Estimating Demand Relations Using Futures Prices

By William G. Tomek*

Preharvest production forecasts can be combined with contemporaneous price quotations for futures contracts to estimate demand equations, but the methodology has limitations for estimating structural coefficients. An application using data for corn highlights the difficulties. The methodology, however, does seem to be a promising descriptive tool, and it may also provide helpful information about structural relationships.

Keywords

Futures prices
Demand
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In 1974, Roger Gray (*3*) wrote "The demand curve for grains may have grown steeper at higher price levels."[1] He did not test this hypothesis, but presented an example that used observations on futures prices and on crop size forecasts to compute elasticities for 2 different years. An objective of this article is to elaborate on the use of futures prices to estimate expected demand relations. Gray's simple procedure is formalised and illustrated with data for corn. Then, his hypothesis is revisited, and the results are given a somewhat different interpretation. The principal conclusion, however, is that the procedure probably has more use as a descriptive tool for students of commodity markets than as a method of estimating structural coefficients.

METHODOLOGY

The U.S. Department of Agriculture's preharvest forecasts of crop size provide a measure of expected supply. A corn production forecast, for example, is available no later than July 12 based on July 1 conditions (*13*).[2] This estimate and a corresponding futures price (say, the closing quotation for December delivery on July 13) may be viewed as the point of equilibrium of supply and demand schedules, given the information available in mid-July. Crop forecasts for corn are also made in August, September, October, and November. Hence, five observations are generally available each year on price and quantity.

The question is: Can these observations be used to estimate a demand relation? Although a correct model is needed, just four or five observations exist per year. One simple model is

$$P_t = \alpha + \beta Q_t + e_t \qquad (1)$$

where

Q = crop size forecast made by USDA,
P = price quotation for a futures contract at the time of release of Q,
t = 1, 2, ... T (T = 4 or 5)

In demand analyses for many farm products, Q is assumed to be predetermined, and P is the endogenous variable adjusting to the changes in supply.

In estimation of a demand relation, however, equation (1) is likely to be underidentified in some years, the first potential problem. If supply shifts while demand remains stable, the regression would provide an identifiable estimate of the demand parameters. Changes in demand, however, may be large relative to changes in supply, and the changes may be correlated. Revisions in crop forecasts are sometimes serially correlated (say, revised downward each month), and if demand changes are also serially correlated over the same time interval, the shifts will be correlated. Clearly, the slope coefficient of the estimated regression need not estimate the slope of the demand function.

A second potential problem is a lack of precision in estimation. The variance of a regression coefficient is related inversely to the variance of the explanatory variable. In many years, the variance of the crop forecast is small. Thus, even if the demand relation is identifiable, it may not be possible to obtain precise estimates of it.

A third problem is the possibility of Q's being measured with error. The question here is not whether the forecast equals the final estimate, it typically will not. Rather, does the reported forecast correctly measure the market's expectations about supplies? Current price reflects the contemporaneous market view of economic conditions. Market participants, on balance, may not believe the USDA predictions, or crop conditions may have continued to deteriorate after the survey. The prediction is subject to varying interpretations by market participants. Thus, little correlation may exist between the forecast and price as observed at

*The author is a professor of agricultural economics at Cornell University, Ithaca, N.Y. At the time this research was conducted, he was a visiting economist with the National Economics Division, ESCS.

[1] Italicized numbers in parentheses refer to items in References at the end of this article.

[2] July estimates were not made in 1971-74, inclusive.

