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Daniel O'Brien and Robert Wisner

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Development of Alternative Wheat and Corn Price Forecasting Models

Daniel O'Brien and Robert Wisner*

Models of U.S. corn and wheat prices are estimated for the purpose of making forecasts of futures and average cash prices. The supply-demand based price models developed are based on economic theory with attention given to the econometric properties of both the models and the data series involved in their estimation. Forecast results for these models during 1994-1996 are comparable to that of associated corn and wheat futures contracts. These price forecast models may provide valuable information to forecasters regarding future price direction and the responsiveness of corn and wheat prices to potential changes in supply-demand factors.

Introduction

Recent evaluation of the accuracy of University Extension and private commodity price forecasts have shown the need for improved grain price forecasting models and procedures. The inconsistent performance of price model forecasts and the econometric challenges involved in model development have caused many economists to abandon efforts to develop structural price models. Consequently, many economists favor reliance on the informational efficiency of commodity futures prices to provide accurate price forecasts. For price model forecasts to be of value, they must produce price forecast and market direction information that is in addition to what is already available through existing futures and options markets. With potentially increased grain price volatility under the 1996 F.A.I.R. Act, improved grain price forecast information from price models would be of value in analyzing price risk and formulating risk management strategies for farmers and agribusiness.

Structural models of grain market supply and demand have been developed for forecasting and policy analysis purposes by Houck, Ryan and Subotnik; Chen; Arzac and Wilkinson; and Westhoff, et al.. Single equation price models have been developed by Van Meir; Westcott, Hull and Green (1985); Westcott and Hanthorn (1987), and Baker and Menzie. Switching regressions, rational expectations commodity modeling approaches have been used by Shonkwiler and Maddala, and Holt to represent grain markets that are alternately in equilibrium and disequilibrium. O'Brien, et al., used a structural supply-demand corn price model patterned after Shonkwiler and Maddala in a Monte Carlo-based multivariate conditional price forecasting procedure to derive corn futures price probability distributions. With regard to price model development, Chen and Dharmartne developed a systematic approach for modeling agricultural commodity markets in terms of alternative factor demands.

Daniel O'Brien is an Extension Agricultural Economist in Northwest Kansas and an Assistant Professor in the Department of Agricultural Economics at Kansas State University. Robert Wisner is a University Professor in the Department of Economics, Iowa State University.

Many efforts have been made to analyze the market efficiency and forecast accuracy oi grain futures prices. Eales, et al. compared subjective price forecast distributions from Illinois farmers and grain merchandisers to distributions embodied in corn and soybean futures and options prices for the 1987-88 marketing year, following related work by Fackler and King; an Sherrick, Irwin, and Foster. Considering the forecast accuracy of futures prices alone, Kenyon Jones, and McGuirk found preharvest December corn and November soybean futures prices to poor predictors of final harvest futures price levels during the 1974-1991 period.

The objective of this research is to develop wheat and corn price models for use in applied commodity price forecasting. The factor demand approach of Chen and Dharmartne, t corn harvest futures price model in O'Brien, et al., and the annual average price model used by Wisner provide the basis for most of the models presented here. Following analysis of the econometric properties of each price model and its dependent and explanatory variables, out oi sample price forecasts are derived using the Monte Carlo-based conditional price forecasting procedure in O'Brien, et al.. Emphasis is placed on evaluating each model's ex post out-of-sample forecast accuracy during the 1994-1996 period relative to existing futures price forecas

Developing Grain Price Forecasting Models

The process of developing structural models for grain price forecasting should be sounc rooted in economic and econometric theory and should avoid the biases introduced by data "mining". One goal of this paper is to present U.S. grain price forecast models which are theoretically based and which are developed using a minimal amount of data experimentation. second goal is to focus on the econometric properties of the dependent and explanatory variabl used in the models. In this analysis, if econometric problems such as data nonstationarity, multicollinearity, and outliers exist, then explanatory variables are either detrended, first differenced, or excluded from the model. Then alternative models are also estimated based on the original factor-price relationships but using the newly transformed explanatory variables.

The U.S. corn and wheat price models presented here originate from four sources. The first group of models are based on the factor demand approach of Chen and Dharmartne. Corn futures price models #1 and #3 are feed factor demand models, while wheat futures price mode #1 and #3 are food factor models. Alternatively, corn futures price models #2 and #4 are based on the reduced form of a basic two equation structural supply-demand price model used by O'Brien, et al.. The U.S. corn average cash price models #1, #2, and #3 are based on price models currently used by Wisner at Iowa State University in applied price forecasting. Finally, wheat futures price models #2 and #4 are based on stock / demand or use ratio factors with a production variable included. Selection of the explanatory variables in wheat futures models #: and #4 is based on the authors judgement regarding factors that determine wheat prices. These price models are formally presented in Tables 2, 3, and 4. Before presenting the models, the econometric properties of their dependent and independent variables are examined.

Properties of Price Model Dependent and Independent Variables

Properties of the nontransformed variables used in the corn and wheat price models in this paper are presented in Table 1. Along with the mean, standard deviation, minimum and maximum values of each variable, the results of statistical tests are presented indicating whether each variable has a trend or is a random walk with drift. Variables are tested for trends in part to determine the potential for multicollinearity among other model explanatory variables.

