Relationships between Quarterly Corn Prices and Stocks

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Abstract

This article estimates a model relating quarterly corn prices to quarterly corn stocks for 1971-81 Results are consistent with expectations that higher stocks in any specific quarter yield lower corn prices and that any given level of stocks later in the marketing year yields lower prices than does the same level earlier in the marketing year Preharvest information on the new crop affects prices in the June-September quarter The relationships estimated here enable analysts to forecast corn prices and to respond to other situation and outlook questions

Keywords

Corn, prices, stocks, free stocks, forecasts, quarterly econometric model

Van Meir (*3*) recently investigated the effects of yearend stocks on annual season-average corn prices.[1] Because stocks summarize the effects of both supply and demand factors, annual prices are highly correlated with stocks

Our article investigates the relationship between quarterly corn stocks and prices As in an annual framework, higher ending stocks in any specific quarter result in lower farm-level prices. The effect of stocks on prices, however, differs throughout the marketing year, largely reflecting the annual nature of corn production Early in the marketing year, large levels of stocks are necessary to meet demand until the next harvest As the market year progresses and the next harvest approaches, lower stocks are sufficient to meet demand A given level of stocks later in a marketing year, consequently, results in lower prices than does the same level of stocks earlier in the marketing year.

The Model

The general framework used here relating quarterly prices to ending stocks derives from a disequilibrium model where ending stocks clear the market as a residual In a quarterly framework, a disequilibrium model is more appropriate than an equilibrium model because, with shorter time periods, the market is more likely to be observed in adjustment than as approximating equilibrium.

The functional form used here derives from the general hyperbolic function $(P - a)(S - d) = c$, where P is the quarterly corn price, S denotes quarterly ending stocks of corn, and a, c, and d are parameters (*1*) To avoid nonlinearities in estimation, we assume the parameter, d, equals 0 When one solves for price, $P = a + cS^{-1}$ To represent the different effects of stocks throughout the year, we assume a separate c parameter for each quarter S is measured relative to the scale of activity in the corn industry, represented here by use (U) This procedure is necessary because of industry growth in the past 15 years Furthermore, we include lagged price to reflect stickiness of prices in a quarterly framework, largely due to the lag structures in underlying supply and demand functions Including lagged price also allows us to conduct the analysis using nominal prices, thereby circumventing the

*The authors are agricultural economists with the National Economics Division, ERS They thank an anonymous reviewer for many helpful comments The model discussed here is part of a quarterly situation and outlook forecasting model of the agricultural sector now being developed in ERS

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

issue of choosing an appropriate price deflator. These adjustments result in the following equation:

$$P = a + b\,\mathrm{lag}(P) + \sum_{i=1}^{4} c_i D_i (S/U)^{-1} \qquad (1)$$

D_i represents four quarterly dummy variables (equal to 1 in the i^{th} quarter and to 0 elsewhere), lag(P) is the 1-quarter lag of P, and a, b, and c_i are parameters to be estimated The subscript, i, denotes quarters, where $i = 1$ is the January-March quarter, $i = 2$ is the April-May quarter, $i = 3$ is the June-September quarter, and $i = 4$ is the October-December quarter. All other variables are as defined before

