SIMPLIFIED SHORT-RUN PRICE FORECASTING MODELS FOR WHEAT AND CORN

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ABSTRACT

Models were developed which are simple enough for use by farmers and rural distributors in short-term price forecasting. The models express annual U.S. wheat and corn prices as a function of world stocks and projected levels of world production and consumption. The wheat model had a 6.6% average error in annual prices over the 12 years of data and the corn model averaged 1.2% error over 11 years of data. The models predicted 1986/87 prices to increase 6% for wheat and decrease 20% for corn using U.S.D.A. projections of production and consumption as of August, 1986. Price responsiveness indicators were also examined.

INTRODUCTION

Prices of agricultural commodities are volatile when compared to many other economic goods. The price volatility exists both within and among years. For example, between 1970 and 1985, average annual variation in corn prices was 17% or $0.44/bu. (USDA, Ag. Statistics, 1985). Agricultural commodities are also volatile over short periods of time. The price of corn in 1982 and the price of wheat in 1976 changed more than 30% in less than 12 months (Chicago Board of Trade, 1984). The average within-year price variation on wheat between 1974 and 1983 was 25.4% or $0.87/bu. (Chicago Board of Trade, 1984).

Price uncertainty in agricultural commodities is a persistent problem for producers and merchants of the commodities and producers and purchasers rarely have price forecasting tools which are readily adaptable to their management systems. Producers typically must make price sensitive production decisions before they plant a crop with little indication of price levels at the time of harvest. Producers and merchants may also lose revenue through poorly timed marketing decisions because of lack of accurate price expectations.

Economics literature provides numerous price forecasting models for agricultural commodities, but they consist primarily of complex structural long-run models. For example, Roy and Ireland (1975) developed a simultaneous equations model to forecast annual U.S. sorghum prices with a set of supply and demand relationships for determining market prices. Paddock (1985) used the same general approach to forecast quarterly and annual wheat prices. Johnson et al. (1986) likewise employed a multi-sector econometric model to forecast annual prices for corn and wheat. These types of forecasting tools are productive for policy analysis and long-range price projections but have limited application for short-term (within-year) price forecasts. In addition, they require extensive knowledge of econometric modeling and computers, which few business managers possess.

If producers and merchants had a simplified price forecasting model for commodities, such as corn and wheat, they might improve the profitability of their production and marketing decisions. They need a method for price forecasting that is accurate, but it should also be simple enough to use easily. The objective of this study was therefore to develop a short-run (up to one year) price forecasting model for corn and wheat that is readily usable by producers and merchants to complement the general price forecasts available from various public and private agencies.

METHODS AND PROCEDURES

The steps involved in the analysis included: (a) developing price forecasting models for wheat and corn based on economic principles, (b) collecting data and estimating coefficients in the models, and (c) testing, analyzing and evaluating the models.

Models

Wheat and corn prices are established by interaction of demand and supply forces. Supply relationships are established primarily by cost factors and supply is shifted by forces such as weather, government programs, and alternative uses of production resources. The demands for corn and wheat, in domestic and export markets, are shifted by changes in population, incomes, values and quantities of other products in which corn is an input, prices of competing products, and consumer tastes and preferences (in both domestic and export markets).

These relatively complex relationships may be captured in simpler relationships between price and indicators of production, consumption, and inventory or stock levels. For example, when demand for wheat decreases (supply constant), price decreases and stocks in storage rise. When supply of wheat decreases, price increases and stocks decline. When consumption increases, other things constant, prices are bid up, etc. The relationship between price and each of these factors is expected to be non-linear because prices are more sensitive to small changes in demand or supply forces when stocks, production, and consumption are small and less sensitive when they are large.

For this study, U.S. prices of wheat and corn were expressed as functions of world stocks, utilization (consumption plus losses) and production of the respective grains because the U.S. market reflects global conditions in the corn and wheat markets for the period analyzed. For example:

\[ Pw = f(Sw, Uw, PDw) \]
\[ Pc = g(Sc, Uc, PDC) \]

where

- \( Pw, Pc \) = price of wheat and corn, respectively
- \( Sw, Sc \) = stock levels of wheat and corn, respectively
- \( Uw, Uc \) = utilization levels of wheat and corn
- \( PDw, PDC \) = production levels of wheat and corn

In order to capture the expected nonlinear relationships the natural logarithms of variables were used in the model, abbreviated by the symbol "ln".

Various combinations of the dependent price variable evaluated included annual U.S. average corn and wheat prices in
nominal terms and adjusted for inflation by using various 
price indexes (adjusted prices), and the natural log of adjusted 
prices.

