ESTIMATING THE STRUCTURE OF TIME LAGS BETWEEN WHOLESALE AND FARM PRICES FOR COTTONSEED

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Previous analysis on annual wholesale marketing margins for cottonseed has indicated a need to establish the structure of short-period time lags between prices for cottonseed products and resulting farm prices for the gin-run seed [4]. In particular, this would help assess large wholesale margins since the beginning of the 1972 crop year, when cottonseed oil and meal prices began an inflationary surge that has resulted in increases of over 100 percent (4, Table 2).

Objectives of this paper are: (1) to formulate and estimate the monthly distribution of lagged response of cottonseed prices to changes in wholesale cottonseed product prices in the United States and (2) to use the estimation results in examining recent behavior of cottonseed prices and wholesale marketing margins.

Economic theory states that demand at farm level is derived from wholesale demand, which in turn is derived from consumer demand. Thus, if the market is free to operate, farm cottonseed prices are expected to be a direct function of wholesale values of cottonseed products. However, price adjustments are never instantaneous from one market level to another. Farm prices will "follow" wholesale prices over a period of time. The length and configuration of lagged response of cottonseed prices to changes in wholesale values are of primary interest in this paper.

WHOLESALE MARKET VALUES VERSUS FARM COTTONSEED PRICES[1]

Four marketable products are obtained from cottonseed: oil, meal, linters and hulls. During the past sixteen years (1958-73), yields of these products per ton of United States cotton have averaged the following percentages: oil - 16.6%, meal - 46.4%, linters - 9.0% and hulls - 23.4%. The remaining 4.6% of average volume is waste material which has no market value.[2]

Using the foregoing percentages to weigh market prices of each product, an aggregate wholesale value of all products obtained from a ton of cottonseed can be estimated. These wholesale values may then be used in conjunction with readily available data on cottonseed prices to examine the farm-to-wholesale marketing spread.

DISTRIBUTED LAGS

A general expression for a distributed lag function is:

$$(1)\quad Y_t = \sum_{k=o}^{M-1} \beta_k X_{t-k} = \beta_o X_t + \beta_1 X_{t-1} + \dots + \beta_{m-1} X_{t-(M-1)}$$

where Y_t is the dependent variable at time t, X_{t-k} is the independent variable at time t−k, $\{\beta_k\}$ are the coefficients of the lag structure, and M−1 is the number of past periods covered by the lag function. (Including the current period t, there are M periods in all.)

An unconstrained statistical estimation of the coefficients $\{\beta_k\}$ is generally not feasible. Therefore, it has been common practice to estimate the $\{\beta_k\}$ subject to the restriction that they be, in some sense, a smooth function of K. It

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[1]Sources of data and method of computation are detailed by Ethridge (4). Monthly data used in this paper are explained in the section on empirical application.

[2]These percentages differ somewhat from the simple averages of the four major U.S. production regions (4, Table 1). U.S. averages are weighted by volume of production in each region.

is beyond the scope of this paper to suvey the various types of lag specifications, but econometric literature on the subject is readily available [5, 7, 13].

This analysis addresses itself to a finite distributed lag whose coefficient are restricted to lie on a polynomial of low order. This was first applied by Almon [1] and has since been used and/or modified by several economists [2, 6, 8]. Chen, Courtney and Schmitz [3] used a polynomial lag formulation in an attempt to estimate the supply response of California milk producers. The author is not aware of any studies using polynomial lag — or any other distributed lag formulation — to analyze price relationships along agricultural marketing channels.

If the polynomial used is of degree (or order) N, then

$$(2)\ \beta_k = \sum_{j=o}^{N} a_j k^j = a_1 + a_1 k + a_2 k^2 + \cdots + a_N k^N$$