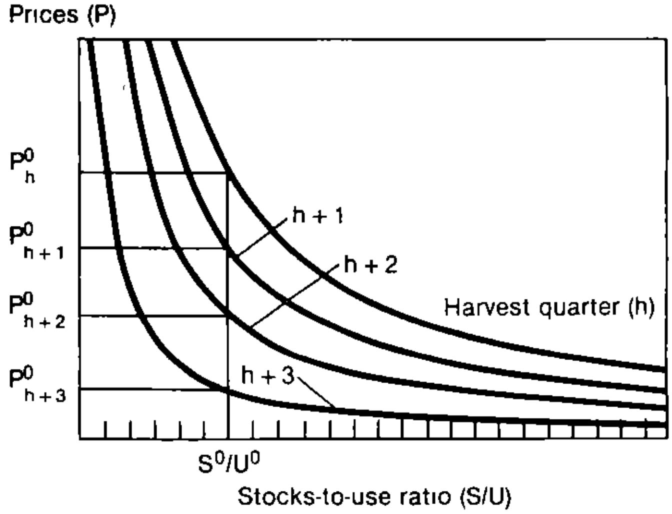
The inclusion of four $c_i D_i (S/U)^{-1}$ terms allows stocks to affect prices differently in each quarter Each c_i is expected to be positive, with the largest coefficient occurring in the harvest quarter and successively smaller coefficients occurring in the three following quarters Thus, equation (1) is expected to yield a family of four hyperbolic curves such as in figure 1, which shows prices related to the stocks-to-use ratio.[2] As the stocks-to-use ratio increases in any given quarter, price falls, indicated by a move along that quarter's curve For any given stocks-to-use ratio (such as S^0/U^0), the resulting prices (P^0_h, P^0_{h+1}, P^0_{h+2}, P^0_{h+3}) are smaller later in the marketing year, indicated by a move from one curve to the next

Data: Definitions and Sources

The farm price of corn, which we used to estimate equation 1, is a monthly series published by the U S Department of Agriculture in *Agricultural Prices* We derived quarterly prices by averaging the monthly prices from each quarter Use and total stocks data are from supply and disappearance tables for corn published in the *Feed Outlook and Situation* (based

Figure 1

Hyperbolic Family of Curves Relating Quarterly Prices to the Stocks-to-Use Ratio



on data from the Statistical Reporting Service)[3] Data for the categories that comprise total stocks are from the Agricultural Stabilization and Conservation Service

We used three alternative definitions of stocks to estimate equation (1) total stocks and two alternative definitions of free stocks. Total stocks include stocks that are privately held, owned by the Commodity Credit Corporation (CCC), under outstanding CCC loans, and in the farmer-owned reserve (FOR) The first free-stock definition is total stocks less CCC-owned stocks less FOR stocks The second free-stock definition further subtracts outstanding CCC loans from total stocks. The latter free-stock definition represents removal of all Government program stocks, whereas the former free-stock definition includes outstanding CCC loans which can be redeemed at any time without penalty Units for stocks and use categories are million bushels, whereas units for prices are dollars per bushel

[2]Although the hyperbolae being estimated can be expressed to show a direct relationship between prices and the stocks to-use ratio (S/U) (fig 1), the inverse of that ratio, $(S/U)^{-1}$, is the appropriate explanatory variable to use in estimating equation (1) Therefore, we refer to the inverse of the stocks-to use ratio in discussing estimation results but to the stocks-to-use ratio in discussing implications drawn from these parameter estimates

[3]The use data have been adjusted because the corn marketing year has uneven quarters – two 3 month quarters, one 2 month quarter, and one 4-month quarter We multiplied use in the April May quarter by 1 5 and use in the June September quarter by 0 75 Thus, all four quarters of adjusted use data are on a pro rated, 3 month equivalent basis, thereby allowing the scale of activity deflation of stocks to be comparable

Model Estimation

Equation (1) was estimated over 1971-81 (44 observations) with each of the three stock definitions, the first free-stock definition proved superior The estimated equation is

$$
\begin{aligned}
P = & - 0\ 358 + 0\ 718\,\mathrm{lag}(P) + 1\ 978\,D_1(S/U)^{-1} \\
& \quad (1\ 8) \qquad (10\ 1) \qquad\qquad (3\ 8) \\
& + 1\ 462\,D_2(S/U)^{-1} + 0.551\,D_3(S/U)^{-1} \\
& \quad (3\ 6) \qquad\qquad\qquad (4\ 1) \\
& + 2\ 351\,D_4(S/U)^{-1} \\
& \quad (3\ 3)
\end{aligned}
$$

$\bar{R}^2 = 0\ 873$ MAE = 0 162
TPE1 = 12   TPE4 = 4   (2)