Table 1. Variables For Corn and Wheat Price Forecast Models

Variable	Description	Mean	Std Dev	Min	Max	Trend	R Walk w. Drift
U.S. Corn Harvest Futures Price Forecasting Model Variables (1974-1995)							
CnDFut	December Corn Futures Thursday Closes, October 16-31 Period ($/bu.)	2.66	0.57	1.69	3.78	No	No
BgStk	Beginning Stocks (Million Bu.)	1736.10	1294.00	295.00	4882.00	No	Yes
Prodn	U.S. Corn Production (Million Bu.)	7089.30	1412.30	4259.00	9602.00	Yes	No
GCAU	Grain Consuming Animal Units (Millions)	77.45	4.01	71.60	85.40	Yes	No
CSbMCn	Ratio: Soybean / Corn Cash Prices, Current Month	2.40	0.50	1.45	3.64	No	Yes
Expt	U.S. Corn Exports (Million Bu.)	1804.50	424.45	825.00	2550.00	No	No
UseL1	Total Use, Year t-1 (Million Bu.)	7094.50	1013.20	4841.00	9405.00	Yes	No
StkUsL1	Ratio: End Stocks / Use, Yr. t-1	0.24	0.18	0.05	0.66	No	Yes
U.S. Corn Marketing Year Average Cash Price Forecasting Model Variables (1973-1995)							
CnAvgP	Corn Cash Price-Mktg Year Ave ($/bu.)	2.46	0.41	1.50	3.24	No	Yes
StkUse	Ratio: End Stocks / Total Use	0.25	0.17	0.05	0.66	No	No
ExpSply	Ratio: Exports / Total Supply	0.21	0.05	0.12	0.28	Yes	Yes
ShtCrop	Short Crop Dummy Variable (0/1)						
Loan	USDA Corn Loan Rate ($/bu.)	1.88	0.47	1.05	2.65	No	Yes
PriceL1	Corn Cash Price-Mktg Year t-1 ($/bu.)	2.37	0.42	1.50	3.21	No	No
U.S. Wheat Harvest Futures Price Forecasting Model Variables (1977-1995)							
WhSFut	September KC Wheat Futures Closes, Thursdays, August 16-31 Period ($/bu.)	3.45	0.66	2.31	4.57	No	No
Prodn	U.S. Wheat Production (Million Bu.)	2293.00	286.77	1817.00	2769.00	No	No
USPop	U.S. Population (Millions)	241.20	0.01	220.02	263.03	Yes	No
Expt	U.S. Wheat Exports (Million Bu.)	1293.40	215.03	1000.00	1775.00	No	No
StkUse	Ratio: End Stocks / Total Use	0.44	0.20	0.19	0.83	No	Yes
StkUsL1	Ratio: End Stocks / Use, Yr. t-1	0.46	0.21	0.20	0.97	No	Yes
FrnSUL1	Ratio: Non-U.S. Wheat End Stocks / Use, Year t-1	0.23	0.03	0.20	0.28	No	No

If several of a price model's explanatory variables have positive trends, then the potential for multicollinearity and inaccurate regression results is increased. All of the trends in these variables that were statistically significant were positive. If any variable has a significant positive trend, a detrended transformation of that variable is used in a second price model based on the same theoretical construct as the initial model. Detrended transformations are identified by placing a "Dt" prefix in front of the variable's name. Variable's that have the statistical properties of a random walk with drift are determined to be nonstationary time series. Including nonstationary variables in econometric models has negative consequences for model properties. As for variables with positive trends, if any variable is determined to be a random walk with drift (i.e., nonstationary), then a first differenced transformation of that variable is used in a second price model based on the same theoretical construct as first. First differenced transformations are identified by placing a "Df" prefix in front of the variable's name.

Among the dependent price variables, neither corn and wheat futures price series have significant trends or are determined to be random walks with drift. Therefore, these futures price series are used as dependent variables (after natural log transformation) in each of their associated price models. Conversely, the U.S. corn average cash price series is determined to be a random walk with drift. Consequently, a corn price change model is estimated, (U.S. corn average cash price model #3) in which the dependent variable price series and all explanatory variables (except for a "0 / 1" short crop dummy variable) are transformed into first differences. This model is estimated in addition to models #1 and #2 in which untransformed, level average cash corn prices and explanatory variables are used.

<u>U.S. Corn Harvest Futures Price Forecast Models</u>

Four U.S. corn harvest futures price models are presented in Table 2. The dependent variable is the natural logarithm of average Thursday closes of the December corn futures contract during the October 16-31 (or harvest) period. These log-linear (exponential) models are consistent with the common assumption that commodity prices are lognormally distributed. Lognormally distributed functions are strictly positive, which is characteristic of commodity prices in general. The coefficients of these semilog models represent the proportionate rate of change in price per one unit change in the explanatory variable. For instance, in corn harvest futures price model #2 below, a one unit change (1 million bushels) in corn will have more price impact when corn prices are relatively high than when prices are low. Harvest time average price model results indicate that there is a $0.02 to $0.044 per bushel decrease in harvest time average corn prices for every 100 million bushel increase in U.S. corn production based on the responsiveness of corn prices over the 1975-1995 price range of $1.69 to $3.78 per bushel. The price responsiveness at the mean 1975-1995 harvest futures price of $2.66 is $0.03 per bushel.