Equation (1) becomes

$$(3)\ Y_t = \sum_{k=o}^{M-1} \left(\sum_{j=o}^{N} a_j k^j\right) X_{t-k}$$

Almon [1] used Lagrangian interpolation polynomials to estimate the distributed lag coefficients. Hall and Sutch [6] have since developed a more direct technique that produces identical estimates.[3] It is assumed that $\beta_M = 0$; i.e., beyond period M−1. past values of the independent variable no longer affect current values of the dependent variable. Thus,

$$(4)\ a_o + a_1 M + a_2 M^2 + \ldots + a_N M^N = 0$$

Solving equation (4) for a_o and substituting into equation (2) gives

$$(5)\ \beta_k = \sum_{j=1}^{N} a_j (k^j - M^j)$$

Define N new variables, Z_{tj}, as follows:

$$(6)\ Z_{tj} = \sum_{K=0}^{M-1} (k^j - M^j) X_{t-k} \quad , j = 1, \ldots, N$$

Then

$$(7)\ Y_t = \sum_{j=1}^{N} a_j Z_{tj}$$

To estimate the coefficients $\{a_j\}$, regress Y_t on the N variables $\{Z_{tj}\}$. The distributed lag coefficients $\{\beta_k\}$ may then be estimated from equation (5).

APPLYING A POLYNOMIAL DISTRIBUTED LAG STRUCTURE TO ESTIMATE COTTONSEED PRICES

The polynomial lag formulation was chose in this application for three major reasons:

(1) It is flexible enough to allow approximation of an arbitrary distributed lag function to any desired degree of accuracy.

(2) It gives consistent estimates of the $\{\beta_k\}$ in the presence of serial correlation — an almost inevitable occurrance with monthly time series data.

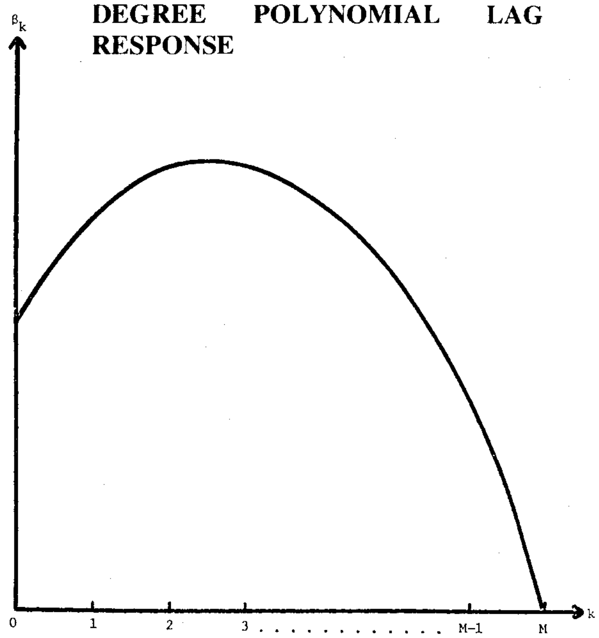
(3) There are good reasons to expect the lagged effect of wholesale product values on cottonseed prices to be adequately explained by a polynomial function to the second (or perhaps third) degree.

The first two reasons relate to general attributes of the polynomial lag formulation. The third requires justification in context of this application.

A second degree polynomial lag is most appropriate when the dependent variable's response over time to changes the independent variable first increases at a decreasing rate, reaches a maximum, then decreases at an increasing rate until it goes to zero (at some past period). A "typical" configuration of second degree polynomial lag coefficients is illustrated in Figure 1. Shape of the lag responses may vary; e.g., the peak (or head) of the distribution may be more or less prominent and the length of lag may vary. But the curve is always concave downward. If the true shape of the lag distribution has an inflection point, a third degree polynomial would be appropriate. If it has more than one peak, an even higher degree polynomial would be needed.

[3] This technique was applied by Chen, Courtney and Schmitz (3).

Figure 1. TYPICAL SHAPE OF A SECOND DEGREE POLYNOMIAL LAG RESPONSE



There are inevitable transfer, processing and transportation lags involved in transforming cottonseed into marketable products. It is reasonable, then, to expect cottonseed prices to reflect these lags. Thus, as possession changes from farms to gins to crushing mills to wholesalers, it is not likely that a short-term price change at wholesalers' level would have its complete impact on farm prices within, for example, the current month. Its largest impact may occur in the second or third month, with declining influence for a few more months. This lagged influence in the cottonseed market is augmented by the practice of forward contracting for future delivery, especially during months prior to cotton harvesting.[4]

Information from cotton industry personnel indicates that a lagged effect of wholesale product values might last six months, but probably not more than seven. The exact lag length (M) and the degree of polymial (N) should both be determined by comparing statistical results using alternative values of these parameters.

