Forecasting the Probability Distributions of U.S. Harvest Time Corn Prices

by

Daniel O'Brien, Marvin Hayenga, and Bruce Babcock

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A procedure is given for making pre harvest forecasts of the probability distribution of U.S. harvest time corn prices. The probability distributions of corn yields and production are forecast at monthly intervals throughout the U.S. corn growing season. Crop-weather models are used to forecast yields for seventeen homogeneous corn producing regions in the U.S. Corn Belt. Corn production forecast distributions for each Corn Belt crop reporting district are aggregrated together with a non Corn Belt corn production forecast distribution to obtain total U.S. production forecast distributions. A corn price model is used together with the monthly U.S. corn production forecast distributions to forecast U.S harvest time corn price probability distributions. The corn price model is estimated using supply and demand information available to the market at harvest time. Price forecasts are made using the U.S. corn production forecast probability distributions along with the most recent growing season USDA estimates for the corn marketing year of beginning stocks, feed use, exports, and total old crop corn use.

Forecasting Corn Production Distributions

Corn crop-weather model estimates for 1974-1991 are used to forecast 1992 corn yields and production. Forecasts are made as of July 1, August 1, September 1, and October 1 for crop reporting districts in seventeen homogeneous corn production regions throughout the U.S. Corn Belt. These production estimates and their associated forecast probability distributions are then aggregated together to derive a Corn Belt production forecast probability distribution. The Corn Belt distributions are combined with a forecast production distribution for non Corn Belt areas to obtain a probability distribution for the forecast of total U.S. corn production.

Data

The corn crop-weather models are estimated from crop reporting district level yield, acreage and weather data for the major corn producing states of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio and Wisconsin. Monthly total precipitation and average temperature information is used. In addition, 10 and 20 day precipitation and temperature data for July and August for mid and eastern Corn Belt crop reporting districts is used in model estimation. State level estimates of percent planted by mid May are utilized as a proxy to represent planting progress in each of the crop reporting districts in that state. Only in Missouri and Ohio are the geographic

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boundaries of crop and weather reporting districts not identical. Only in Missouri are major adjustments needed to match crop and weather reporting district data. The 1974-1991 period was chosen for model estimation because different weather patterns and corn prodcution technology existed during this time than during earlier years.

Determination of Corn Production Regions

Homogeneous regions or groupings of crop reporting districts are determined by a combination of three methods: cluster analysis (using Ward's method), expert opinion from climatologists and agronomists, and from personal observation of yield and weather data for the various crop/weather reporting districts. In the western Corn Belt, Kansas and Nebraska are broken into five separate but overlapping irrigated (two) and nonirrigated (three) corn production regions. By combining crop reporting district data for 1974-1991 into homogeneous groups, a cross-section time series data set is formed for each of the corn production regions.

Model Specification

Crop-weather models are estimated for each of the corn production regions for July 1, August 1, September 1, and October 1. These dates coincide with the target dates of USDA corn yield and production estimates. USDA estimates are released approximately 8 to 12 days after the first of each month. Each successive monthly model is estimated using only data for weather conditions that have actually occurred to that point in time. When these models are used for forecasting, the use of only observed (not projected) weather data allows for the application of unconditional forecasting techniques. In turn, this permits the derivation of yield forecast distributions based on normality assumptions. The structure of the successive monthly crop-weather models and definitions of the explanatory variables included in each are available from the authors upon request.

Crop-Weather Model Estimation Methods

Two methods are used to estimate the monthly crop-weather models, ordinary least squares (OLS) and the fitting of a beta distribution using maximum likelihood methods (MLBETA). There are three advantages to using OLS based crop-weather model estimates. First, with OLS the assumption that the distribution of estimation errors is normal permits the formation of crop-weather model estimation and forecast error distributions in unconditional forecasting applications. Second, calculation of the forecast error variance readily follows from OLS results. Third, after estimating and forecasting corn yield conditional on technology and weather information, the OLS error term will be independent of the factors that would make the forecast errors in the various regions highly correlated. As a result, the production probability distributions for the seventeen regions can be aggregated without adjustment for covariance among the regions. The second and third points above do not hold true for MLBETA estimation. Because the beta distribution results do not allow for

proper aggregation of independent regional corn production distributions, and do not readily fit the unconditional forecasting equation, only the OLS model is used for crop-weather model estimates and forecasts of corn production probability distributions.

The OLS estimate of the August 1 crop-weather model for the Iowa/Southern Minnesota corn producing region is given below. All variables except Trnd are measured in normalized deviations from 1974-1991 levels.

$$
\begin{aligned}
Yield = {} & 89.41 + 2.60.Trnd - 5.36.Nov/May\ Precip \\
& - 4.86.\%Plntd(5/15) + 3.66.May\ Temp \\
& - 4.82.June\ Temp\ - 8.33.HOT\ June + 0.31.June\ Precip \\
& - 3.65.July1\text{-}10\ Temp + 1.01.July1\text{-}10\ Precip \\
& + 1.46.July11\text{-}20\ Temp + 3.20.July11\text{-}20\ Precip \\
& + 0.45.July21\text{-}31\ Temp + 3.78.July21\text{-}31\ Precip \\
& - 13.24.HOTDRY\ July11\text{-}31 - 1.66.WET\ July\ 11\text{-}31 \\
& + 8.12.CRDDV\#32 \\
& + 5.20.CRDDV\#33 \\
& + 3.69.CRDDV\#35 \\
& + 5.09.CRDDV\#58 \\
& + 1.46.CRDDV\#59
\end{aligned}
$$