The model estimation results are given below. Model #1 is a feed factor demand model, while model #3 is the identical model with transformed (detrended and first differenced) variables. Analysis of Model #1 properties indicated little or no autocorrelation, multicollinearity, or heteroskedasticity, although there was indication of possible structural change after 1982. Model #2 is the reduced form of the two equation structural model used by

Table 2. U.S. Corn Harvest Futures Price Forecast Models [a]

Variables	Corn Futures Price Model #1	Corn Futures Price Model #2	Corn Futures Price Model #3	Corn Futures Price Model #4
Dependent Variable:	ln(CnDFut)	ln(CnDFut)	ln(CnDFut)	ln(CnDFut)
Independent Variables				
Constant	0.492	0.842 ***	0.130	0.450
StkUsL1	0.337			
Prodn	–0.0000713 ***	–0.000116 ***		
GCAU	0.013 *			
CSbMCn	–0.278 ***			
Expt	0.000325 ***	0.00023 ***	0.000432 ***	0.00026
BgStk		–0.0000738 ***		
UseL1		0.0000873 ***		
Df StkUsL1			–0.0501	
Dt Prodn			–0.0000919 ***	–0.000085 **
Dt GCAU			0.011	
Df CSbMCn			0.0801	
Df BgStk				–0.000022
Dt UseL1				0.000066
DV-1974		0.361 **		0.559 **
DV-1982		0.372 ***		0.332 *
R^2	0.82	0.85	0.61	0.72
R^2 Adjusted	0.76	0.79	0.49	0.61
Standard Error	0.0995	0.098	0.1466	0.135
Degrees of Freedom	15	15	15	15

[a] Significance at 0.10, 0.05, and 0.01 denoted by 1, 2, or 3 asterisks, respectively.

O'Brien, et al., with dummy variables for outlier observation years. Outlier observations were determined using standardized coefficients and DFBETAS analytical tests in SHAZAM©. Analysis of Model #2 properties indicated no multicollinearity or structural change, but possible autocorrelation and heteroskedasticity. Models #3 and #4 are identical to #1 and #2, respectively, except for the use of detrended and first differenced explanatory variables. More information regarding the econometric properties of the models with transformed variables is available from the authors.

U.S. Corn Average Cash Price Forecast Models

The price models in Table 3 closely represent the models used by Wisner in applied price forecasting and market analysis. Models #1 and #2 are both linear and identical except for the inclusion of average corn cash prices for the previous year as an explanatory variable. The lagged price was excluded from Model #2 to determine whether the econometric properties of the model and the accuracy of the model's forecasts would be effected. In terms of model fit and individual explanatory variable significance, the inclusion of lagged prices has little effect.

Table 3. U.S. Corn Average Cash Price Forecast Models [a]

Variables	Corn Cash Price Model #1	Corn Cash Price Model #2	Corn Cash Price Model #3
Dependent	CnAvgP	CnAvgP	Df CnAvgP
Independent Variables:			
Constant	1.568 ***	1.783 ***	−0.138
PriceL1	0.148		
StkUse	−1.074 **	−1.169 **	
ExpSply	1.007	1.265	
ShtCrop	0.481 ***	0.444 ***	0.569 ***
Loan	0.247	0.308 **	
Df StkUse			−1.509 *
Df ExpSply			−1.347
Df Loan			0.389
R^2	0.77	0.75	0.70
R^2 Adjusted	0.70	0.70	0.63
Standard Error	0.2265	0.2265	0.293
Degrees of Freedom	17	18	16

[a] Significance at 0.10, 0.05, and 0.01 denoted by 1, 2, or 3 asterisks, respectively.

Analysis of Model #1 properties indicated little or no multicollinearity, heteroskedasticity, or structural change. However, possible autocorrelation exists. Analysis of Model #2 properties indicated little or no multicollinearity or heteroskedasticity, but there is the likelihood that autocorrelation and structural change are present. Model #3 is a first differenced version of Model #2 (without lagged prices), and was included to account for the nonstationarity of corn average cash prices. The explanatory variables are also transformed to first differences (except for the short crop dummy variable) to facilitate a "price change"-oriented model representation.

U.S. Wheat Futures Price Forecast Models

Four U.S. wheat futures price models are presented in Table 4. The dependent variable is natural logarithm of average Thursday closes of the September Kansas City Wheat futures contract during the August 16-31 period. Hard red winter wheat harvest in Kansas typically occurs during July, with the first post-HRW harvest government supply-demand report occurring by mid-August. The August 16-31 period was selected because of the increased accuracy of the August USDA U.S. winter wheat production estimate over the July estimate. With better information, it is hypothesized that the wheat futures market would be able to more accurately assess supply-demand impacts upon price during the late August period than during the last half of July. As with the corn harvest futures models presented earlier, these log-linear (exponential) models are consistent with the common assumption that commodity prices are lognormally distributed. Model #1 is a food factor demand model, while model #3 is the identical model with transformed (detrended and first differenced) variables. Analysis of Model #1 properties indicated little or no multicollinearity, heteroskedasticity, or structural change. However there are

Table 4. U.S. Wheat Futures Price Forecast Models [a]