Little correlation may exist between the forecast and price as observed at the time the forecast is released

the time the forecast is released [3]

The variable Q also may be inappropriate, the crop forecast may not be a good measure of total expected supply Carryover and the production of other feed grains can also influence the price of corn

A current price quotation for a futures contract also reflects current and expected demands Thus, a fourth possible problem is the omission of some variables related to changes in demand One can observe, for a year or a quarter, systematic changes in variables affecting demand, such as the number of animal units influencing the demand for corn This becomes more complex on a daily, weekly, or monthly basis Truly new information occurs randomly through time If it were known or predictable, such information already would be reflected in price When new information occurs in a perfect market, prices move promptly and correctly to the level warranted by the information (*10*, *14*)

Markets are not perfect, but prices apparently adjust rapidly to new information (*6*, *11*) Price changes on futures markets are expected to be martingales (*10*) Over a month, the observable changes in production forecasts may or may not, as mentioned, provide a periodic measure of changing expectations about supply But comparable measures of demand changes usually do not exist

The empirical analysis here treats some, but not all, of the problems enumerated For omitted variables, some modifications can be made in the model without influencing the degrees of freedom Corn production could be deflated, for example, by animal units being fed, adjusted by estimates of carryover, and adjusted to include other feed grain production forecasts Prices might be deflated Many alternative model specifications are possible and are not the prime consideration here Thus, only a few different price deflators are explored, particularly price indexes based on livestock futures prices

A trend variable was also considered as a proxy for omitted variables Trend was introduced through the first difference equation

$$\Delta P_t = \alpha + \beta(\Delta Q_t) + u_t, \text{ where}$$

$$\Delta P_t = P_t - P_{t-1}, \text{ and so on} \qquad (2)$$

In equation (2), one degree of freedom is lost, and, following Samuelson (*10*), the error term may be heteroscedastic [4] Moreover, trend is likely to be a poor measure of demand changes The hypothesis alpha equals zero is likely to be accepted in most years, partly because expected demand did not change smoothly over the sample period Nonetheless, the equation is of interest because of its relationship to the martingale model

Equations (1) and (2) are fitted by least squares, but a simple instrumental variables estimator is also used to examine the errors-in-variables problem As single equations are fitted to a limited number of observations, the identification issue cannot be faced directly

APPLICATION TO CORN

Observations were obtained for USDA corn production forecasts by month for a series of years These forecasts are released by the 12th of the month (*13*) A "final" estimate is released in January, and a revised final estimate is published the following January Just the five forecasts in each year are used here

Closing price quotations for December and March futures were obtained for the 13th of the same months for which crop forecasts are available Corn prices adjust rather promptly to new information In most years, the crop forecast is not entirely new information, traders' expectations are similar to the forecast (*6*)

In estimation of equation (1), both nominal and deflated prices of

[3] As the crop surveys are made on the first of the month, price quotations also might be taken on the first of the month In principle, the market may reflect the information contained in the announcement prior to the actual release of the announcement Research by Gorham (*2*) and by Pearson and Houck (*8*) suggests that, at least in some years, there is an "announcement effect" for corn prices Use of price quotations on the 13th of the month seems a safe choice to reflect the information in the release of the crop forecast

[4] Rutledge (*9*) did not find heteroscedasticity in changes in soybean prices Futures prices are linked closely to cash prices for seasonally produced, continuous inventory commodities (*12*) Hence, the variance of the futures series is not likely to increase unless the variance of cash prices increases Heteroscedasticity perhaps is not a serious problem in the 4 or 5 months prior to the maturity of grain contracts, but this is an empirical question that requires analysis

Both nominal and real prices were plotted against the production forecasts

corn were considered, and three indexes were explored in deflating The simplest to use, because it is published, is the Index of Prices Received by Farmers for Livestock and Livestock Products (1967 = 100), an index of cash prices For estimation of expected demand for corn, however, it may be preferable to use an index based on livestock futures prices Futures prices are available for live cattle, live hogs, shell eggs, and iced broilers [5] Two indexes of livestock futures prices have been computed One uses quantity weights derived from the official index of prices received, the other uses weights based on grain consumption Results from the analyses of nominal prices and of deflated prices using the grain-weighted livestock futures index are reported in this article (Index data appear in an appendix table)

