prescott 1976).

Model and Data

The state-level acreage response model for corn was specified as follows:

(14) $AC = f(LAC, EPCO, EPSY, WSPCO, WDPCO, T)$,

where *AC* is the acreage planted to corn (million acres); *LAC* is the acreage planted to corn, lagged one period; *EPCO* and *EPSY* are the quasi-rational expectations of the market price for corn and soybeans, respectively, relative to a variable input price index; *WSPCO* is the weighted support price for corn; *WDPCO* is the weighted diversion payment; and *T* is a linear trend variable.

Quasi-rational price expectations were used as a proxy for producers' price expectations. These expectations are based on Nerlove's idea that producer price expectations can be successfully modeled using univariate or small multivariate models. Price data were analyzed over the period of 1939–56 to determine the appropriate ARIMA representation of the series. The corn price series was identified as an ARIMA (0,1,0) or random-walk model, while the soybean price followed an ARIMA (1,1,0). The ARIMA predictions for the study period (1957–82) were used as proxies for producer price expectations. The variable input price index used here was a national index of prices of all production items obtained from *Agricultural Prices*. Due to a lack of state-level input price indices, the national index was used as a proxy. The producer price expectations were deflated using this index.

The weighted support price and weighted diversion payment variables were constructed in a manner similar to that of Houck et al., based on information obtained in *Feed Situation* (U.S. Department of Agriculture) and Cochrane and Ryan. National data were used in the construction of these variables which were in turn employed as proxies for their state-level counterparts.

Following Cooley and DeCanio, the parameters were assumed to be subject to both permanent and transitory changes with $\Sigma_\upsilon = \Sigma_\nu$. The standard errors of the parameters obtained from maximum likelihood estimation under the assumption of parameter constancy were used as the diagonal elements of Σ_υ and Σ_ν. The diagonal elements were scaled so that $\Sigma_{\upsilon 1,1} = \Sigma_{\nu 1,1} = 1$.

Empirical Results

The estimates of the permanent components of the β vector along with their approximate standard errors and the estimates of τ are presented in table 1. The estimated price elasticities of corn acreage with respect to the expected prices of corn and soybeans are shown in table 2. The elasticities were calculated for each period using that period's estimated permanent β vector along with the period's price and quantity data. The averages and modes of

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the permanent changes relative to transitory changes. The maximum likelihood estimation was carried out for $0 \leq \hat{\tau} < 1$ in increments of .02. Note that at $\tau = 1$, the variance-covariance matrix Ω is singular and estimates cannot be obtained.

[c] Approximate standard errors in parentheses. *LAC* is the acreage planted to corn, lagged one period; *EPCO* is the expected price of corn; *EPSY* is the expected price of soybeans; *WSPCO* is the weighted support price for corn; *WDPCO* is the weighted diversion payment for corn; *T* is a linear trend variable.

Note: Single asterisk indicates significant at the .10 level; double asterisk indicates significant at the .05 level.

Table 2. Estimates of Short Run Own-Price and Cross-Price Elasticities of Corn Acreage Response with Respect to Corn and Soybean Prices in Iowa 1957-82

Year	Own-Price Elasticity	Cross-Price Elasticity
1957	0.181461	−0.12281
1958	0.168134	−0.11169
1959	0.131118	−0.08789
1960	0.019506	−0.06159
1961	0.065300	−0.09687
1962	0.170799	−0.13422
1963	0.077463	−0.05981
1964	0.070916	−0.08711
1965	0.151621	−0.09711
1966	0.123786	−0.05351
1967	0.084347	−0.02865
1968	0.099087	−0.07444
1969	0.116997	−0.16344
1970	0.133928	−0.04827
1971	0.125934	−0.04741
1972	0.162001	−0.08392
1973	0.132380	−0.06481
1974	0.165091	−0.06307
1975	0.192280	−0.14818
1976	0.089067	−0.07558
1977	0.064025	−0.12606
1978	0.111996	−0.14886
1979	0.136745	−0.06530
1980	0.056618	0.01392
1981	0.080520	−0.05084
1982	0.075736	−0.08389

the elasticities for "program" and "nonprogram" years are summarized in table 3. The program years were 1957–58, 1961–73, and 1978–79 while the nonprogram years were 1959–60, 1974–77, and 1980–82. The program years correspond to periods when feed grain acreage control programs were in effect while the nonprogram years are those when market forces dominated. These divisions correspond with the temporal disaggregation used in Lee and Helmberger's analysis.

The average and modal elasticities for the program periods were higher than were observed for the nonprogram periods. The average elasticity for the program years was .124 while the nonprogram average elasticity was .097 (table 3). While this result is consistent with Lee and Helmberger's findings, it indicates that the difference between program and nonprogram periods may not be as great as their estimates suggest. The average and modal cross-price elasticities of corn acreage with respect to soybean price were found to be only slightly higher (in absolute value) during the program years than the nonprogram years. In addition, the year-to-year changes in elasticities were found to be somewhat less variable under the government program years than the nonprogram years as evidenced by the standard deviations (table 3).