No. observations = 108
Std Error of the Reg. = 10.89
R-Square = .75
Adj R-Square = .70

Where,
Trnd = Linear time trend, representing technical change
%Plnted(5/15) = Percent of corn planted by mid-May (state level)
Nov/May precip = Total precip. Nov. of previous year to May of current year
May Temp = Avg May temperature
June Temp = Avg June temperature
HOT June = Effect of June temps 1.5 normalized units above average
June Precip = Total June monthly precipitation
July 1-10 Temp = Avg July 1 to 10 temperature
July 1-10 Precip = Total July 1 to 10 precipitation
July 11-20 Temp = Avg July 11 to 20 temperature
July 11-20 Precip = Total July 11 to 20 precipitation
July 21-31 Temp = Avg July 21 to 31 temperature
July 21-31 Precip = Total July 21 to 31 precipitation
HOTDRY July11-31 = Effect of combined high temps (>.5 normalized units above avg)   and low precip (>.5 normalized units below avg) for July 11 to 31
WET July11-31 = Effect of precip >.5 normalized units above avg for July 11-31
CRDDV = Crop reporting district dummy variables

Distributions of Forecast Corn Yield and Production

Yield forecasts are made using actual historic weather information occurring up to the point in time of model estimation during the corn growing season. Because ex-post actual values are used for explanatory variables, these are unconditional

forecasts. This allows for the assumption that the distribution of forecast errors is normal (see Pindyck and Rubenfield, 1992). With an unconditional forecast, the greater the difference between the value of a forecast period explanatory variable and the mean of that variable over the period of model estimation, the larger the forecast error is in relation to the standard error of the estimated econometric model. The multivariate unconditional forecasting formula is:

$$s_f^2 = s^2 \cdot [1 + \hat{X}(X'X)^{-1}\hat{X}]$$

Where,

s_f^2 = Forecast Error of the OLS model forecast

s^2 = Standard error of the OLS model estimate

X = Multivariate explanatory variable matrix

Probability distributions of corn yield forecasts for 1992 are calculated for each of the Corn Belt crop reporting districts, based on the regional crop-weather model which each crop reporting district is in. The forecast distributions are derived using the district level forecast error and the percentage points of a t distribution. Each of the identfied t distribution points along the forecast yield distribution are then multiplied by estimates of harvested corn acreage for each of the crop-weather reporting districts to obtain the corn production forecast distribution for that district. This linear "scaling up" the CRD level yield forecast distributions to obtain Corn Belt forecast production distributions does not change the distributions shape or properties. The unit of measurement becomes total bushel of corn production instead of yield per acre.

Aggregation of crop reporting district corn production forecast distributions is straight forward because the crop-weather model estimation errors across the seventeen regions are assumed to be independent. Covariance in yields across these crop production regions is mainly due to growing season weather conditions which are generally multi region in scope. The explanatory variables in these models (weather and yield trend) are the same variables that would cause the covariance in yields across the regions. After accounting for the impacts of technological trend and weather conditions through the explanatory variables of the model, it is reasonable to assume that the error terms in the seventeen OLS regional models are independent of one another. The highest potential for forecast yield covariance across regions will be with the July 1 model. This is because as of July 1 the majority of the multi regional weather conditions that will affect corn yields have not yet occurred. As time passes, the later monthly models have successively less potential for estimation error covariance. Therefore, the July 1 model has the highest potential for forecast yield covariance, with successively less potential effect in the August 1, September 1, and October 1 models. Given this possible covariance across regions in the early season crop-weather models, the OLS crop-weather model results are linearly aggregated without adjustment for covariance among the disturbance terms.

Aggregation of district level production forecast distributions into an overall monthly Corn Belt production forecast distribution is carried out by summation

across the distributions. The bushels of corn production associated with specific probability weighted points along the district level cumulative forecast distributions are summed across all districts to derive the total Corn Belt production forecast associated with those specific cumulative distribution points. The non Corn Belt corn yield forecast distribution is a function of forecast Corn Belt yields. The non Corn Belt yield forecast distribution is scaled by an estimate of non Corn Belt harvested acreage to derive a non Corn Belt production forecast distribution. The non Corn Belt production distribution is aggregated together with the Corn Belt production forecast distribution to obtain a total U.S. corn production forecast distribution. This process is repeated on July 1, August 1, September 1, and October 1 to derive monthly U.S. corn production forecast probability distributions. The 1992 forecast U.S. corn yield distributions for the July 1, August 1, September 1, and October 1 crop-weather models are shown in Figure 1, with the associated U.S. corn production estimates in Figure 2. Figures 3a and 3b illustrate the confidence intervals for U.S. corn production forecasts given by this forecasting procedure and by the USDA during the 1992 growing season.

In order to use these forecast distributions in the harvest time corn price model that follows, probabilities are assigned to points along the U.S. corn production forecast distribution. The mid points of adjacent ten percent intervals are selected along with the mid points of five percent intevals in the upper and lower tails of the distribution. A total of eleven probability weighted forecasts of U.S. corn production are identified. This process of selecting probability weighted U.S. corn production quantities is carried out successively for the July 1, August 1, September 1, and October 1 corn production forecasts. The corn production forecast quantities associated with the midpoints of the probability distribution ranges are used directly in the corn price model described below.