Both nominal and real prices were plotted against the production forecasts (figs 1 and 2) The observations indicate a distinct break between 1970-72 and 1973-78,[6] although of course the deflated prices vary less The level and perhaps the slope of the price-quantity relationship have changed

A simple instrumental variable (IV) estimator was, as mentioned above, used for some equations If we assume Q is observed with error, the IV procedure involves ordering Q from the largest to smallest, grouping the observations using the median of Q (omitting the middle observation when five data points exist), and using the observations −1 and 1 as the instrumental variable for the two groups of observations on Q In practice, this involves the computations

$$b_{IV} = \frac{\bar{P}_2 - \bar{P}_1}{\bar{Q}_2 - \bar{Q}_1},$$

and

$$a_{IV} = \bar{P} - b_{IV}\bar{Q},$$

where subscripts denote the respective group averages (see *5*, pp 283-285)

Equations fitted by year using nominal prices appear in table 1 As each equation has few degrees of freedom, the coefficient of determination adjusted for degrees of freedom, $\bar{r}^2$, is given It can be negative and the negative coefficients should be interpreted as a zero correlation

The slope coefficients of equations (1) and (2) are alternative estimates of the same parameter For any given year, the first difference equation (2) generally provides a larger (in absolute value) estimate than equation (1), and, for both equations, the slope coefficients differ widely from year to year

The intercept coefficient in equation (2) measures, the "trend," if any, in price from mid-July to mid November of each year Eight of the nine intercepts are negative, but only two have large t ratios First difference regressions for 1965-69 (not reported) also have negative intercepts with small t values Either futures prices decline seasonally or demand has declined more often than it has increased in the past 14 years (after changes in Q are accounted for) Both explanations are inconsistent with the hypothesis that $E(P_t - P_{t-1})$ equals zero for equation (2) with nominal futures prices Cash prices decline seasonally from mid July to mid-November, but such behavior should be anticipated in futures prices Similarly, years with increases in demand should about equal those with decreases It is, however, dangerous to overinterpret the results, especially for a short period of years Statistically, most of the intercepts are zero

For estimation of a demand relation, I see no compelling reason to use first differences The model is of interest in examining the martingale

[5] The futures prices in the index are for the April delivery of cattle and hogs and the January delivery of eggs and broilers For instance, one price in the July 1974 index is the closing price on July 13, 1974 of the April 1975 live cattle contract January contracts are used for eggs and broilers because in some years these futures were not traded until 6 or 7 months in advance of delivery, and observations for April delivery are not always available in July All prices pertain to the new crop year in any case, and, hence, represent market expectations about livestock prices for the new year The weights for the prices are simply the percentages that feed grain disappearance for each livestock item represent of total disappearance for the four commodities For simplicity the weights are computed from 1970 71 crop year data, and the price index is on a 1970=100 base Cattle and hog futures started in the mid-sixties Some markets in the early years were not actively traded—price quotations were not available in July for contracts requiring delivery in the next year, and data were not available until 1970

[6] Since it is difficult to construct an index of livestock futures prices prior to 1970, the sample period was limited to 1970-78 However, if nominal prices or a cash price deflator are used, the scatter of observations in the sixties resembles those of 1970 72 The 1970-72 period apparently is representative of earlier years