The fact that participation in the government programs was voluntary contributes to the difference in price elasticities between program and nonprogram periods. The individual producer's decision to participate depends upon evaluation of the relative returns to participation versus nonparticipation. Consequently, acreage control programs are less than 100% effective. Following the logic developed by Lee and Helmberger, if we assume that individual producers within a given geographic area (e.g., Iowa) hold different "indifference prices" for program participation, then the number of farmers participating depends upon the level of program payments relative to these indifference prices. It is the participation decision that leads to a higher aggregate own-price responsiveness of corn acreage. The aggregate situation is illustrated in figure 1. Below a certain minimal price level, P_n, all producers will participate in the program and total acreage is reduced from nonprogram levels. As the expected output price increases above P_n, fewer producers choose to participate as the price reaches their indifference price. The aggregate acreage supplied by these producers is S'. Above the highest indifference price, P_x, all producers become nonparticipants, the aggregate acreage is the same as would exist in a competitive market, and the appropriate aggregate acreage supply is S.

The announcement of an acreage diversion program has an effect on producers' expectations of output price. Producers may revise their subjective expectations on output price upward in anticipation of reduced production. In addition, the effective support price serves as a lower bound on the subjective distributions of program participants. In aggregate, this causes a decrease in the dispersion of price expectations and, *ceteris paribus,* encourages production of the program commodity (Pope).

The estimates of τ, the fraction of parameter variation due to permanent changes, were, on average, higher during the nonprogram periods (.77 versus .61; table 3). These data show that, historically, feed grain acreage control programs have had a stabilizing effect on producers' year-to-year production decisions. This

Table 3. Modes, Averages, and Standard Deviations of the Estimated Short-Run Own-Price and Cross-Price Elasticities for Program and Nonprogram Years and Average Values of $\hat{\tau}$

	Own-Price Elasticity		Cross-Price Elasticity	
	Program[a]	Nonprogram[b]	Program[a]	Nonprogram[b]
Mode	0.125934	0.080520	−0.08392	−0.07558
Average	0.124288	0.097107	−0.08754	−0.07591
Standard Deviation	0.034975	0.052056	0.03714	0.04348
Average value of $\hat{\tau}$	0.61	0.77		

[a] Program years: 1957–58, 1961–73, 1978–79.
[b] Nonprogram years: 1959–60, 1974–77, 1980–82.

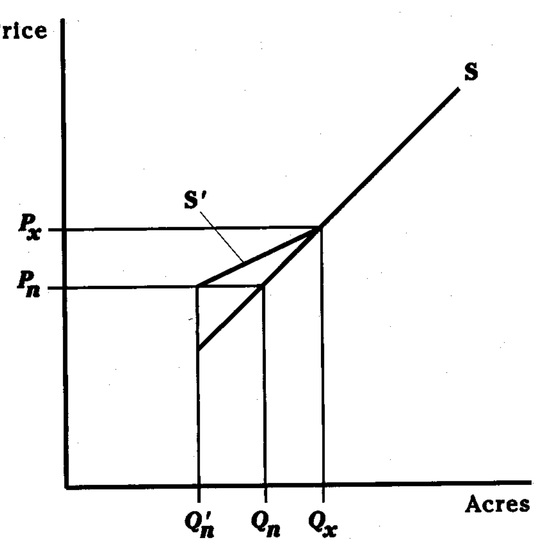
stabilization could be attributed, in part, to the decreased dispersion of price expectations. The τ were estimated as zero in only four periods, suggesting that modeling parameters as constants over time likely would be inappropriate.

The approximate standard errors of the permanent components of the β vectors indicate that the weighted diversion payment and support price are significant even in the nonprogram years. This result suggests that temporal disaggregation of the data may not be appropriate and supports Romain's contention that producers' decisions are influenced by announced support levels even during periods when market forces are thought to be of dominant importance.

Conclusions

This paper has described the variation in acreage response parameter estimates occurring over time. The results of the time-varying parameter estimations are reported for each year and summarized over program and nonprogram periods. Corn acreage response is shown to be more own-price responsive in years when government acreage control programs are in effect. Government programs provide producers with another land use alternative and hence increase their price responsiveness in program years relative to nonprogram years. Although the results support Lee and Helmberger's hypothesis that the own-price elasticity of corn acreage response will be greater in program than nonprogram periods, the magnitude of difference indicated here was less than their results suggest. The results also show that producers' supply response is more stable under government acreage control programs. This suggests that even a policy which does not necessarily influence producers' price expectations may have important impacts on land allocation through its risk-reduction effects. Support-price and diversion-payment variables are shown to be significant in both program and nonprogram periods. Temporal disaggregation, therefore, while allowing parameters to vary between regimes, may ignore the influence of past and present program provisions in nonprogram years. The different values of $\hat{\tau}$ in nonprogram years relative to program years support the argument that farm programs have effected permanent structural changes in corn acreage response. Further, it increases the uncertainty about market conditions that would have developed in the absence of farm programs.

Ignoring the distinction between program and nonprogram years, as has been done in many supply response analyses, likely will re-



Adapted from Lee and Helmberger

Figure 1. Aggregate corn acreage supply under government programs

sult in biased estimates of the price responsiveness of corn producers. This study maintains the distinction between production periods in a systematic manner and provides empirical estimates of elasticities that reflect structural changes over time.

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