Variables	September KC Wheat Futures Model #1	September KC Wheat Futures Model #2	September KC Wheat Futures Model #3	September KC Wheat Futures Model #4
Dependent Variable:	ln(WhSFut)	ln(WhSFut)	ln(WhSFut)	ln(WhSFut)
Independent Variables:				
Constant	1.559 ***	1.992 ***	1.304 ***	2.166 ***
StkUsL1	–0.628 ***	0.131		
Prodn	–0.000376 ***	0.000117	–0.000349 **	0.0000858
USPop	-0.77×10^{-6}			
Expt	0.000775 ***		0.000575 ***	
StkUse		–0.546		
FrnSUL1		–3.629 **		–4.841 ***
Df StkUsL1			–0.347 *	–0.313
Dt USPop			0.000233 ***	
Df StkUse				–0.000942
DV-1979		0.339 **		0.390 **
DV-1990		–0.389 **		–0.403 **
R^2	0.74	0.70	0.66	0.64
R^2 Adjusted	0.67	0.58	0.58	0.49
Standard Error	0.1130	0.1276	0.1280	0.1409
Degrees of Freedom	17	15	17	15

[a] Significance at 0.10, 0.05, and 0.01 denoted by 1, 2, or 3 asterisks, respectively.

indications that autocorrelation may exist. The original version of Model #1 had both U.S. population and consumption expenditures over time (both with significant positive trends), and exhibited a large amount of multicollinearity between these two variables. Eliminating consumption expenditures from the model drastically reduced the multicollinearity with little adverse effect on the explanatory power of the model. Model #2 is a use ratio model with dummy variable adjustments made for outlier observations. The inclusion of lagged foreign stocks to use ratios is a primary feature in this model, but is it troubling that U.S. production does not have a significant negative effect on prices. Analysis of Model #2 properties indicated no heteroskedasticity or structural change. However, some autocorrelation may exist, and moderate multicollinearity may exist between current and lagged stocks to use variables. Model #4 is identical to #2 except for the use of detrended and first differenced explanatory variables.

Price Forecasting Procedure

The corn and wheat price forecasting procedure used here follows that used and described in O'Brien, et al.. This Monte Carlo-based multivariate forecasting procedure produces grain price forecast probability distributions. To generate these price forecast probability distributions, econometric price models, their standard error estimates, explanatory variable forecast variance and covariances, and projections of explanatory variables are used together as elements o Monte Carlo simulation procedure. This multivariate conditional forecasting procedure f from the univariate conditional forecasting approach of Feldstein, which calculates confid intervals for conditional forecasts based on Chebyshev's inequality (Pindyck and Rubinfel 195-201). Confidence intervals derived by Feldstein's method will tend to be outer-bound estimates, generally wider than the forecast confidence intervals resulting from unconditio forecasting methods which rely on known, nonstochastic regressors. Detailed explanation this Monte Carlo multivariate price forecasting procedure are available in O'Brien, et al., a O'Brien and Wisner. The price forecast distributions for 1994-1996 from these models are represented in terms of the 25%, 50% (i.e., the median) and 75% quartiles of the distributic The focus of this paper is on analyzing the accuracy of median price model forecasts. The 50%, and 75% quartile prices will be graphically represented in the price forecast performa figures that follow along with futures price forecasts for the same time periods.

Preharvest Forecasts of Explanatory Variables

Preharvest projections of the supply-demand and price factors used in these price fo models are taken from public reports available through the USDA World Agricultural Outlo Board and Agricultural Marketing Service. The USDA releases its supply-demand projectic on a monthly basis during the preharvest growing season and throughout the year. The varia and covariance matrix of the preharvest forecast accuracy of these USDA supply-demand projections is a key element of the Monte Carlo forecasting procedure used here. For instanc June forecasts are being made of December corn futures prices during the October 16-31 (i.e harvest) period, then the historic forecast variance - covariance matrix of USDA supply-dem factor forecasts from June to October is used in this price forecast procedure. The forecast accuracy of the USDA for these explanatory variables almost always increases from the beginning to the end of the preharvest forecast period as more is known about crop supply an demand prospects for these commodities in the U.S. and abroad. However, in many cases the positive or negative covariance of these explanatory variable forecasts change little througho the period. For each monthly preharvest forecast in this paper during the 1994-1996 period, a updated forecast variance - covariance matrix is used in the forecast procedure. These matrice are not presented here to conserve space, but are available from the authors upon request.

Consecutive Re-estimation of Price Forecasting Models

To measure the performance of these forecast models over time, monthly price projections are made for 1994, 1995, and 1996. To produce out of sample forecasts and use st all the data available for model estimation, this set of price models and forecast variance - covariance matrices is first estimated using data available through 1993 for making the 1994 forecasts. Then, price models are re-estimated using data available through 1994 and used in making the 1995 forecasts. Finally, the models and forecast variances, etc. are re-estimated ag using data available through 1995, and used for making the 1996 forecasts. While the depende and independent variables used in each model are unchanged, the price models and forecast variance-covariance matrices are updated annually to include all information that is available in order to improve explanatory ability. Price models presented in Tables 2, 3, and 4 are estimate with data available through 1995, and are used in making the 1996 forecasts.

Price Model Forecast Performance Results

The performance of these price forecast models during 1994, 1995, and 1996 is presented in Tables 5, 6, and 7. The futures prices used for comparison are the average of futures contract closes for the five market days immediately following the release of the USDA Crop Production and World Agricultural Outlook Board reports. The USDA reports are typically released during the period of the 8th to the 12th day of each month. This period is chosen to represent the consensus view of the futures market immediately following the release of the updated USDA supply-demand numbers, and to reduce the likelihood that other factors (such as changing crop prospects) will begin to dominant futures price direction.