Numbers shown in parentheses are t-statistics Over 87 percent of quarterly corn price variation is explained by equation (2). The mean absolute error (MAE) of 16 2 cents per bushel over the estimation period represents a 7 3-percent error relative to the average price of $2 22 per bushel over the estimation period TPE1 and TPE4 are the number of 1-quarter and 4-quarter turning point errors (TPE's)[4] over the 44-quarter estimation period The TPE's for equation (2) indicate reasonably good performance

All coefficients are significant at the 5-percent level As expected, all coefficients of the inverse stocks-to-use ratios are positive The largest coefficient occurs in the harvest quarter (subscript = 4) and coefficients for successive quarters diminish in size. Lagged price also plays an important role

The Effects of New Crop Information

We estimated another equation to assess the effects on prices of preharvest information about the crop being grown As new information becomes available—such as planted acres and weather developments—expectations about harvest size influence prices in the months prior to harvest Large acres planted and weather favorable to crop development lead to expectations of a large harvest, pushing corn prices down in the third quarter Factors leading to expectations of a small harvest are expected to push prices up

[4]An i quarter TPE (for i equal to 1 or 4) is defined to occur when $(p_t - a_{t-1})(a_t - a_{t-1}) < 0$, where p and a are the predicted and actual prices respectively, in the quarter indicated by the subscript

To account for these effects, we added Corn Belt temperature for July and national corn acres planted to equation (2)[5] Units for Corn Belt temperature in July (JT7) are degrees (F), and units for acres planted (COAPLD3) are million acres To estimate the preharvest price impacts of these variables, we allowed them to occur only in the third quarter and set them equal to zero in the other quarters[6] Separate intercepts and separate lag price parameters were also assumed, allowing an unrestricted estimate of a different process for price determination in each quarter[7]

The additional estimated equation is

$$
\begin{aligned}
P = & - 1\ 697 + 1\ 974\,D_1 + 1\ 807\,D_2 \\
& \quad (3\ 0) \qquad (2\ 6) \qquad (2\ 7) \\
& - 4\ 828\,D_3 + 0.849\,D_1\,\mathrm{lag}(P) \\
& \quad (1\ 8) \qquad\quad (5\ 2) \\
& + 0\ 852\,D_2\,\mathrm{lag}(P) + 0\ 744\,D_3\,\mathrm{lag}(P) \\
& \quad (4.5) \qquad\qquad\quad (3\ 7) \\
& + 0\ 804\,D_4\,\mathrm{lag}(P) + 0\ 243\,D_1(S/U)^{-1} \\
& \quad (7\ 9) \qquad\qquad\quad (0\ 2) \\
& + 0\ 331\,D_2(S/U)^{-1} + 0\ 757\,D_3(S/U)^{-1} \\
& \quad (0\ 3) \qquad\qquad\quad (4\ 8) \\
& + 5\ 224\,D_4(S/U)^{-1} - 0\ 0418\,\mathrm{COAPLD3} \\
& \quad (3.4) \qquad\qquad\quad (2\ 0) \\
& + 0\ 119\,\mathrm{JT7} \\
& \quad (3\ 2)
\end{aligned}
$$

$\bar{R}^2 = 0\ 908$ MAE = 0 121
TPE1 = 7   TPE4 = 3   (3)

[5]Corn Belt precipitation for July was also included, but did not provide a statistically significant effect

[6]These variables will also influence prices in the following marketing year because the size of the harvest affects supply use, and stocks throughout the next year However, those effects are already accounted for by the inverse stocks-to-use variables through the next marketing year, whereas these additional variables are intended to measure the price impacts of preharvest information before that information is realized in production, use, and stocks

[7]The resulting equation is equivalent to estimating a separate equation for each quarter However, because the summary statistics of most interest for this study are for the full price series, we present the combined equation The appendix gives the four equivalent quarterly equations

The relative performance of this equation has improved, the $\bar{R}^2$ has increased while the MAE (representing a 5.4-percent error) and the TPE's have decreased Both COAPLD3 and JT7 have the expected signs, and both are statistically significant However, other coefficients are not all statistically significant