Forecasting Harvest Time Corn Prices

Estimating a Harvest Time Corn Price Model

The corn price model used in this study is patterned after the Shonkwiler and Maddala Dynamic Disequilibrium Model of U.S. Corn Prices (1991). The general S&M model is given below:

$$S_t = a_1 \cdot P_t^* + a_2' \cdot W_t + e_{1t} \qquad a_1 > 0 \qquad \text{(Supply Equation)}$$

$$D_t = b_1 \cdot P_t + b_2' \cdot X_t + e_{2t} \qquad b_1 < 0 \qquad \text{(Demand Equation)}$$

$$D_t = S_t \quad \text{if} \quad P_t \geq P_{t^-} \qquad \text{(Equilibrium Condition)}$$

$$D_t < S_t \quad \text{if} \quad P_t < P_{t^-} \qquad \text{(Disequilibrium Condition)}$$

Where,
S_t = Quantity supplied
D_t = Quantity demanded

P_t = Market-clearing price
P_{t^-} = Exogenously set lower limit on price
P_t^* = Rational expectation of price, formed when production decisions made
W_t = Supply shifters vector
X_t = Demand shifters vector
e_{1t}, e_{2t} = Estimation errors that are jointly normal with mean zero and
covariance matrix Sigma

A rational expectations equilibrium solution to this model is arrived at by setting demand equal to supply and solving for the equilibrium price.

$$D_t = S_t \quad => \quad P_t = c_1 + c_2'.W_t + c_3'.X_t + e_{3t}$$

The S&M model employs an endogenous switching simultaneous system approach in modeling U.S. corn prices. Because of controls on prices, the market is sometimes in equilibrium and sometimes in disequilibrium. If corn prices are limited or constrained in their downward movement by the U.S. corn support price (i.e., the effective government farm program loan rate), the market is in disequilibrium. If corn prices are greater than or equal to the U.S. corn support price or are otherwise unconstrained by the government price control, the market is in equilibrium. Whether the market is in equilibrium or in disequilibrium is determined endogenously due to the control on price.

In this study the U.S. harvest time corn price model is patterned after the S&M rational expectations equilibrium solution. Harvest time corn futures prices are determined as a function of a set of supply and demand shifters. The variables $PRODN_t$ and $BEGSTKS_t$ are supply shifters, while $FEEDUSE_t$, $TOTUSE_{t-1}$, and $EXPORTS_t$ are demand shifters.

$$P_t = b_0 + b_1.PRODN_t + b_2.BEGSTKS_t + b_3.FEEDUSE_t$$

$$+ b_4.TOTUSE_{t-1} + b_5.EXPORTS_t + u_t$$

Where,
P_t = Harvest time December futures price of corn
$PRODN_t$ = USDA U.S. corn production est. for the current marketing year
$BEGSTKS_t$ = USDA beginning stocks est. for the current marketing year
$FEEDUSE_t$ = USDA feeduse projection for the current marketing year
$TOTUSE_{t-1}$ = USDA total corn use est. for the previous marketing year
$EXPORTS_t$ = USDA U.S. corn exports est. for the current marketing year
u_t = estimation error (normally distributed)
All quantity variables measured in 100 million bushels

Data for the Corn Price Model

U.S. corn exports and prices have been higher and more volatile during the time period of model estimation (1973-1991) than during earlier years. To represent the

U.S. harvest time corn price, Thursdays closing prices during October 15-31 for the nearby December corn futures contract are averaged together. The last half of October typically coincides with the first half of the U.S. corn harvest. Local grain elevators are more likely to have storage available during the early stages of corn harvest than in later stages. Local cash prices may move lower during the later half of harvest as elevators have less storage available and widen their local basis bids to discourage farmers from selling and delivering corn. Depressed late harvest cash prices may affect the nearby December corn futures contract. For these reasons, December corn futures prices during the last half of October (i.e., early harvest) are used as the dependent variable in model estimation. Futures price forecasts can be adjusted to any U.S. location by using an estimate of local basis.

U.S. corn supply and demand projections are used as explanatory variables in the model. These are available from October and November releases of the USDA World Agricultural Supply and Demand Estimates (WASDE). The variable $TOTUSE_{t-1}$ is an estimate of total corn use in the previous (i.e., "old crop") marketing year. Estimates of $BEGSTKS_t$, $PRODN_t$, $FEEDUSE_t$, and $EXPORTS_t$ represent projections for the new crop corn marketing year. The twelve month time period from September 1 through August 31 delineate the marketing year for corn. The USDA World Agricultural Supply and Demand Board estimates are the standard to which private corn market analysts compare their own projections. Therefore, the USDA U.S. corn supply and demand estimates are used as the market's relevant harvest time information set.

October WASDE reports have been available since 1976. November WASDE reports have been released since at least 1970. To form a complete information set back to 1973, the October balance sheets are used back to 1976, and the November figures for 1973-1975. This approach assumes that the October and November WASDE figures are essentially the same. It also implies that during 1973-1975 the market had a general knowledge of the corn supply and demand situation in October prior to the November estimates.