EMPIRICAL RESULTS

Regression estimates were obtained for all feasible combinations of three polynomial specifications (N = 2, 3, 4) and six monthly lag lengths (M = 3, 4, 5, 6, 7, 8).[5] According to appropriate t-statistics, third and fourth degree polynomial terms did not contribute significantly to explanation of cottonseed price levels; therefore, to save space, only results for a second degree polynomial are reported.

Using a second degree polynomial (N=2), the polynomial lag formulation for cottonseed prices is as follows:

$$
\begin{aligned}
(8)\quad P_t &= \sum_{k=o}^{M-1} \beta_k V_{t-k} \\
&= \sum_{k=0}^{M-1} [a_1(k-M)+a_2(k^2-M^2)]\,V_{t-k} \\
&= a_1 \sum_{k=0}^{M-1}(k-M)V_{t-k} + a_2 \sum_{k=0}^{M-1}(k^2-M^2)V_{t-k} \\
&= a_1 Z_{t1} + a_2 Z_{t2}
\end{aligned}
$$

where P_t is cottonseed price at time t,[6] V_{t-k} is wholesale value of cottonseed products at time t−k,[7] and all other terms are as previously defined.

Due to the necessity of accounting for effects of increasing costs along wholesale marketing channels, a marketing cost index was added:

$$(9)\quad P_t = a_1 Z_{ti} + a_2 Z_{t2} + a_3 I$$

where I is annual index of major costs incurred by the wholesale cottonseed marketing system.[8]

Regression estimates of equation [9] for alternative lag lengths are summarized in Table 1.

[4]Almost all cottonseed is sold during an eight month period from August to March. In fact, cottonseed price data are not available for the four months of April to July. Products from cottonseed, of course, are marketed throughout the year, so continuous monthly price series are available at the wholesale level.

[5]It is a statistical necessity that N be less than M. Thus, N=4 and M=3 would not be a feasible combination.

[6]Monthly farm prices per ton of cottonseed in the United States, August 1958-January 1975. Data not availabe for months April-July of each year, resulting in 134 observations. Data obtained from the USDA (12).

[7]Weighted average of the following per-ton wholesale prices:
(1) Monthly price of crude cottonseed oil in tank cars, f.o.b.. Valley points. From USDA (11).
(2) Monthly price of bulk cottonseed meal, 41% protein, Memphis. From USDA (9).
(3) Monthly price of grade 4, staple 4 cotton linters, U.S. From USDA (10).
(4) Season average price of cottonseed hulls, carload lots, Atlanta. From USDA (11).

[8]A weighted average index of costs for labor, machinery, transportation, and fuel and electricity. For data and sources, see Ethridge (4, Table 6).

The appropriate statistic for determining correct length of lag is standard error of regression (6). Since the smallest standard error occurs for a six-month lag period, the equation with $M=6$ is chosen to estimate cottonseed price.

Table 1. REGRESSION ESTIMATES FOR MONTHLY COTTONSEED PRICES, POLYNOMIAL LAG FORMULATION, ALTERNATIVE LAG PERIODS, AUGUST 1958-JANUARY 1975[a,b]

Lag Period	Constant Term	Z_{t1}	Z_{t2}	I_t	Standard Error	R^2
	---Dollars per Ton---					
M=3	12.847* (4.394)	0.414* (5.199)	-0.141* (-6.465)	-0.162* (-3.461)	5.137	0.936
M=4	13.998* (4.493)	-0.026 (-0.862)	-0.007 (-0.181)	-0.176* (-3.519)	5.462	0.923
M=5	11.702* (5.169)	0.151* (6.171)	-0.031* (-7.944)	-0.193* (-5.322)	3.971	0.962
M=6	11.069* (5.093)	0.083* (5.071)	-0.015* (-7.008)	-0.204* (-5.865)	3.803	0.965
M=7	10.494* (4.776)	0.045* (3.518)	-0.008* (-5.439)	-0.212* (-6.052)	3.826	0.964
M=8	10.027* (4.427)	0.021** (2.003)	-0.004 (-3.830)	-0.217* (-6.082)	3.912	0.963

[a]Sample size = 134 observations.

[b]Number in parentheses below each coefficient is the Student's t-ratio for the coefficient.

*Significant at the 99% confidence level.