The forecast performance comparisons that follow each have a three-fold focus. First, comparisons of the monthly average forecast errors throughout the preharvest season are made for 1994, 1995, and 1996. Second, the 1994 through 1996 forecast root mean square errors (RMSEs) are compared to indicate the magnitude of harvest price forecast inaccuracy. Both the monthly average forecast errors and the forecast RMSEs will be compared across price models and futures price forecasts. Third, the performance of the price models in forecasting price direction relative to the futures market will be measured. This measure is called "% Correct Price Direction vs Futures" in Tables 5, 6, and 7. For example, on an ex-post basis it is observed that the harvest price in 1994 for December corn futures is \$2.18 (Table 5). If during the relevant 5 day period in May 1994, Dec Corn futures were trading for approximately \$2.49, while Model #1 in Table 6 was predicting harvest prices to be \$2.11, then the price model was correctly predicting that futures prices would move lower into harvest (i.e., down to \$2.18). Conversely, if the Model #1 forecast in May 1994 had been for harvest futures prices to be higher than \$2.49 (the futures price forecast), then Model #1 would have been incorrect in its prediction of price direction. Measures of % correct price direction relative to the futures are made for separate months and across all months during the 1994-1996 period for each corn and wheat futures price forecast model. A direct December futures price comparison is not appropriate for the corn average cash price models in Table 6, so only the average forecast errors and the forecast RMSEs for 1994-1996 will be shown.

Corn Futures and Futures Price Model Forecast Performance

The ex post forecast performance of the four U.S. corn harvest futures price models described in Table 2 is presented in Table 5. The forecast performance of Model #1 during the 1994-1996 period is shown in terms of the 25%, 50% (median), and 75% quartiles of the price model forecast distributions relative to December corn futures prices. Figures 2, 3, and 4 illustrate the average forecast error, root mean square forecast error, and percentage of correct forecasts of price direction, respectively, for corn futures price Models #1 through #4 relative to December futures for the 1994-1996 period. In comparing monthly average forecast error and forecast RMSEs, corn futures price predictions prove to be comparable to the four corn futures price models in terms of average forecast error. However, the forecast RMSEs of futures are

Table 5. Corn Futures and Futures Price Model Forecast Performance

Forecast Source	Category	Year	May	June	July	August	Sept.	Harvest October
			Year and Month of Price Forecast					
December Corn Futures Prices	Futures Prices	1994	$2.49	$2.67	$2.24	$2.22	$2.20	$2.1
		1995	2.67	2.87	2.92	2.80	3.06	3.3
		1996	3.59	3.50	3.57	3.46	3.19	2.7
	Forecast Error	94-96 Ave Error	0.16	0.26	0.16	0.07	0.06	
		1994-96 RMSE	0.63	0.57	0.52	0.50	0.28	
Corn Futures Price Model #1	Forecasts	1994	$2.11	$2.17	$2.10	$2.01	$2.07	$2.1
		1995	3.02	3.05	3.03	3.08	3.07	3.31
		1996	2.88	2.86	3.03	2.96	2.67	2.77
	Forecast Error	94-96 Ave Error	−0.08	−0.06	−0.03	−0.07	−0.15	
		1994-96 RMSE	0.18	0.16	0.23	0.20	0.16	
	% Correct Price Direction Vs Futures		100.00	100.00	100.00	100.00	100.00	All - 100%
Corn Futures Price Model #2	Forecasts	1994	$2.03	$2.02	$2.00	$1.95	$2.06	$2.18
		1995	2.64	2.80	2.86	2.83	3.15	3.31
		1996	2.58	2.94	2.73	2.78	2.92	2.77
	Forecast Error	94-96 Ave Error	−0.34	−0.17	−0.22	−0.23	−0.04	
		1994-96 RMSE	0.41	0.32	0.28	0.31	0.14	
	% Correct Price Direction Vs Futures		66.67	66.67	66.67	100.00	100.00	All - 80%
Corn Futures Price Model #3	Forecasts	1994	$1.87	$2.53	$1.92	$1.93	$1.91	$2.18
		1995	2.49	2.50	2.53	2.59	2.67	3.31
		1996	2.58	2.65	2.61	2.68	2.71	2.77
	Forecast Error	94-96 Ave Error	−0.44	−0.19	−0.40	−0.35	−0.32	
		1994-96 RMSE	0.52	0.51	0.48	0.44	0.40	
	% Correct Price Direction Vs Futures		66.67	66.67	66.67	66.67	66.67	All - 67%
Corn Futures Price Model #4	Forecasts	1994	$2.07	$2.05	$2.05	$2.04	$1.98	$2.18
		1995	2.48	2.51	2.52	2.74	2.59	3.31
		1996	2.50	2.76	2.57	2.66	2.58	2.77
	Forecast Error	94-96 Ave Error	−0.40	−0.31	−0.37	−0.27	−0.37	
		1994-96 RMSE	0.51	0.47	0.48	0.34	0.45	
	% Correct Price Direction Vs Futures		66.67	66.67	66.67	66.67	66.67	All - 67%

wider than the those of the four price models for May, June, July, and August forecasts. The forecast RMSE of futures for September forecasts is comparable to 2 of the 4 models, but notably larger than the other two models. Model #1 performed best relative to futures among the four models, followed by Model #2. In terms of futures price direction forecasts, Model #1 correctly predicted futures price direction 100% of the time, while Model #2 did so 80% of the time.