Corn Price Model Estimation Results

The harvest time corn price model was estimated via OLS for the 1973-1991 time period. The estimation results are given below (t-ratios in parentheses).

$$P_t = \$4.00 - .034 \cdot PRODN_t - .018 \cdot BEGSTKS_t - .042 \cdot FEEDUSE_t$$
$$ (4.20) \quad (-4.67) \quad\quad (-2.47) \quad\quad\quad (-1.32)$$

$$+ .036 \cdot TOTUSE_{t-1} + .034 \cdot EXPORTS_t$$
$$(2.71) \quad\quad\quad (1.65)$$

$R^2 = .765$
Adj. $R^2 = .675$
19 observations (1973-1991)
13 degrees of freedom
Std Err of Est. = .32

These results indicate that there is a $0.034 per bu. decrease in harvest time corn prices for every 100 million bu. increase in U.S. corn production. This compares to a $0.05 to $0.06 per bu. decrease in season average corn prices for a 100 mln. bu. increase in total corn supply assumed by ISU Extension Grain Marketing Specialist Robert Wisner. The ISU Center for Agriculture and Rural Development (CARD) feed grains model assumes a $0.10 per bu. decrease in season average corn price per 100 mln. bu. corn supply increase. The CARD feed grains model arrives at a solution through an iterative process. Therefore, an initial $0.10 corn price response to a supply change may be larger than the final response of corn prices, after feedback adjustments for other factors such as corn usage and the demand for substitute feed grains.

Examination of harvest time corn prices during 1973-1991 and of model residuals when the model is estimated with all years included shows that prices have not been constrained in their downward price movement at harvest time by the government loan rate. Analysis of studentized residuals is used to determine whether there are any outlier observations among the data. Outliers are data observations for which the relationship between the price and quantity variables is significantly different from other years for which a model is estimated. Studentized residual analysis indicates that the observations for 1974 and 1977 were outliers. Of the two corn marketing years, 1974 is the most extreme outlier. DFBETAS analysis is used to determine whether any observation has an unusually large influence on the value of a particular estimated parameter. The DFBETAS results indicate that many of the explanatory variable observations in 1974 and 1977 have unusually large influences on some of the price model parameters. As in the studentized residual analysis, explanatory variable values for 1974 have the most influence on individual model parameters. There were no indications of outliers or influential data observations from 1978 to the present. A positive aspect of these findings is that only two of 19 model residuals (approximately 11%) are determined to be outliers, and only one of the two (i.e., 1974) an extreme outlier. Considering the small sample, this finding tends to support the assumption that the residuals are normally distributed. See Pindyck and Rubenfeld (1992) for an explanation of studentized residuals and DFBETAS. As a result of these findings, all the annual harvest time observations are considered to be equilibrium market observations and are used in model estimation.

Explanatory variables for price forecasting

June, July, August and September USDA corn supply and demand estimates are used to forecast corn prices on July 1, August 1, September 1, and October 1, respectively. USDA WASDE figures have historically been released sometime during the eighth to the twelfth of each month. For example, the July 1 WASDE estimates of corn supply and demand are released sometime during July 8 to 12. The August 1, 1992, U.S. harvest time corn price forecast probability distribution is derived using the July USDA WASDE projections and the August 1, 1992, U.S. corn production forecast distribution. The September 1, 1992, harvest time corn price forecast distribution is calculated using the August 1 USDA WASDE figures (released August 8-12) together with the September 1 corn production forecast distribution. The same approach is used to make

price forecasts for July 1 and October 1.

Deriving Harvest Time Corn Price Probability Distributions:

The harvest time price forecast distribution is derived primarily from the U.S. corn production forecast probability distribution. Current USDA WASDE values for $BEGSTK_t$, $FEEDUSE_t$, $TOTUSE_{t-1}$, and $EXPORTS_t$ are assumed fixed over the range of corn production forecasts. First, calculate the price forecast distributions associated with each of the eleven probability weighted corn production forecast quantities identified along the U.S. corn production forecast distribution. Each point along these eleven price forecast distributions is then multiplied by the probability weight assigned to their specific U.S. production forecast quantity. The eleven probability weighted price forecast distributions are then summed together to come up with the U.S. harvest time price probability distribution. The process is explained in more detail below:

First, calculate the price forecast distribution for each of the eleven probability weighted production forecast points along the U.S. corn production forecast distribution. USDA projections from the previous month for $BEGSTKS_t$, $FEED_t$, $EXPORTS_t$, and $TOTUSE_{t-1}$ are used along with each of the eleven production forecasts as explanatory variables in the harvest time price model. When this step is completed, there are eleven separate harvest time price forecast distributions, one for each of the identified points along the production forecast distribution.

Second, multiply each of the eleven price forecast distributions from the first step by their assigned probability weights. As a result there are eleven probability weighted price forecast distributions.

Third, sum the eleven probability weighted price forecast distributions across commonly identified probability points along those distributions to derive the aggregate U.S. harvest time price forecast distribution. To illustrate the third step:

- Sum across the probability weighted t distribution 1% points to derive the 1% point along the U.S. harvest time corn price cumulative distribution.
- Sum across the probability weighted t distribution 2.5% points to derive the 2.5% point along the U.S. harvest time corn price cumulative distribution.
- Sum across the probability weighted t distribution 5% points to derive the 5% point along the U.S. harvest time corn price cumulative distribution.
- etc.

The dates of the price forecasts coincide with the July 1, August 1, September 1, and the October 1 crop-weather model forecasts. Figure 4 illustrates the forecast price distributions for July 1, August 1, September 1, and October 1 from the procedure used in this paper. Figures 5a and 5b also illustrate the harvest time price forecast confidence intervals based on the U.S. corn production forecasts developed in this procedure from the crop-weather models and from the USDA production forecasts.