Combinations of independent variables tested in the models 
included ending stock levels, beginning stock levels, production 
levels, utilization levels, and ratios such as beginning 
stocks divided by production and beginning stocks divided 
by utilization, and stocks, utilization, and production lagged 
one year. These variables were examined at world and U.S. 
levels. The natural logs of these variables were also evaluated.

The model was estimated by Ordinary Least Squares regression analysis. The estimated models were evaluated statistically 
by examining R-squared values for the estimated equations, statistical significance of the explanatory variable 
coefficients and theoretical consistency of coefficient signs. 
Theory suggests that production and stock variables should have negative coefficient signs while the utilization coefficient 
sign should be positive. After selecting the best statistical 
models, forecasted prices were compared with the actual 
prices.

Responsiveness of price with respect to each variable was 
evaluated. Price flexibility with respect to each variable shows 
the percentage change in price associated with a one percent 
change in the variable. For example, price flexibility of stocks 
was calculated as \( \frac{\Delta P}{\Delta S} \) where \( S \) and \( P \) are mean 
values of stocks and price, respectively. This procedure was 
followed for both corn and wheat models.

### Data

For both corn and wheat, no data were collected prior to 
the year 1974. In 1973 and 1974 significant structural changes 
occurred in international grain markets. Including data prior 
1974 might decrease the accuracy of a model designed 
to forecast current prices.

Data were collected for corn and wheat on a crop market-
ying year basis. Marketing years were October/September for 
corn and June/July for wheat. This means, for example, that 
in the 1974/75 year for corn the data were for the year 
October 1974 through September 1975. For the 1980-81 year 
for wheat the data were for the year July 1980 through June 
1981.

The price data collected were crop marketing year asking 
prices at Rotterdam for 30-day delivery, as shown by Hamburg 
Mercantile Exchange. Prices were quoted for U.S. no. 2 
Northern Spring wheat at 14% moisture. For corn the prices 
were for U.S. no. 3 Yellow corn.

It was not certain whether the estimation models should 
use nominal or real prices, so a number of price indexes were 
collected so that the price could be adjusted. The indexes 
collected and their sources included (a) the GNP implicit price 
deflator and the index of prices received by farmers (U.S.D.A., 
June 1985) and (b) the world non-fuel commodity price index, 
the world food price index and the agricultural raw 
products price index (International Monetary Fund, 1986). 
These price indexes were converted from a calendar year to 
a marketing year basis by multiplying the price index of the 
first year by the percentage of the crop that fell into that year 
and then adding it to the percentage of the price index for 
the next year that fell in the that marketing year. The price 
indexes were all converted to a base year of 1985/86.

For both wheat and corn, world production levels, total world 
utilization levels, and ending world stock levels were in millions 
of metric tons and were collected for the marketing years 
levels and net trade levels (exports minus imports) were also 

### FINDINGS

Several model forms were evaluated. Beginning stock levels 
were better predictors of prices than were ending stocks 
in all cases. Ratio variables such as stock levels as a percent-
tage of production and stock levels as a percentage of utiliza-
tion were also less effective than separated variables. U.S. data 
did not yield results as reliable as the world data.

#### Wheat

The best (semi-log) model for wheat used the nominal 
(unadjusted) price as the dependent variable. The equation 
selected for estimating wheat prices was:

\[
P_w = -1004.0 \cdot 177.04(\ln SB_w) + 936.83(\ln U_w) - 610.43(\ln PD_w)(1) 
\]

\( \text{(-2.55)(-3.61)(3.96)(-3.55)} \)

where \( P_w = \text{average marketing nominal price of wheat in} 
\)

Rotterdam U.S. dollars per metric ton.

\( SB_w = \text{world marketing year beginning stocks of} \)

wheat, millions of metric tons.

\( U_w = \text{world marketing year utilization of wheat} \)

millions of metric tons.

\( PD_w = \text{world marketing year production of wheat,} \)

millions of metric tons.

\( \ln = \text{natural logarithm.} \)

The coefficient \( t \)-values are in parentheses below the estimated 
parameters. All parameter estimates were statistically signifi-
cant at the .01 significance level. The \( R^2 \) for the estimated equa-
tion was .674, indicating that the model explained 67.4% of the 
The average percentage error for the wheat price equation over the 12-year period was 6.6%; i.e., the actual 
price average being 6.6% above or below the price predicted by 
the equation.