Equation (3) implies that a 1-million-acre difference in planted acres causes a 4 2-cent-per-bushel difference in third-quarter corn price, giving a price flexibility (evaluated at the means) of 1 5 A 1-degree difference in Corn Belt temperature in July causes an 11 9-cent-per-bushel difference in third-quarter corn price, implying a price flexibility of 4 0

Plots

Figures 2 and 3 show plots of the quarterly hyperbolic curves that result from the estimated equations The figures illustrate the relative positions of the estimated hyperbolae relating price to the stocks-to-use ratio, other things being constant Therefore, mean values for other variables over the estimation period ($2 22 per bushel corn price, 79 1 million acres planted, and 75 4 degrees) were assumed for the plots

Higher stocks relative to use give lower prices within each quarter, and any specific level of stocks relative to use later in a marketing year gives lower prices than does the same level earlier in the marketing year Because equation (2) was restricted to have the same intercept and the same lag price parameter across quarters, the resulting quarterly plots in figure 2 show four hyperbolae from the same family of curves With those parameter restrictions relaxed for equation (3), each of the resulting quarterly plots is from a different family of curves, as shown by the four quarterly hyperbolae in figure 3 Nonetheless, the general properties about the slope of each curve and the relative positions of the four quarters' plots are preserved

In figure 3, the plots for the first and second quarters are from the flatter parts of their hyperbolae, whereas the plots for the third and fourth quarters are from the steeper parts of their hyperbolae This difference indicates that prices adjust most near harvest, as the size of the new crop becomes known, prices adjust during the transition from one marketing year to the next Price adjustments in the other quarters are smaller because relatively little new information regarding crop supplies becomes known then The estimation period data

Figure 2

Plot of Equation (2)

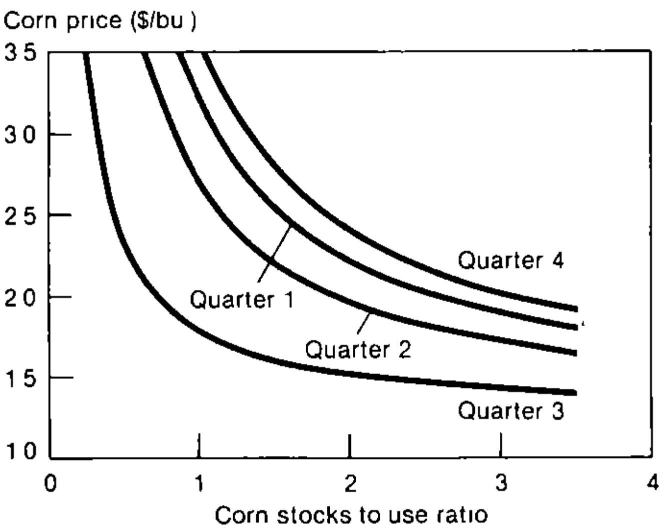
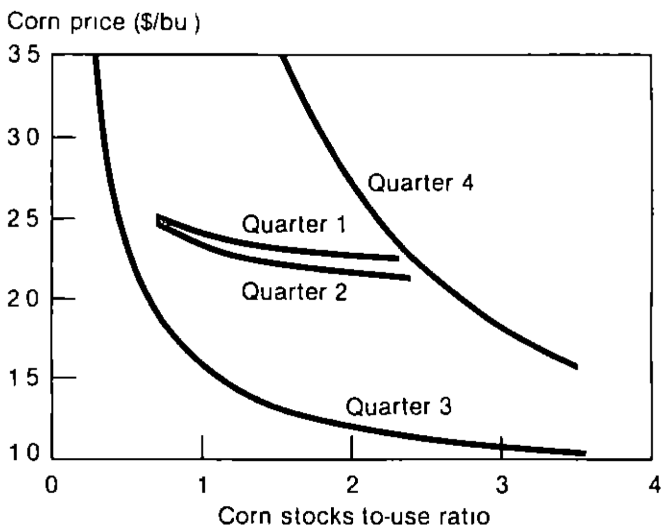