**Significant at the 95% confidence level.

According to equation (8), substituting wholesale values for Z_{t1} and Z_{t2} in the regression equation gives

$$(10)\ \hat{P}_t = \underset{(5.093)}{11.069} + \underset{(2.048)}{0.043}V_t + \underset{(15.857)}{0.111}V_{t-1} + \underset{(50.000)}{0.150}V_{t-2} + \underset{(17.444)}{0.157}V_{t-3} + \underset{(13.500)}{0.135}V_{t-4} + \underset{(11.857)}{0.083}V_{t-5} - \underset{(-5.865)}{0.204}I$$

All coefficients are significant at the 95 percent confidence level as indicated by the t-statistics under each coefficient.[9] The impact of a change in wholesale value on cottonseed price is relatively small in a current month, but increases steadily for wholesale values one, two and three months in the past. The effect of wholesale value in the fourth previous month declines only slightly, but impact of the fifth month's value declines substantially.[10] Figure 2 pictures the distribution of lag estimated in equation (10). These results agree very well with prior expectations of the distributed lag effects. The sign and magnitude of the marketing cost index (I) coefficient also appear reasonable.

[9]The t-statistic for $\hat{\beta}_k$ (estimated value of β_k) is given by

$$t_{\hat{\beta}k} = \frac{\hat{\beta}_k}{\sqrt{\mathrm{Var}(\hat{\beta}_k)}}$$

where

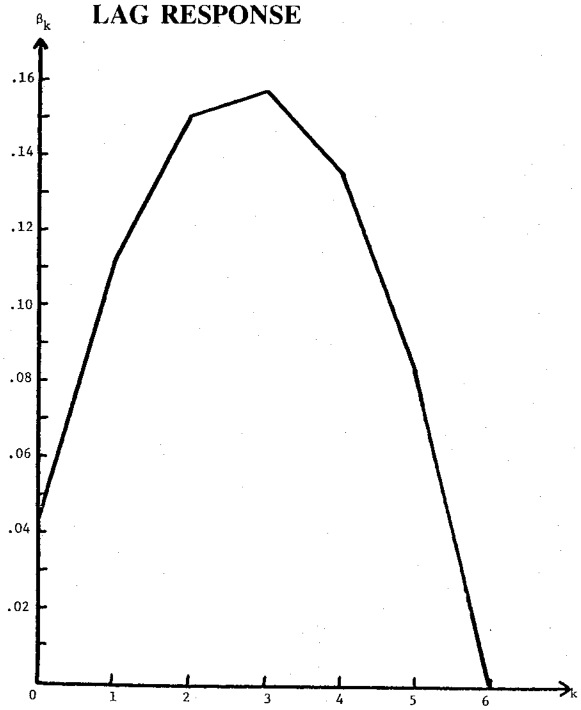
$$\mathrm{Var}(\hat{\beta}_k) = \mathrm{Var}\,[\hat{a}_1(k-M)+\hat{a}_2(k^2-M^2)] = (k-M)^2\mathrm{Var}\,(\hat{a}_1)+(k^2-M^2)^2\mathrm{Var}\,(a_2) + 2(k-M)(k^2-M)\,\mathrm{Cov}(a_1a_2)$$

[10]The cumulative or "long-run" effect of a monthly change in wholesale value is obtained by adding the effects over all six periods. Thus,

$$.043 + .111 + .150 + .157 + .135 + .083 = .679$$

is the cumulative effect. In words: "For each dollar that the monthly wholesale value of products from a ton of cottonseed increases, cottonseed prices will eventually increase 67.9 cents per ton."

Figure 2. SHAPE OF ESTIMATED DISTRIBUTED LAG RESPONSE



IMPLICATIONS FOR MARKETING DURING 1972-74 CROP YEARS

It has been shown that annual average wholesale marketing margins were quite large during the 1972 and 1973 crop years [4]. Use of zero-one shift variables in regional regression equations indicated that, for those two years, average farm-to-wholesale spread was between 30 and 40 dollars per ton more than historical relationships between prices could explain (4, Table 7). However, wholesale values of cottonseed products were generally increasing substantially from month-to-month during this period. Given the time lags in wholesale-to-farm prices changes, margins may be expected to widen during periods of increasing wholesale values and narrow during periods of decreasing ones. The framework developed in this paper should allow a more realistic appraisal of how unusual marketing spreads were during the past three years.