Figure 1
Corn: Relationship Between Futures Prices and Crop Forecasts

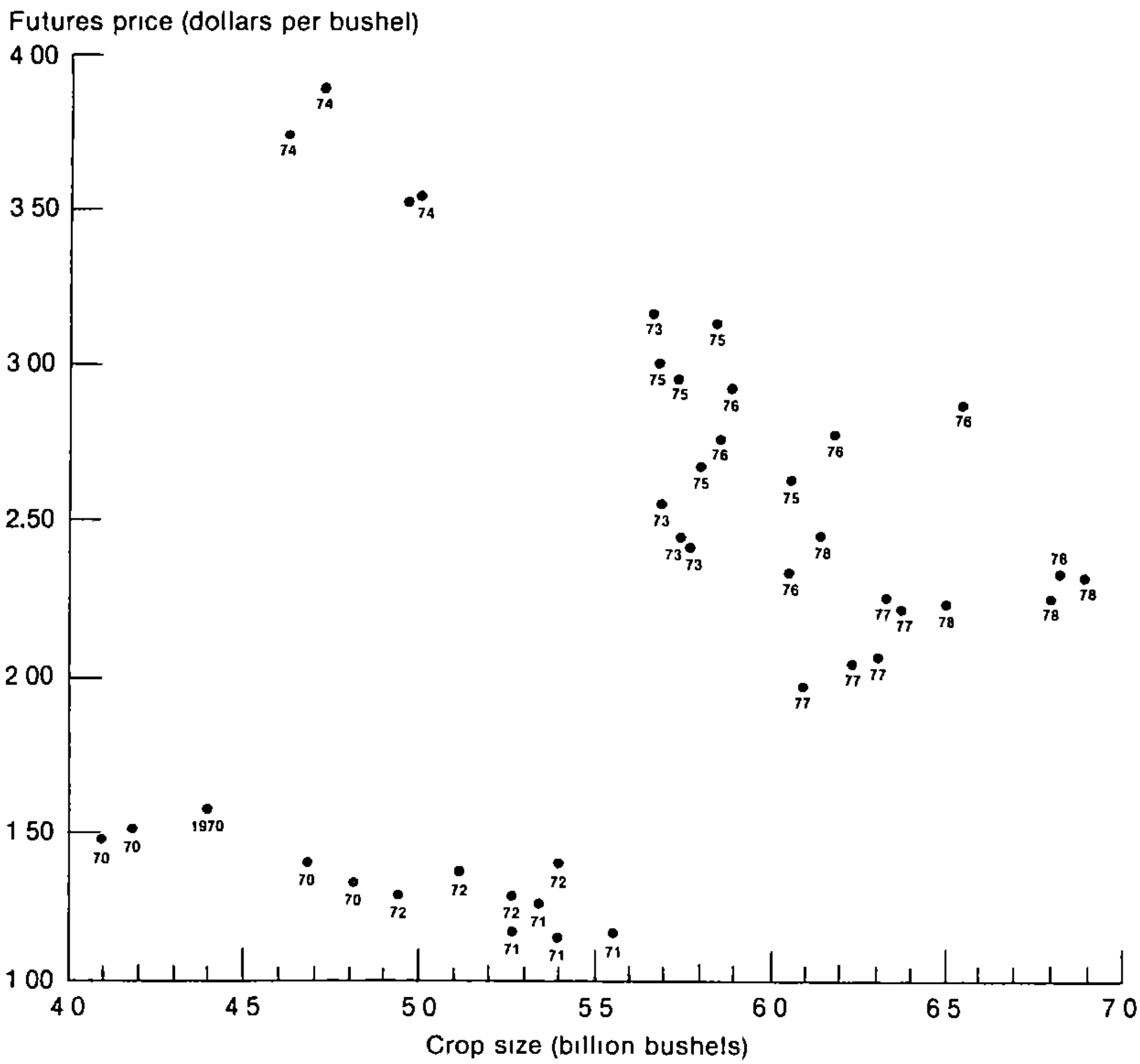
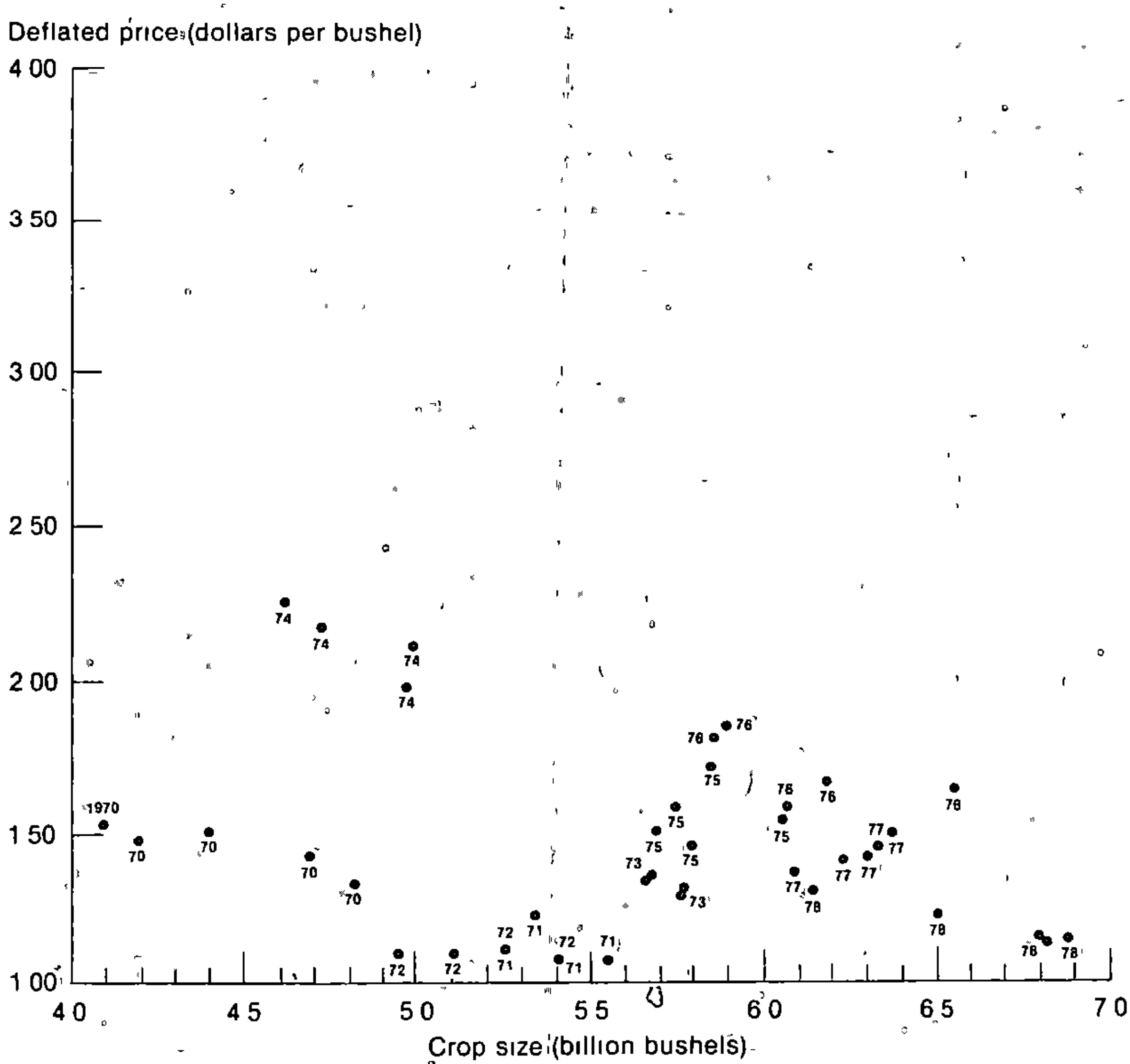