One measure of price responsiveness, the partial derivative of 
price with respect to each explanatory variable, measures the 
change in price resulting from a one unit change in the vari-
able. The partial derivative for the stock utilization, and produc-
tion variables were 

\[
\begin{align*}
\frac{\partial P_w}{\partial SB_w} &= -177.04/174.62 = -1.01, \\
\frac{\partial P_w}{\partial U_w} &= 936.83/174.62 = 5.37, \\
\frac{\partial P_w}{\partial PD_w} &= 610.43/174.62 = 3.52 \\
\end{align*}
\]

At different levels of production, utilization and stocks the price 
responsiveness is different. Price responsiveness measured at 
"low", "high", and mean level of the variables responsiveness are 
shown in Table 1. At the mean value for \( SB_w = 88.9 \), a change 
(increase) in world beginning stocks of one million metric tons 
causes wheat prices to change (decrease) by $1.99 per metric ton. 
At the mean value for \( U_w = 433 \), a one million metric ton change 
in utilization causes a $2.16 per metric ton change (in-
crease) in the price of wheat. At the mean value of \( PD_w = 439 \), 
a one million metric ton change (increase) in the level of produc-
tion causes a $1.39 per metric ton change (decrease) in the price of 
wheat.

The price flexibilities, the percentage change in price from one 
percent change in explanatory variable, measured at the me-
ans of the variables are also shown in Table 1 at the low, high 
and mean values for the twelve years of data. The price flexi-
bility at the mean for the stock variable is 

\[ P_w (\text{mean} SB_w/\text{mean} P_w) = -1.99 (88.9/174.62) = -1.01. \]

This indicates that 

for a one percent change (increase) in the beginning world stock 
level, the price of wheat will change (decrease) by 1.01%. The 
price flexibilities of utilization and production were calculated 
similarly.

The indicators of price flexibility show that wheat prices are 
most sensitive to changes in world utilization, next to
changes in production, and least sensitive to change in stocks, other things constant. Price is more sensitive to changes in all three variables at lower prices.

Table 1. Measures of Price Responsiveness for Wheat.

<table>
<thead>
<tr>
<th>Variable (X)</th>
<th>Levels of Prices (Xi)</th>
<th>Corresponding Price1</th>
<th>Price Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stocks</td>
<td>million metric tons</td>
<td>283.63</td>
<td>-2.78</td>
</tr>
<tr>
<td></td>
<td>88.9 (mean)</td>
<td>174.62</td>
<td>-1.99</td>
</tr>
<tr>
<td></td>
<td>125.7 (high)</td>
<td>113.30</td>
<td>-1.41</td>
</tr>
<tr>
<td>Utilization</td>
<td>367 (low)</td>
<td>19.69</td>
<td>2.55</td>
</tr>
<tr>
<td></td>
<td>433 (mean)</td>
<td>174.62</td>
<td>2.16</td>
</tr>
<tr>
<td></td>
<td>498 (high)</td>
<td>299.99</td>
<td>1.89</td>
</tr>
<tr>
<td>Production</td>
<td>357 (low)</td>
<td>300.83</td>
<td>-1.71</td>
</tr>
<tr>
<td></td>
<td>439 (mean)</td>
<td>174.62</td>
<td>-1.39</td>
</tr>
<tr>
<td></td>
<td>511 (high)</td>
<td>81.91</td>
<td>-1.19</td>
</tr>
</tbody>
</table>

1Assuming other variables at mean levels.

Corn

The best-fit corn model (semi-log) used an adjusted price, the natural log of the price divided by the GNP deflator, as the dependent variable. The independent variables for the corn model were the beginning world stock level, world utilization and world production. For the corn model the data were for the 1975/76 crop year (ending stock levels for the 1973/74 crop were not available) through 1985/86. The corn price equation chosen as the best for prediction purposes was:

\[ \ln P_c' = 6.05565 - 0.00604 \times \ln S_b_c + 0.0366 \times U_c - 0.00509 \times P_d_c (2) \]

where:

- \( P_c' \) = average marketing year price of corn in Rotterdam, U.S. dollars per metric ton, adjusted for inflation by dividing by the U.S. GNP deflator (1985-86 = 100).
- \( S_b_c \) = beginning world marketing year stocks of corn, millions of metric tons.
- \( U_c \) = world marketing year utilization level of corn, millions of metric tons.
- \( P_d_c \) = world marketing year production of corn, millions of metric tons.
- \( \ln \) = natural logarithm

The t-values in parentheses below estimated parameters indicate that the estimated stock coefficient is significant at the .02 level, the production coefficient significant at the .01 level, and the utilization coefficient significant at the .07 level. The model \( R^2 \) was .822. The average annual percent error for the model was 1.2%.

Levels of corn price responsiveness at mean, low and high observed values for the variables are listed in Table 2. The partial derivative of the stock variable at the mean with respect to price, \( \frac{\partial P_c'}{\partial S_b_c} = -0.00604(P_c') \), is \(-0.00604(168.09) = -1.02\). This indicates that at mean levels of production and use, for every one million metric ton change in stock level, world stocks the price of corn will change (decrease) by \$1.02 per metric ton. At the mean world production of corn, a one million metric ton change (increase) in corn consumption changes (increases) the price of corn by \$0.62 per metric ton. The price of corn appears to be most flexible to changes in stocks. For the stock variable the price flexibility at the mean is \( \frac{\partial P_c'}{\partial S_b_c} = -0.00604(168.09) = -1.02\). This indicates that for a one percent change (increase) in the world stock levels of corn the price of corn will change (decrease) by .33% at the mean. The other price flexibilities in Table 2 were calculated similarly.