Discussion

The accuracy of the 1992 corn yield and production forecasts was hurt by historically large rainfall amounts during the summer and by pre maturity frost damage. The large amounts of rainfall received in 1992 were far greater than the average for the 1973-1991 period. In the unconditional forecasting approach used here, such an outlier value for an explanatory variable will lead to large forecast errors. The slower than normal rate of crop development and related pre maturity frost damage to corn in the northern Corn Belt also diminished the accuracy of the 1992 yield forecasts. Forecast inaccuracy from this source can be attributed to model misspecification since no related variables are included in the crop-weather models. Variables measuring the impact of slow crop development and poor harvest time weather conditions should be included in future versions of the crop-weather models. Another possible source of inaccuracy in yield forecasts is the implicit assumption in the pooled cross-section time series approach that the effects of weather events on corn yields are equal across all the crop reporting districts within a homogeneous corn producing region. The corn production forecast distribution also may be affected by the method of calculating the non Corn Belt yield forecast distribution. Whereas the Corn Belt forecast production distribution is an aggregation of unconditional forecasts, the non Corn Belt production forecast distribution is based on the Corn Belt yield forecast. Since the Corn Belt yield forecast is a stochastic variable, the non Corn Belt yield forecast does not qualify as an unconditional forecast with the associated normality properties. The aggregation of this non normal non Corn Belt production forecast distribution together with the total Corn Belt distribution may hurt the accuracy of the total U.S. corn production forecast distribution.

The corn price modeling approach taken here is pragmatic in nature, relying on USDA estimates of marketing year corn supply and demand for estimation and forecasting purposes. Since the explanatory variables for price forecasting are forecasts themselves, the price forecasts are conditional forecasts, which do not strictly meet the required conditions for normally distributed forecast errors. However, weighting each of the eleven corn production forecasts along the production forecast distribution by the probability of its occurrence may compensate for this inaccuracy. None of the eleven individual probability weighted U.S. corn production forecasts along the price forecast distribution are designated as the single production forecast. Instead, a probability weighted range of forecasts is taken into account. According to Pindyck and Rubenfeld (1991), if the procedures of conditional forecasting were strictly adhered to, then the most accurate estimate of a probability distribution should be derived using a method developed by Feldstein based on Chebyshev's Theorem. Feldstein's approach to conditional forecasting will likely give wider, less indicative price probability distributions than the approximate method used in this paper. However, there is a tradeoff between the tractability of the method used here and the theoretical correctness of the Feldstein conditional forecasting method.

A possible problem is that the price model does not explicitly account for

simultaneity among the different explanatory variables in the determination of harvest time corn prices. No attempt is made to model the entire simultaneous system of equations that would reflect the numerous price and quantity adjustments that would occur in response to a change in the quantity of corn produced. Implicit in the single equation price model used here is the USDA's method of determining changes in projected corn supply and demand in response to changes in forecast corn production and prices at harvest time. To imitate the USDAs efforts econometrically would require a simultaneous system of equations for determination of corn prices and the various supply and demand factors. The negative coefficient for $FEEDUSE_t$ in the corn price model is the result of the USDAs implicit simultaneous determination of supply, demand, and price as reflected in the WASDE reports. At face value this negative coefficient implies that increased projections of $FEEDUSE_t$ in the coming marketing year would have a negative impact on the harvest time corn price. In truth this negative coefficient illustrates that the in its corn usage forecasts the USDA is making a simultaneous upward adjustment in their $FEEDUSE_t$ projection in response to anticipated increases in corn production and associated lower prices. Therefore, what looks like a negative causal relation with increased $FEEDUSE_t$ leading to lower prices (P_t) is actually a matter of increased $PRODN_t$ leading to lower P_t which in turn leads to increased $FEEDUSE_t$.

There may be a question about whether the response of harvest time corn prices to alternative production forecasts is modeled adequately. For each monthly price forecast, the values for $BEGSTK_t$, $FEEDUSE_t$, $TOTUSE_{t-1}$, and $EXPORTS_t$ from the previous months USDA WASDE reports are substituted into the price model as explanatory variable forecasts. Then each of the eleven probability weighted $PRODN_t$ forecasts are substituted separately into the price model along with the unchanged values for $BEGSTK_t$, $FEEDUSE_t$, $TOTUSE_{t-1}$, and $EXPORTS_t$ to calculate eleven price forecast probability distributions. With the probability weighting process described above, one aggregate harvest time price forecast distribution is calculated. The eleven probability weighted forecast values for production (i.e., the eleven chosen values along the production forecast probability distribution) have the most influence on the harvest time price forecast distribution. The forecast explanatory variable values for $BEGSTK_t$, $FEEDUSE_t$, $TOTUSE_{t-1}$, and $EXPORTS_t$ do not change in the price model as $PRODN_t$ changes along the production forecast distribution. Does this approach over state the change brought about in harvest time corn prices by only adjusting for production changes? The estimated coefficient for $PRODN_t$ is measuring the independent effect of a change in corn production on harvest time corn prices. The coefficient for the $PRODN_t$ variable measures the net effect of a change in corn production on harvest time corn prices, implicitly accounting for the adjustments and readjustments among the other corn supply and demand categories. When price is regressed on production and a constant alone, without the other explanatory variables, the coefficient is nearly the same as when the other variables are included in the equation. Also, this coefficient indicates a smaller price response than some other corn price models and forecaster's rules of thumb for price flexibility. Therefore, it seems reasonable to assume that the model is not greatly over estimating the responsiveness of harvest time corn prices to changes in corn production.