Figure 2

Corn: Relationship Between Deflated Futures Prices and Crop Forecasts



Prices in 1973 and 1974 were above support levels, and when deflated, the equations have similar slopes

Table 1—Regression estimates by year, prices not deflated

Year	Equation[1]	Intercept	Slope	$\bar{r}^2$
1970	(1)	2 473	–0 229	0 39
		[2](4 59)	(1.90)	
	(2)	–0 073	–0 621	02
		(0.51)	(0.85)	
1971	(1)	1 965	–0 147	– 32
		(1 31)	(0 53)	
	(2)	–0 059	0 370	91
		(4 92)	(3.86)	
1972	(1)	0 467	0 167	41
		(0 95)	(1 76)	
	(2)	–0 257	1 903	32
		(0 97)	(1 09)	
1973	(1)	30 750	–4 917	42
		(1 94)	(1 78)	
	(2)	–0 179	–4 584	83
		(1 39)	(2 81)	
1974	(1)	7 594	–0.816	57
		(4 33)	(2 25)	
	(2)	–0 073	–1.273	36
		(0 39)	(1 15)	
1975	(1)	8 187	–0.914	14
		(1 97)	(1 28)	
	(2)	–0 103	–1 782	41
		(0 66)	(1 59)	
1976	(1)	2 114	0 099	– 31
		(0 73)	(0 21)	
	(2)	–0 228	–0 776	63
		(2 64)	(2 30)	
1977	(1)	–3 442	0 884	58
		(1 60)	(2 57)	
	(2)	–0 020	0 988	77
		(0 42)	(3 10)	
1978	(1)	3 485	–0 179	18
		(4 00)	(1 36)	
	(2)	0 019	–0 442	– 08
		(0 16)	(0.89)	

[1] Equation number in text, (2) is first difference equation [2] t ratio in parentheses

hypothesis for futures prices, but, given the paucity of observations, the loss of a degree of freedom is serious The estimated slope coefficients for equation (2) are even more erratic than for equation (1) Analysis of the levels of variables is simple and it seems adequate for summarizing the available information

Equation (1) using corn prices deflated by an index of livestock futures prices (see footnote 5) was fitted both by ordinary least squares (OLS) and IV (table 2) Not surprisingly, deflating tends to raise $\bar{r}^2$ The slope coefficients are more stable from year to year after deflating, but the yearly coefficients still vary from 0 46 to -0 56 (OLS estimates) The price support program for corn influences the slope coefficients in 1971, 1972, and 1978 (and probably 1977) The loan rate places a floor under prices, and demand is essentially perfectly elastic at that price Thus, the slope coefficient in such years is biased toward zero

Prices in 1973 and 1974 were above support levels, and when deflated, the equations have similar slopes The years 1975 and 1976, also with relatively high prices, have small $\bar{r}^2$'s and imprecise estimates of the slopes The year 1970 is difficult to interpret As the corn blight developed and production forecasts declined, prices rose, but the initial July price may have been affected by the loan rate Hence, it is unclear whether this slope, like those of nearby years, is biased toward zero The slopes in 1970 and 1978 are similar to each other

Typically, the IV estimator gives results close to the OLS estimator The IV estimator apparently has no

An equation for a particular year can be quite different from the underlying demand structure

Table 2—Estimates of equation (1) by year, deflated prices[1]

Year	Estimator[2]	Intercept	Slope	$\bar{r}^2$	Range of Q
1970	IV	2 394	-0 213		
	OLS	2 483	-0 233	0 76	706
		[3](8 85)	(3 69)		
1971	IV	3 800	-0 498		
	OLS	2 399	-0 238	- 23	134
		(1 25)	(0 67)		
1972	IV	1 090	0		
	OLS	1 126	-0 007	- 43	452
		(9 74)	(0 32)		
1973	IV	4 278	-0 521		
	OLS	4 420	-0 546	85	107
		(5 93)	(4 18)		
1974	IV	4 838	-0 563		
	OLS	4 826	-0 561	69	374
		(4 90)	(2 75)		
1975	IV	0 354	0 326		
	OLS	1 045	0 087	- 31	377
		(0 47)	(0 23)		
1976	IV	3 872	-0 356		
	OLS	3 309	-0 263	23	688
		(3 04)	(1 48)		
1977	IV	-1 733	0 504		
	OLS	-1 464	0 461	74	275
		(1 78)	(3 51)		
1978	IV	2.855	-0 253		
	OLS	2 851	-0 253	97	745
		(19 93)	(11 72)		