Table 2. Measures of Price Responsiveness for Corn.

<table>
<thead>
<tr>
<th>Variable (X)</th>
<th>Levels of Prices (Xi)</th>
<th>Corresponding Price1</th>
<th>Price Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stocks</td>
<td>million metric tons</td>
<td>-1.02</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>5.6 (low)</td>
<td>53.9 (mean)</td>
<td>106.6 (high)</td>
</tr>
<tr>
<td>Utilization</td>
<td>326 (low)</td>
<td>130.58</td>
<td>437 (high)</td>
</tr>
<tr>
<td></td>
<td>395 (mean)</td>
<td>168.09</td>
<td>437 (high)</td>
</tr>
<tr>
<td>Production</td>
<td>328 (low)</td>
<td>247.12</td>
<td>437 (high)</td>
</tr>
<tr>
<td></td>
<td>403 (mean)</td>
<td>168.09</td>
<td>437 (high)</td>
</tr>
<tr>
<td></td>
<td>482 (high)</td>
<td>112.44</td>
<td>-1.19</td>
</tr>
</tbody>
</table>

1Assuming other variables at mean levels.

USING THE MODELS

To use the models for short-run prediction purposes, projected current-year production and utilization levels are needed. The Foreign Agricultural Service, U.S.D.A. publishes estimated world production and utilization levels for both wheat and corn for the current and upcoming crop years. For forecasting the 1986/87 marketing year prices for wheat and corn the models used the following estimates from U.S.D.A. (Sept. 1986) in equations (1) and (2):

- \( P_w \) = \(-1004.0 - 177.04 \times \ln 123.5\) \( \times \ln 123.5\) = 121.4.

For wheat, \( P_w \) = 936.83 (\ln 123.5) = 175.97 per metric ton. Thus, as of September, 1986, the model would have suggested a marketing year price of \$175.97 per metric ton for 1986/87, a 5.6% increase from the \$160.43 price for 1986/87. However, with 1986/87 estimates of stock, production, and use levels as of August, 1987, the model estimate was \$135.25 per metric ton. These compare to an actual price of \$155.40 per ton (U.S.D.A., Aug. 1987).

For corn, \( P_c' = 6.05565 - 0.00604(121.4) + 0.0366(444) = 175.97\) \times \ln 123.5\) = 175.97 per metric ton. Thus, as of September, 1986, the model would have suggested a marketing year price of \$175.97 per metric ton for 1986/87, a 6.5% increase from the \$160.43 price for 1986/87. However, with 1986/87 estimates of stock, production, and use levels as of August, 1987, the model estimate was \$153.18 per metric ton. These compare to an actual price of \$155.40 per ton (U.S.D.A., Aug. 1987).

SUMMARY AND CONCLUSIONS

Many variables affect prices of agricultural commodities and no model can forecast prices without error. The models developed in this study consider major supply and demand factors in estimating prices of wheat and corn. They are simple enough to be usable without sophisticated computer equipment, e.g., Lotus 1-2-3 (Lotus Development Corp.), and needed data are published on a regular basis and are readily available.
accessible. Larger, more complex models could have been estimated that might have been more accurate, but they would have been more difficult to use.

The models are sufficiently reliable to facilitate general forward planning decisions by producers, agribusiness firms and merchants who need a basis for price expectations six to nine months in advance. The wheat model averaged 6.6% error when the model was used to predict the prices for the last 12 crop years. The largest error was 22.9% in 1977/78. The corn model was slightly more accurate, averaging only 1.2% error over the last 11 crop years. The error in the models should be considered when using the models to forecast prices. Forecasted prices for 1986/87 using the USDA world production and use estimates as of August, 1986, were about $94 per metric ton for corn, down 20% from the 1985/86 price, and about $176 per metric ton for wheat, 6% above the 1985/86 price. The prices obtained from the models should be looked at as a general level of prices for the next crop year, not as an exact forecasted price for any one date. Consequently, forecasted prices might be expanded to a range of plus or minus seven or eight percent.

The price flexibilities obtained from the models indicate that the price of corn is less responsive to changes in stock levels than is the price of wheat. The price of wheat is more responsive (has higher absolute value of price flexibilities) to production and utilization than the price of corn. The price of wheat is most responsive to changes in the utilization of wheat and least responsive to changes in stocks of wheat. The price of corn is most responsive to changes in the production levels of corn and least responsive to changes in stock levels of corn.

REFERENCES