Corn Cash Price Model Forecast Performance

The forecast performance of the three U.S. corn cash price models described in Table 3 is presented in Table 6. Figure 5 graphically displays forecasts from corn cash price Model #1 during the 1994-1996 period in terms of the 25%, 50% (median), and 75% quartiles of the price model forecast distributions. December futures prices are included in Figure 5 only to illustrate

Table 6. Corn Cash Price Model Forecast Performance

Forecast Source	Category	Year	Year and Month of Price Forecast					Mktg. Year Cash Price*
			May	June	July	August	Sept.	
Corn Average Cash Price Model #1	Forecasts	1994	$2.44	$2.54	$2.40	$2.38	$2.39	$2.26
		1995	2.90	2.89	2.93	2.93	2.94	3.24
		1996	2.64	2.65	2.66	2.69	2.64	2.70
	Forecast Error	94-96 Ave Error	−0.07	−0.04	−0.07	−0.07	−0.08	
		1994-96 RMSE	0.22	0.26	0.20	0.19	0.19	
Corn Average Cash Price Model #2	Forecasts	1994	$2.39	$2.54	$2.36	$2.34	$2.36	$2.26
		1995	2.88	2.89	2.93	2.93	2.94	3.24
		1996	2.54	2.56	2.56	2.58	2.52	2.70
	Forecast Error	94-96 Ave Error	−0.13	−0.07	−0.12	−0.12	−0.13	
		1994-96 RMSE	0.24	0.27	0.20	0.20	0.21	
Corn Average Cash Price Model #3	Forecasts	1994	$2.45	$2.46	$2.09	$2.30	$2.35	$2.26
		1995	2.64	2.64	2.67	2.67	2.64	3.24
		1996	3.04	3.07	3.06	3.13	3.06	2.70
	Forecast Error	94-96 Ave Error	−0.02	−0.01	−0.13	−0.03	−0.05	
		1994-96 RMSE	0.41	0.42	0.40	0.41	0.41	

* Marketing Year Cash Prices represent the latest available cash price estimates for the respective Marketing Years

relative price movements, not for measurement of forecast accuracy. Figures 6, 7, and 8 illustrate the average forecast error, root mean square forecast error, and percentage of correct forecasts of price direction, respectively, for corn cash price Models #1 through #3 for the 1994-1996 period. An examination of the average forecast error and RMSEs, the corn cash price models shows that they performed fairly well. This was especially true for Model #1 which had the smallest average forecast error each month among the models and comparable forecast RMSEs. The performance of Model #2 was quite similar to Model #1, with only a moderately larger average forecast error. The only difference between Models #1 and #2 is the exclusion of a lagged average corn price variable in #2. The average error of Model #3 was, in most cases, the smallest among the three models. However, the monthly forecast RMSEs for #3 was notably wider than for #1 and #2.

Wheat Futures and Futures Price Model Forecast Performance

The forecast performance of the four U.S. wheat HRW futures price models described in Table 4 is presented in Table 7. The forecast performance of wheat futures price Model #1 during the 1994-1996 period is shown in terms of the 25%, 50% (median), and 75% quartiles of the price model forecast distributions relative to September KC wheat futures prices in Figure 8. Figures 9, 10, and 11 illustrate the average forecast error, root mean square forecast error, and percentage of correct forecasts of price direction, respectively, for wheat futures price Models #1 through #4 relative to September KC wheat futures for the 1994-1996 period. In comparing average forecast error and forecast RMSEs for 1994-1996, wheat futures contracts had comparable average forecast accuracy to the most accurate of the four wheat futures price models

Table 7. Wheat Futures and Futures Price Model Forecast Performance

Forecast Source	Category	Year	May	June	July	August
			Year and Month of Price Forecast			
September KC Wheat Futures Prices	Futures Prices	1994	$3.28	$3.47	$3.33	$3.64
		1995	3.71	3.99	4.71	4.57
		1996	6.39	5.67	5.15	4.75
	Forecast Error	94-96 Ave Error	0.14	0.06	0.08	
		1994-96 RMSE	1.09	0.64	0.30	
Wheat Futures Price Model #1	Forecasts	1994	$3.19	$3.24	$3.18	$3.64
		1995	3.47	3.54	3.50	4.57
		1996	3.42	3.35	3.15	4.75
	Forecast Error	94-96 Ave Error	–0.96	–0.94	–1.04	
		1994-96 RMSE	1.03	1.03	1.14	
	% Correct Price Direction Vs Futures		33.33	33.33	66.67	All - 44%
Wheat Futures Price Model #2	Forecasts	1994	$4.09	$4.10	$4.01	$3.64
		1995	4.86	4.71	4.71	4.57
		1996	5.02	5.24	5.15	4.75
	Forecast Error	94-96 Ave Error	0.34	0.36	0.30	
		1994-96 RMSE	0.35	0.40	0.32	
	% Correct Price Direction Vs Futures		100.00	100.00	33.33	All - 78%
Wheat Futures Price Model #3	Forecasts	1994	$4.15	$4.14	$4.08	$3.64
		1995	4.17	4.25	4.24	4.57
		1996	4.03	4.00	3.74	4.75
	Forecast Error	94-96 Ave Error	–0.20	–0.19	–0.30	
		1994-96 RMSE	0.56	0.55	0.66	
	% Correct Price Direction Vs Futures		100.00	100.00	100.00	All - 100%
Wheat Futures Price Model #4	Forecasts	1994	$3.81	$3.89	$3.86	$3.64
		1995	4.59	4.57	4.59	4.57
		1996	5.00	5.06	5.09	4.75
	Forecast Error	94-96 Ave Error	0.15	0.19	0.19	
		1994-96 RMSE	0.17	0.23	0.23	
	% Correct Price Direction Vs Futures		100.00	100.00	100.00	All - 100%