Figure 3

Plot of Equation (3)



confirm this relationship The mean absolute price changes in the third and fourth quarters are larger than those in the first and second quarters

Model Estimates for 1982 and 1983

To assess the performance of the estimated equations, we used each to estimate quarterly corn prices for 1982 and 1983, 2 years beyond the estimation period In each quarter, actual exogenous and lagged endogenous data were used For 1983, we made two data adjustments for the third and the fourth quarters to reflect the effects of the payment-in-kind (PIK) program

First, we added to free stocks any unpaid PIK entitlement stocks in the farmer-owned reserve or in CCC inventories (stock positions not normally considered free) if the PIK participants' 5-month entitlement period had begun In the third quarter, the entitlement period began for only a small amount of PIK payment corn (estimated at 70 million bushels representing participants in Florida, Louisiana, and much of Texas) However, for the fourth quarter of 1983, all PIK payment corn had begun the 5-month entitlement period, so all remaining PIK payment corn in the FOR or owned by CCC was assumed to be free (estimated at 1,418 million bushels) This adjustment affects both equations in the third and fourth quarters

Second, we made an adjustment to represent effects on prices of anticipated PIK payments prior to those payments. Similar to the preharvest effects of planted acreage, anticipated PIK payments would hold prices lower than otherwise because many PIK payments came from "nonfree" stocks We assumed that anticipated PIK payments affect prices as do preharvest expectations regarding the size of the new crop (represented in equation (3) by the planted acres variable) Therefore, we represented the effect of anticipated PIK payments by adjusting the planted acreage variable by an estimated amount of land that would have to be planted, on average, to give a harvest equal to the PIK entitlement [8] This adjustment affects third-quarter 1983 price estimates from equation (3), but does not affect estimates from equation (2)

[8]We adjusted required conservation use acreage for corn under the PIK program (2) by the PIK payment rate and by an average-planted-to-harvested-acreage estimate to derive 22 million acres

The table shows the actual 1982 and 1983 quarterly corn prices, the two equations' estimates, and summary statistics for each equation Both equations perform reasonably well in 1982 with a similar pattern estimated by each. The MAE for equation (2) is 20.1 cents per bushel, which represents an 8 4-percent error relative to the average 1982 corn price (only slightly greater than that attained over the estimation period) The MAE for equation (3) is slightly larger, with 21.3 cents per bushel representing an 8.9-percent error Two 1-quarter TPE's occur for equation (2) in 1982, but no 4-quarter TPE occurs Equation (3) has one 1-quarter TPE and one 4-quarter TPE

Equation (2) continues to perform well in 1983, although equation (3) performs less satisfactorily The MAE of 13.2 cents per bushel for equation (2) represents a 4 4-percent error, considerably less than that attained over the estimation period The MAE for equation (3), however, represents an 18 3-percent error One 1-quarter TPE occurs for equation (2) in 1983, but no 4-quarter TPE occurs Equation (3) again has one 1-quarter TPE and one 4-quarter TPE

The largest 1983 forecasting error for each equation occurs in the fourth quarter, partly because of the combined effects of the PIK program and the 1983 drought which decreased stocks Fourth-quarter free stocks—as adjusted by the PIK considerations discussed earlier—represented a much lower share of use than occurred for any fourth quarter in the estimation period. The 1983 fourth-quarter ratio of free stocks to use was 78 percent of the minimum value for that ratio in fourth quarters from 1971 through 1981 Anytime exogenous variables attain values far outside the range from the estimation period, forecasting problems can occur With the hyperbolic function we used, this problem is greater at the lower end of the range because lower stocks-to-use ratios move the price estimates into the steeper sections of the quarterly hyperbolae where prices are more sensitive to stock changes

Large supplies of wheat may have also contributed to the forecasting errors in the fourth quarter of 1983 Wheat feeding in the second half of 1983 was larger than in most years This situation probably held corn prices lower than otherwise, but would not have been captured by the current model