[1] Q in equation (1) is crop size forecast in billion bushels, range of Q in millions, P is December futures price for corn deflated by an index of livestock futures prices (see text) [2] IV is instrumental variable defined in text [3] t ratio

special benefit for solving the errors-in-variables problem, although this estimator is simple to compute in this particular application

Results for equations using the price of March futures (not reported) have slopes similar to the December equations, but typically their intercept coefficient is larger than for the December results

Given the diversity of results, what conclusions can be drawn? To analyze demand and especially to compare different years, one seems justified in deflating, relative prices matter Moreover, deflation can reduce the variance of the dependent variable while leaving the variance of the independent variable unchanged In this context, if the slope coefficient is positive or is negative with a small t ratio, then, of course, a demand relation has not been fitted, at least not precisely An $\bar{r}^2$ greater than 0 6 seems a necessary, but not sufficient, condition

A large range for Q is useful in obtaining a precise, identifiable estimate of the slope coefficient, other things being equal But prices must be above the support level The range of Q was large in 1978, but the variance of prices was influenced by the loan rate If the range of Q is small, as in 1973, one must raise questions about identification For the deflated equations, however, the slopes in 1973 and 1974 are close to each other, for nominal prices, the slopes are very different, and, presumably, the 1973 slope is far different than the true demand parameter

In sum, an equation for a particular year can be quite different from the underlying demand structure The best conditions for obtaining a demand relation occur when Q has a large variance and P is above the loan rate—a relatively unusual phenomenon Considerable judgment is required in interpreting results Nonetheless, five observations per year convey more information than the single final crop estimate and cash price The Government support program clearly influences corn prices in certain years Perhaps this effect would be less evident with a single observation per year The data highlight a possible structural change in demand, and the simple analysis of futures prices and crop forecasts is a useful descriptive tool

In principle, the analysis could be extended by pooling the intrayear observations A plausible model specification would allow for a change in the price-quantity slope coefficient from 1970-72 to 1973-78 and permit changes in the level of the function from year to year Conventional demand shifters could be used As noted, however, numerous prices were influenced by the support program The slope coefficients for both (pooled) periods consequently are biased toward zero unless the model takes explicit account of the support program

GRAY'S HYPOTHESIS REVISITED

In retrospect, Professor Gray was extremely fortunate to have selected 1970 and 1974 as years for comparison Among the diverse results of the individual years, these two provide plausible approximations of demand relations for the respective periods (Gray wrote in 1974, and, of course, he was limited to data available at that time)

Gray based his elasticities on the arc elasticity formula which uses just two observations per year Moreover, his computation for 1974 uses quantity forecasts made by Conrad Leslie rather than USDA [7] For purposes of comparison with Gray, I use the least squares regressions for the individual years 1970 and 1974 (table 2) to compute price elasticities of demand (table 3)

Table 3—Price elasticities of demand for corn

Alternatives	Elasticity[1]
1970 equation	
$\bar{P}$ $\bar{Q}$	-1 40
Q = 4 7	-1 27
Q = 4 7, 1974 level	-2 00
1974 equation	
$\bar{P}$, $\bar{Q}$	-0 78
Q = 4 7	-0 83
Q = 5 7	-0 51
Q = 6 7	[2]-0 28

[1] Elasticity computed as reciprocal of the price flexibility, F = *b*(Q/P) Estimated equation in table 2 [2] Based on a computed price below current Government loan rate (support level)

Gray obtained an elasticity of -0 93 in 1970 and -0 23 in 1974, and he interpreted the elasticities as being computed on two arcs of a given demand relation It is preferable, given the differing regressions, to think in terms of two different demand schedules, but comparison of elasticities in different time periods is difficult Measured elasticities can change because supply shifts along a given demand function, which causes the elasticity to be computed at different points on the given schedule (Gray's interpretation) Elasticities can also change because of the changing slope and level of demand or for a mixture of these reasons