listed. However, the monthly forecast RMSE of the futures forecasts were wider than for t price models for the May forecasts, wider than 3 or 4 models for June forecasts, but essenti equal to or smaller than 2 of the price 4 models for the July forecasts. Wheat futures price #4 forecasts performed best relative to futures among the four models, with a comparable average forecast error, and much smaller monthly forecast RMSEs than futures. Model #2 performed moderately well, with larger forecast errors than either futures or Model #4, but smaller forecast RMSEs for May and June (and essentially equal RMSE for July forecasts). terms of correctly forecasting futures price direction, Models #4 and #3 correctly predicted futures price direction 100% of the time, while Model #2 did so 78% of the time during 199

Summary and Conclusions

These preliminary results indicate that the price models and the forecasting procedure presented in this paper offer potential benefits to grain price forecasting practitioners. They also provide support for the practice of taking a theoretically and econometrically sound approach to price model development and forecasting. During the 1994-1996 period, forecast errors of the best performing of these forecasting models were equal to or better than comparable futures contracts. Also, the forecast root mean square errors of the model-based price forecasts were notably smaller than those of futures prices in most cases. Finally, some these models performed well during 19994-96 period as predictors of the correct direction in which futures prices would eventually move as harvest approached. The corn average cash price model forecasts were also reasonably accurate.

Attention to a number of factors is critical to the development of price models and in their use for forecasting purposes. First, focusing on the theoretical basis of such models guides their development and reduces the temptation to inappropriately "mine" data to find reasonably appearing price factor relationships. Second, attention to the statistical properties of the models and underlying data increases the likelihood that models are econometrically sound and that they will provide accurate forecasts. Third, composite forecasts of prices and price direction using a number of models together seems more prudent than reliance on forecasts from any one model alone. Fourth, almost intimate familiarity with the design and properties of the models and the explanatory data, and with each model's past forecasting performance is necessary to avoid their misapplication. Knowledge of how different model's forecasts have performed well or poorly under alternative market scenarios is a necessity. It would be better to not use these price forecasting models at all than to naively use one or a number of them for forecasting without understanding their theoretical foundations, econometric properties, or past performance under alternative market conditions. Fifth, presenting model based price projections in the form of probability distributions rather than point estimates potentially improves the informative value of the forecasts by quantifying the degree of forecast confidence and accuracy.

These model-based price predictions may be of most use to practitioners as a resource in the development of their market outlook and analysis. They can directly apply information regarding how past supply, demand, or input price changes have historically affected prices in their analysis of the expected price impact of possible market scenarios. These model based forecasts are also of value to those attempting to develop grain price risk management strategies using forward contracts, futures hedges, put option-based price floors, and call option-based price ceilings. Specifically, such information can be be of aid in assessment of probable costs and benefits of alternative marketing strategies. Future efforts should focus on model development and updates along with reassessment of each model's econometric properties and forecast performance. It is a goal of the authors to make these preharvest price forecasts available during the May-September 1997 period to University Extension grain market analysts. It is hoped that this information may be of use to them in analyzing price prospects and in developing marketing risk management strategies for farm and agribusiness decision makers.

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Figure 1. Harvest Corn Price Model #1 Forecasts vs Dec Futures Comparing Preharvest Forecasts for 1994-1996

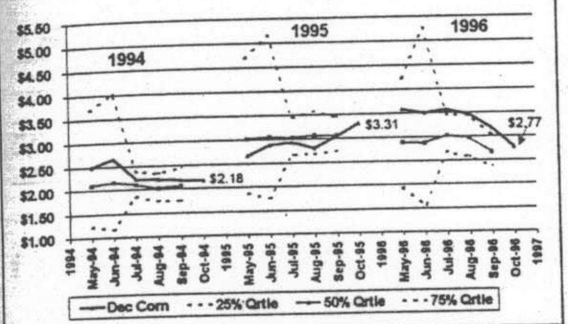


Figure 2. Corn Futures and Price Models: 1994-96 Average Forecast Errors

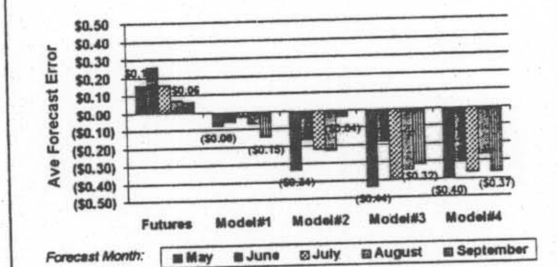


Figure 3. Corn Futures and Price Models: 1994-96 Forecast Root Mean Square Errors