Utilizing monthly zero-one shift variables for each year of the 1972-74 period, four additional regression equations were generated using a six months lag (Table 2). Inclusion of shift variables caused some alterations in previous regression results. The constant terms are no longer significantly different from zero and absolute magnitudes of all other coefficients are somewhat smaller.[11]

Using a shift variable for the entire period 1972-74 (Table 1, solution 1) results in the conclusion that cottonseed prices during this period averaged about seven dollars per ton lower than can be accounted for by wholesale values and the marketing cost index; i.e., the marketing margin averaged about seven dollars per ton more than is explained by historical relationships among variables. Such an increase in the marketing margin is hardly insignificant; however, it is not large enough to cause alarm about market performance. The unprecedented increases in wholesale values during this period undoubtedly increased uncertainty in the market, one economically valid reason why the marketing system might increase its operating margin.

To further examine margin behavior during the last three years, two shift variables were used. The first applied to individual years and the second to the other two years not covered by the first variable (Table 2, solutions 2, 3 &4). Briefly, results indicate that the margin was significantly larger in 1972 (solution 2) and 1973 (solution 3). But in 1974, when wholesale prices were finally beginning to level off, the shift variable is insignificantly different from zero (solution 4). This indicates that the marketing margin may be returning to normal.

CONCLUSIONS

Usefulness of a polynomial lag formulation in estimating and analyzing cottonseed prices has been demonstrated. Perhaps distributed lag

[11] Converting the first regression equation (Table 2, solution 1) to obtain the $\{\hat{\beta}_k\}$,

$$\begin{aligned}\hat{P}_t = \underset{(0.978)}{2.693} + \underset{(3.333)}{0.070}V_t + \underset{(15.250)}{0.122}V_{t-1} + \underset{(32.391)}{0.149}V_{t-2} \\ + \underset{(16.667)}{0.150}V_{t-3} + \underset{(15.200)}{0.126}V_{t-4} + \underset{(15.200)}{0.076}V_{t-5} \\ - \underset{(-3.671)}{0.133I} - \underset{(-4.496)}{7.188\text{ Shift Var.}}\end{aligned}$$

It is seen that the impact of current wholesale value is estimated to be about 63 percent larger than it was in equation (10). For the other $\{\beta_k\}$, however, estimates are quite similar for the two specifications.

analysis would be appropriate for studying price movements at various market levels and for various commodities. Certainly there are many agricultural commodities for which time lags in the marketing system are common.

Additional analysis might yield more detailed information on cottonseed prices. For example, the possibility was not explored that different cottonseed product prices, components of the wholesale value, may have different lagged effects on farm price. Also, it would be of methodological interest to compare these distributed lag results with those of a spectral analysis of lagged behavior between cottonseed prices and wholesale values. Hopefully, the two methods would support similar conclusions.

Table 2. ADDITIONAL REGRESSION ESTIMATES FOR MONTHLY COTTONSEED PRICES, USING A SIX-MONTHS LAG AND APPLYING ZERO-ONE SHIFT VARIABLES TO ALTERNATIVE PERIODS OF THE 1972-74 CROP YEARS[a]

Regression Number	Applicable Time Periods for Shift Variables: First	Applicable Time Periods for Shift Variables: Second	Constant Term	Z_{t1}	Z_{t2}	I	First Shift Variable[b]	Second Shift Variable[b]	R^2
			Dollars per Ton						
1	1972-74	None	2.624	0.067*	-0.13*	-0.134*	-7.185*	--	0.973
			(0.957)	(5.124)	(-7.682)	(-3.701)	(-4.508)		
2	1972	1973-74	0.895	0.070*	-0.014*	-0.161*	-6.347*	-11.564*	0.973
			(0.305)	(5.326)	(-7.876)	(-4.042)	(-3.800)	(-3.630)	
3	1973	1972 & 1974	3.293	0.063*	-0.013*	-0.154*	-9.917*	-6.233*	0.974
			(1.213)	(4.840)	(-7.491)	(-4.197)	(-5.017)	(-3.838)	
4	1974	1972-73	4.593	0.061*	-0.012*	-0.135*	-2.971	-6.809*	0.973
			(1.575)	(4.516)	(-6.853)	(-3.764)	(-1.075)	(-4.277)	

[a]Numbers in parentheses are t-ratios.

[b]Equal to one for each month during applicable period and equal to zero otherwise.

*Significant at 99% confidence level.

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