The slope coefficient for the 1974 equation is twice (in absolute terms) the coefficient for the 1970 equation Thus, a 1-billion bushel increase in corn production would have reduced the deflated price of corn 23 cents per bushel in 1970 and 56 cents in 1974 With supply constant at 4 7 billion bushels (within the range of both the 1970 and 1974 equations), the elasticity is -1 27 in 1970 and -0 83 in 1974 The level of demand, however, is larger in 1974, 4 7 billion bushels are estimated to have sold for $1 39 per bushel in 1970 and $2 19 in 1974 (both in real terms) With the 1970 slope at the 1974 level, the elasticity is -2 00 versus the -0 83 computed on the 1974 equation In this sense, the elasticity in 1974 is not quite one-half the elasticity in 1970—a sharp difference, though not the fourfold difference suggested by Gray's illustration

More sophisticated models than those used here have obtained price elasticities of demand for feed grains that range from -0 25 to -0 9 (summarized in *1*, pp 6-14, also see 7) With the 1974 equation, price elasticities vary from -0 83 to -0 28 as corn production varies from 4 7 to 6 7 billion bushels (table 3)

Gray proposed three reasons to support a hypothesis of a more price inelastic demand for corn (a) growing affluence of consumers leading to a diet with more livestock products,

[7] In retrospect, the USDA forecasts in 1974 were reasonable, in the sense that the slope of the equation fitted to the four observations is plausible in light of the other data The four crop estimates also varied less than 7 percent from the final estimate, and the IV estimate differs little from the OLS estimate of the slope

An exceptionally large dose of judgment is required to use the futures price data to estimate demand relations

(b) the entry of state trading on a large scale and its influence on export demand, and (c) a tendency of some importers to stockpile during periods of shortage

A fourth potential reason is the influence of the price support program, especially prior to 1973 The key question is whether the slope coefficient of the 1970 equation is biased toward zero by the support program This question cannot be answered definitively Prices in 1970 were higher than in some previous and subsequent years, yet the slope of the 1970 equation resembles coefficients in some other years where supports were effective (such as 1978)

A scatter diagram for soybeans (not shown) has the qualitative character of figure 1—a sharp break between 1972 and 1973—and soybeans were much less influenced than corn by support levels It would, then, seem to be a mistake to attribute the possible structural change in 1973 solely to the effect (or lack of effect) of the support program It would also clearly be a mistake to apply the slope coefficient for 1974 to years when supports are operating The seeming structural change in demand for corn remains a puzzle that cannot be answered by the simple models used here

CONCLUSION

In this article, I stress the difficulties of estimating a demand function from observations on futures prices for a single year Nonetheless, in some years, it is possible, and this methodology may permit identification of structural changes more rapidly than with annual data An exceptionally large dose of judgment is required to use the futures price data to estimate demand relations

The futures prices-crop forecasts observations, however, convey information even if a demand elasticity is not estimated, and they provide more information than the single final crop estimate and December price In addition, the basic data for corn can be modified by price deflators based on livestock futures prices, by estimates of carryover, and by estimates of the production of other feed grains Graphic analysis or simple regressions easily summarize current market conditions relative to historical conditions Thus, the ideas presented may have more value as simple descriptive and analytical tools for extension economists and other students of commodity markets than as a procedure for fitting precise demand functions

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Appendix Index of futures prices for livestock

Year and month	Index 1970=100
1970	
July	100
August	98
September	105
October	101
November	97
1971	
August	103
September	105
October	106
November	107
1972	
August	117
September	125
October	122
November	126
1973	
August	239
September	189
October	192
November	191
1974	
August	198
September	209
October	217
November	225
1975	
July	170
August	183
September	201
October	186
November	183
1976	
July	175
August	167
September	159
October	153
November	148
1977	
July	154
August	145
September	145
October	145
November	146
1978	
July	188
August	184
September	197
October	208
November	204