Quarterly corn price estimates, 1982 and 1983

Item	Units	Corn prices		
		Actual	Equation (2) estimates	Equation (3) estimates
1982				
Jan -Mar	Dollars/bushel	2 48	2 37	2 43
Apr -May	do	2 57	2 59	2 49
June-Sept	do	2 39	2 91	2 96
Oct -Dec	do	2 12	2 28	2 27
1983				
Jan -Mar	do	2 54	2 50	2 24
Apr May	do	2 99	3 11	2 65
June-Sept	do	3 21	3 30	3 71
Oct -Dec	do	3 16	3 43	4 19
Summary statistics—				
1982				
MAE	do	—	201	213
TPE1	Number	—	2	1
TPE4	do	—	0	1
1983				
MAE	Dollars/bushel	—	132	544
TPE1	Number	—	1	1
TPE4	do	—	0	1

— = Not applicable

Conclusions

Quarterly hyperbolic equations have been estimated relating corn prices to ending corn stocks Higher stocks relative to use in any particular quarter give lower corn prices in that quarter A given level of stocks yields lower prices later in the marketing year than does the same level of stocks earlier in the marketing year New crop expectations based on preharvest information, such as acres planted and weather, influence prices in the June-September quarter Estimates of these effects enable analysts to respond to questions regarding the short-term effects of preharvest information

Corn price estimates for 1982 and 1983 indicate reasonably good model performance for quarters outside the estimation period Although some forecasting problems were encountered in the 1983 estimates, these problems were largely related to unusual circumstances caused by the PIK program and the drought The explanatory variables used here are typically monitored in situation and outlook activities

The relationships we estimated should help analysts forecast corn prices and respond to other situation and outlook questions

References

(1) Green, Robert C "Forecasting Quarterly Grain Prices by Means of the Relation of Stocks to Use " Unpublished, U.S Dept of Agr , Econ Res. Serv., Oct. 1983.

(2) U.S. Department of Agriculture "USDA Updates 1983 Acreage Reduction Programs Report " USDA press release, May 4, 1983

(3) Van Meir, Lawrence W "Relationship Among Ending Stocks, Prices, and Loan Rates for Corn," *Feed Outlook and Situation Report*, FdS-290, U.S Dept. of Agr., Econ Res Serv , Aug 1983, pp. 9-13.

Appendix

Estimated equation (3) in the text is equivalent to the following four equations, one estimated for each quarter.

January-March quarter.

$$P = 0.276 + 0.849\,\mathrm{lag}(P) + 0.243\,(S/U)^{-1}$$
$$\quad (0.5) \qquad (4.6) \qquad (0.1)$$

$$\bar{R}^2 = 0.892 \qquad (3.1)$$

April-May quarter

$$P = 0.110 + 0.852\,\mathrm{lag}(P) + 0.331\,(S/U)^{-1}$$
$$\quad (0.4) \qquad (6.2) \qquad (0.4)$$

$$\bar{R}^2 = 0.948 \qquad (3.2)$$

June-September quarter.

$$P = -6.525 + 0.744\,\mathrm{lag}(P) + 0.757\,(S/U)^{-1}$$
$$\quad (3.0) \qquad (4.5) \qquad (5.9)$$

$$-\,0.0418\,\mathrm{COAPLD3} + 0.119\,\mathrm{JT7}$$
$$(2.5) \qquad (3.9)$$

$$\bar{R}^2 = 0.942 \qquad (3.3)$$

October-December quarter

$$P = -1.697 + 0.804\,\mathrm{lag}(P) + 5.224\,(S/U)^{-1}$$
$$\quad (2.6) \qquad (6.7) \qquad (2.8)$$

$$\bar{R}^2 = 0.888 \qquad (3.4)$$

In Earlier Issues

The general conclusion was that these short-term price movements are unpredictable This implies that prices adjust almost instantaneously to changes that take place in the basic factors that affect the immediate supply and demand situation No significant relationships were found between short-term changes in receipts and in prices of corn This would be expected of a storable commodity, if receipts were temporarily out of line with market requirements, an adjustment could be made at low cost by moving part of the supply into or out of storage

Richard J. Foote and G L Jordan
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