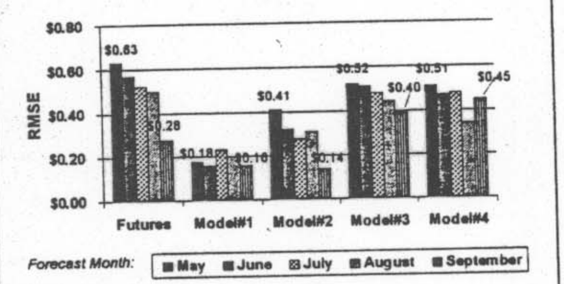


Figure 4. Corn Futures Price Models: 1994-96 Price Direction Forecasts

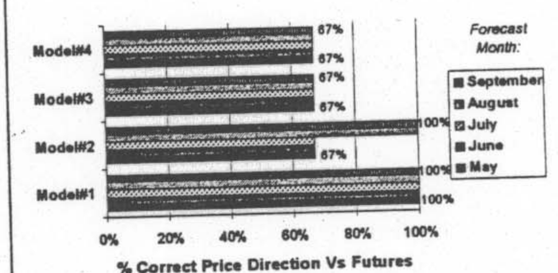


Figure 5. Annual Corn Price Model #1 Forecasts vs Dec Futures Comparing Preharvest Forecasts for 1994-1996

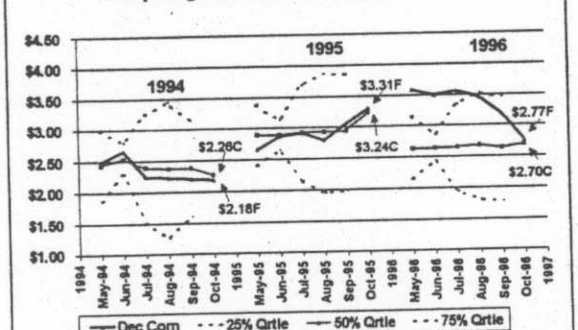
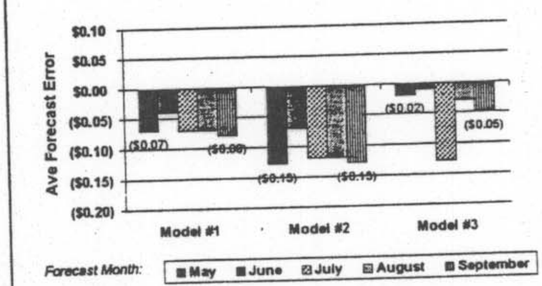


Figure 6. Corn Average Cash Price Models: 1994-96 Average Forecast Errors



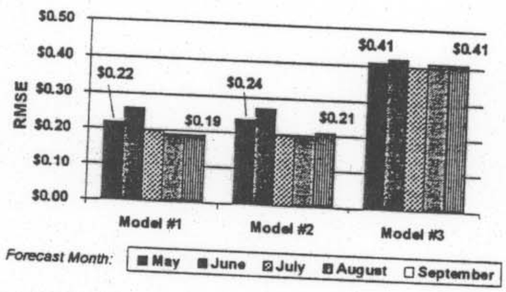


Figure 7. Corn Average Cash Price Models: 1994-96 Forecast Root Mean Square Errors

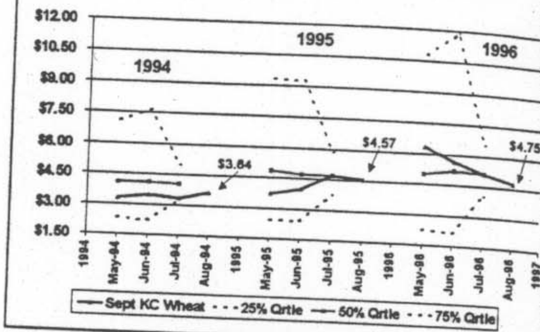


Figure 8. August Wheat Model #2 Forecasts vs Sept KC Futures Comparing Preharvest Forecasts for 1994-1996

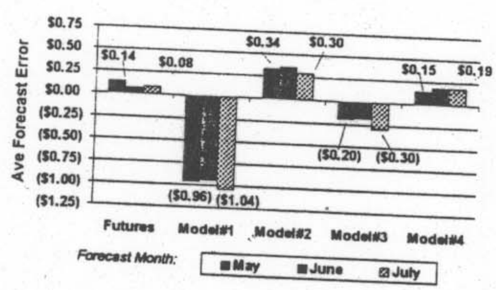


Figure 9. Wheat Futures and Price Models: 1994-96 Average Forecast Errors

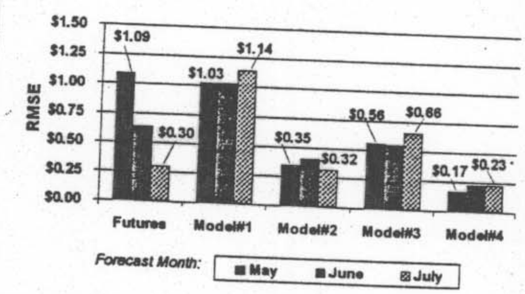


Figure 10. Wheat Futures and Price Models: 1994-96 Forecast Root Mean Square Errors

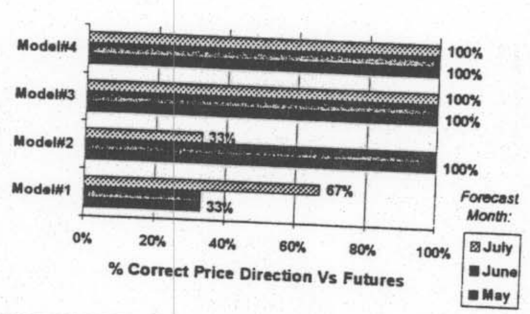


Figure 11. Wheat Futures Price Models: 1994-96 Price Direction Forecasts