Conclusion

The purpose for developing this forecasting procedure is to improve the probabilistic content of grain price forecasts. This procedure is a contribution to probabilistic based price forecasting, but much remains to be done. Performance of the crop-weather model may be enhanced by considering non linear responses to weather variables and alternative representations of the technology trend. The explanatory ability of the crop-weather model may be improved by adjusting the variables for the effect of slower or faster than normal crop development, and by adding variables measuring the effects of early frost and poor harvest conditions. Modeling non linear responses to explanatory variables may also improve the performance of the price model. However, when using logarithmic functional forms to model curvilinear price-factor responses, care must be taken to preserve the normality assumption on which the forecast distributions are built.

After refinement and improvement of this prediction approach, these forecast distributions should be compared to the price probability distributions implied by corn options market premiums. This comparison could provide valuable information regarding the accuracy of the collective judgment of the futures and options traders with regard to pre harvest crop and price prospects. Also, these forecast distributions could provide probability based information upon which grain pricing strategies could be based. The historic performance of probability based marketing strategies could also be investigated. More probabilistic content could then be added to extension pre harvest grain marketing recommendations.

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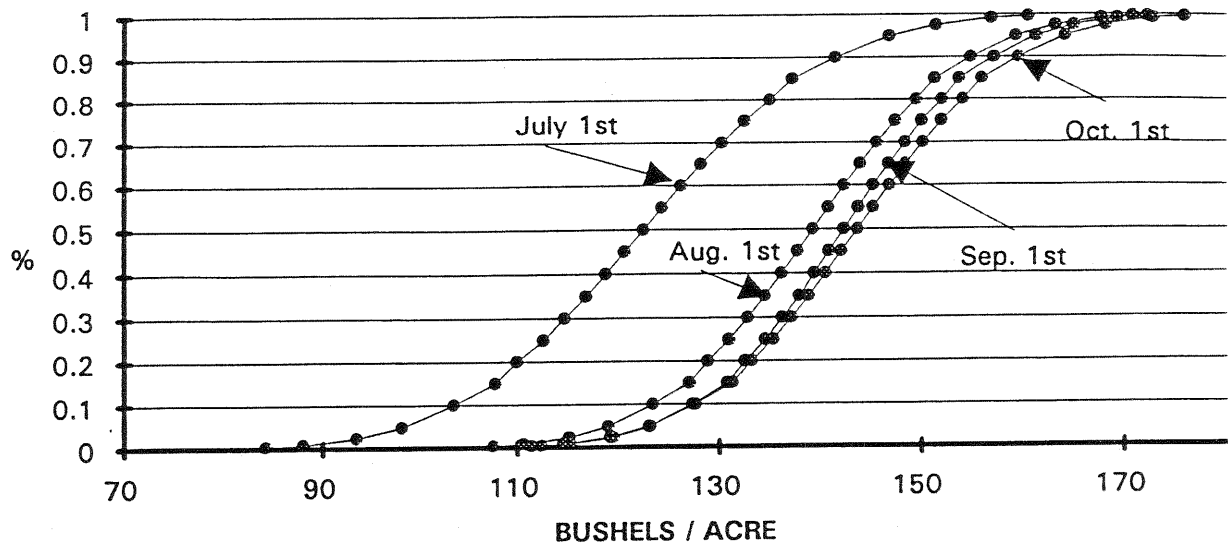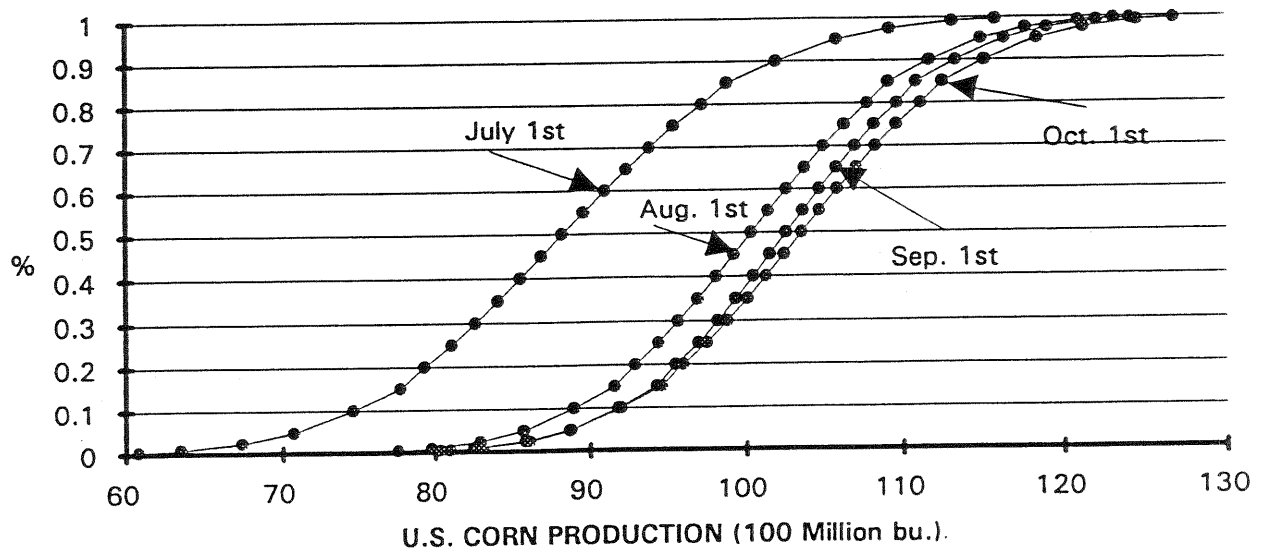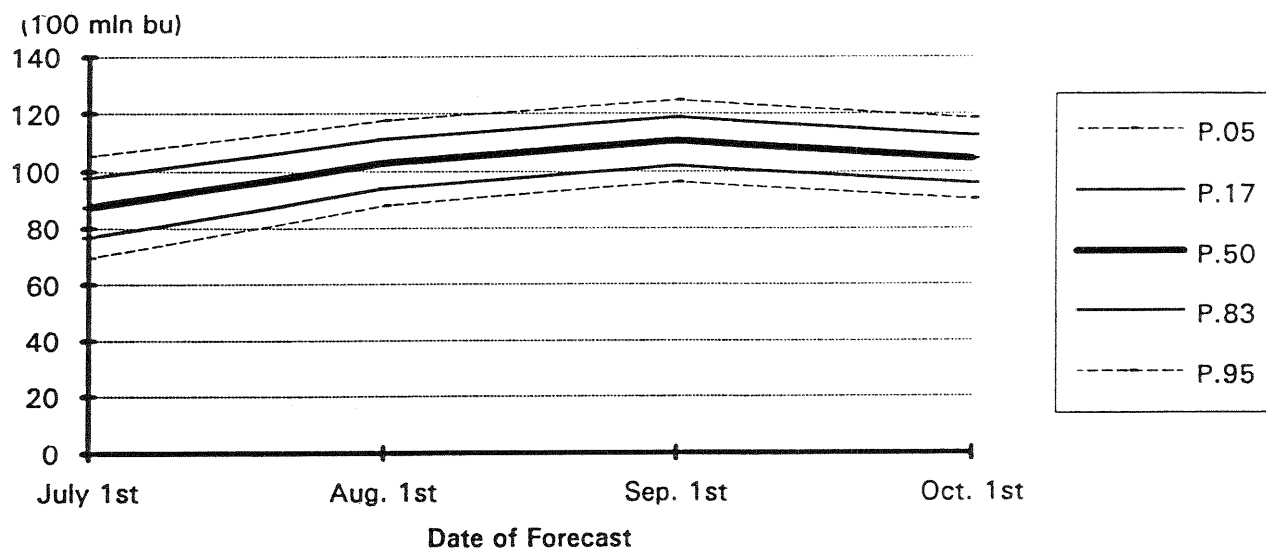## Figure 1. 1992 U.S. CORN YIELD FORECAST DISTRIBUTION

Figure 2. 1992 CORN PRODUCTION FORECAST DISTRIBUTIONS

**Figure 3a. 1992 U.S. CORN PRODUCTION FORECAST
INTERVALS**

**Figure 3b. 1992 U.S. CORN PRODUCTION FORECAST
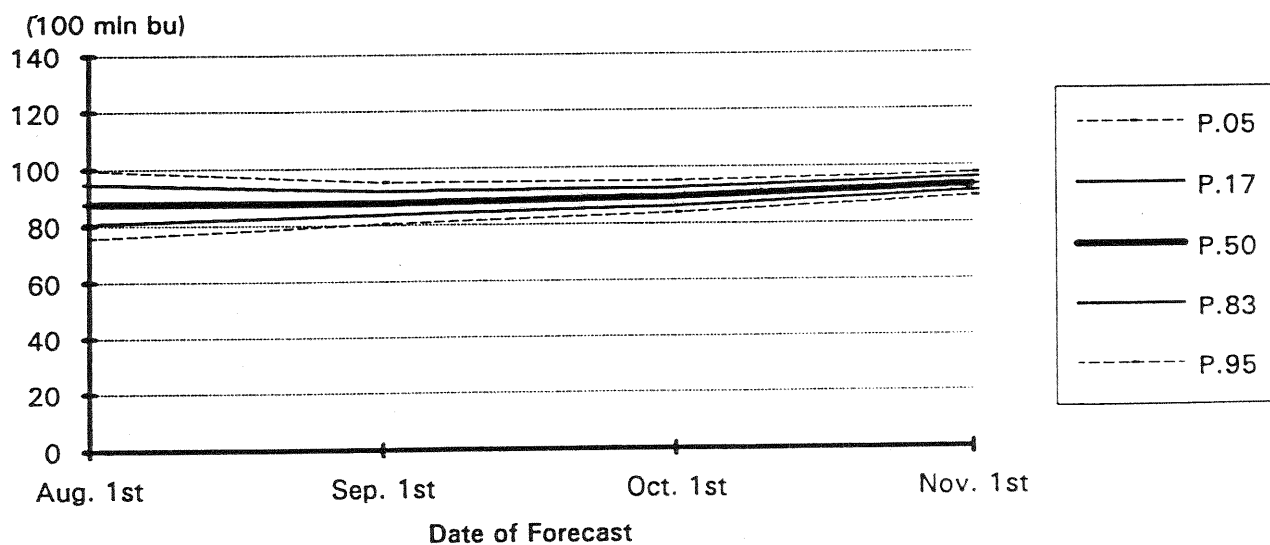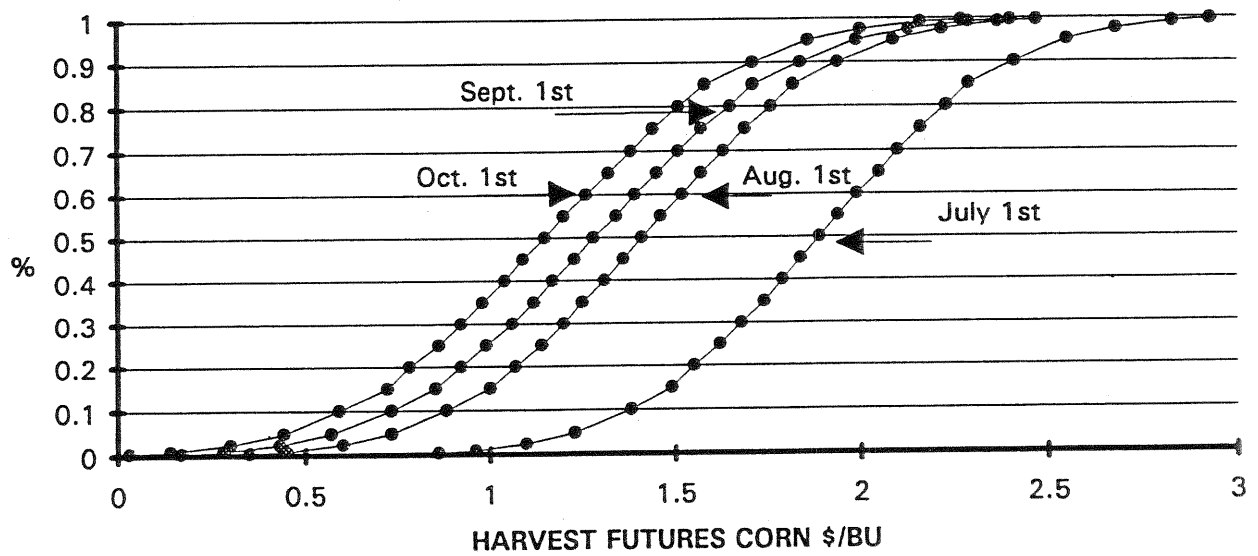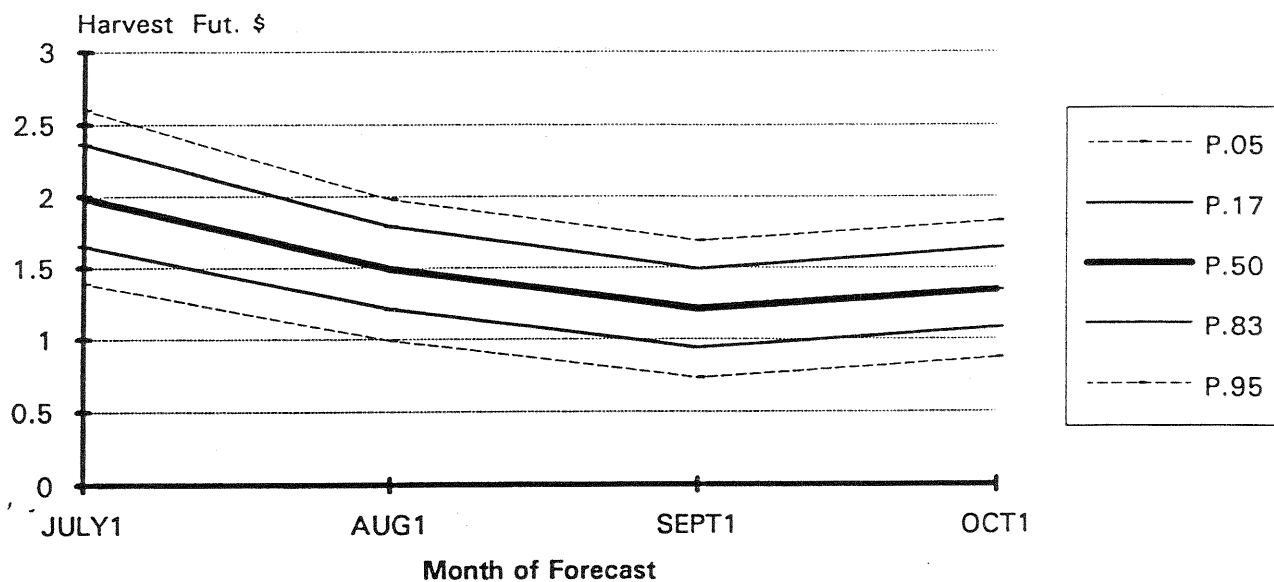INTERVALS FOR THE USDA**

Figure 4. 1992 CORN $ FORECAST DISTRIBUTIONS

Figure 5a. 1992 CORN PRICE FORECAST INTERVALS

Harvest Fut. $

Legend:
- P.05
- P.17
- P.50
- P.83
- P.95

Month of Forecast

Figure 5b. 1992 CORN PRICE FORECAST INTERVALS USING USDA PRODUCTION ESTIMATES

Harvest Fut. $

Legend:
- P.05
- P.17
- P.50
- P.83
- P.95

Month of Forecast