Empirical Confidence Intervals for WASDE Forecasts of Corn, Soybean and Wheat Prices.

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Practitioner's Abstract

This study suggests that confidence intervals for WASDE forecasts of corn, soybean, and wheat prices may be improved if they are estimated using an empirical approach. Empirical confidence intervals are calculated following Williams and Goodman's (1971) method and use historical forecast errors to estimate forecast error distributions which is then used to predict confidence limits for future forecast errors. Three procedures for empirical distribution estimation are compared: 1) histogram, 2) changing distribution, 3) fixed distribution. The results suggest that the fixed distribution approach using logistic distribution provided accurate confidence intervals for WASDE corn, soybean, and wheat price forecasts.

Key Words: Confidence intervals, corn, empirical methods, forecasting, interval forecasts, prediction intervals, soybeans**,** wheat

Introduction

Agricultural markets are inherently unstable, primarily due to a combination of inelastic demand for food and production technology that is subject to the natural vagaries of weather, disease and pests. Price volatility causes many agricultural firms to rely on forecasts in decision-making. Consequently, the U.S. Department of Agriculture (USDA) devotes substantial resources to agricultural situation and outlook programs (Offutt, 2002). It is a commonly held belief of market participants and analysts that these forecasts function as the "benchmark" to which other private and public estimates are compared (e.g., Irwin, Gerlow, and Liu, 1994; Kastens, Schroeder and Plain, 1998).

A prominent example of USDA forecasting efforts is the WASDE (World Agricultural Supply and Demand Estimates) program, which provides monthly forecasts for major crops, both for the U.S. and the world. WASDE price forecasts (unlike all other WASDE estimates) are published in the form of an interval. Interval forecasts, in contrast to point estimates, represent a range of values in which the realized value of the series is expected to fall with some pre-specified probability (Diebold, 1998, p. 41). WASDE price forecasts are generated using a balance sheet approach, with published intervals reflecting uncertainty associated with prices in the future (Vogel and Bange, 1999). For example, the October 2004 WASDE forecast of the 2004/05 marketing year average farm price was $1.75-$2.15/bushel for corn, $4.70-$5.50/bushel for soybeans and $3.10-$3.50/bushel for wheat. Vogel and Bange (1999) note that, "The process of forecasting price and balance sheet items is a complex one involving the interaction of expert judgment, commodity models, and in-depth research by Department analysts on key domestic and international issues" (p. 10). Thus, these forecasts cannot be described by a formal statistical model.

The need for probability and interval forecasting has been repeatedly expressed in the agricultural economics literature (e.g., Teigen and Bell, 1978; Timm, 1966; Bessler and Kling, 1989; Bessler, 1989). However, application and analysis of interval and probability forecasts has received relatively little attention. Sanders and Manfredo (2003) examined one-quarter ahead WASDE interval forecasts of livestock prices from 1982 to 2002. They find that actual market prices fall in the forecasted ranges a relatively small proportion of the time, about 48 % of the time for broilers and only 35% of the time for hogs. Isengildina, Irwin, and Good (2004) showed that monthly WASDE interval forecasts of corn and soybean prices during the 1980/81 through 2001/02 marketing years also had relatively low hit rates (the proportion of time the interval contains the subsequent actual price) ranging from 36 to 82% for corn and from 59 to 89% for soybeans depending on the forecast month. In addition, actual prices were more likely to be above the forecast intervals, suggesting that observed symmetric USDA forecast intervals did not reflect the true asymmetry in the distribution of underlying prices.

Given the importance of WASDE price forecasts and low accuracy of forecast intervals demonstrated in previous studies, the approach used to estimate the intervals should be revised and improved. Numerous procedures have been proposed for calculation of confidence intervals for forecasts generated by statistical models (e.g., Chatfield, 1993, Prescott and Stengos, 1987; Bessler and Kling, 1989). These statistical procedures provide little guidance for forecasts based on a combination or a consensus process rather than formal models, as is the case with WASDE forecasts. However, confidence intervals for WASDE price forecasts may be estimated by using an empirical approach to their estimation. This approach was first introduced by Williams and Goodman (1971) and is based on the notion that by accumulating forecast errors through time one can obtain an empirical distribution of forecast errors. If the key assumption of this method is satisfied and future forecast errors belong to approximately the same distribution as past forecast errors, confidence limits for future forecasts can be determined by using the percentage points of the empirical distribution generated from past errors. The benefit of this method is that it can be applied in a straightforward manner to any type of error distribution, including fat-tailed and/or asymmetric distributions.

The purpose of this paper is to apply and compare three procedures for calculating empirical confidence intervals for WASDE forecasts of corn, soybean, and wheat prices during the period from 1980/81 to 2004/05. These procedures include estimation of forecast error distributions using histograms, changing distributions, and a fixed distribution. The procedures are compared based on out-of-sample performance, where the first 15 observations (1980/81-1994/95) are used to generate confidence limits for the 16th year (1995/96); the first 16 observations are used to generate confidence limits for the 17th year (1996/97) and so on. The accuracy of the out-of-sample intervals generated using the three procedures will be compared to each other and to actual intervals in terms of hit rates. Statistical significance of the differences of hit rates from a 90% confidence level will be assessed using an unconditional coverage test developed by Christoffersen (1998). The results of this research will provide valuable information that can be used to more accurately estimate confidence intervals for WASDE price forecasts.

Data

This study examines corn, soybean, and wheat interval price forecasts from USDA WASDE reports over the 1980/81 through 2004/05 marketing years. These forecasts are part of reports released monthly by the USDA, usually between the 9th and 12th of the month. The first price forecast for a marketing year is released in May preceding the U.S. marketing year (September through August). Estimates are typically finalized by September (for wheat) or November (for corn and soybeans) of the following marketing year. Thus, 19 forecast updates of corn and soybean prices and 17 forecast updates of wheat prices are generated in the WASDE forecasting cycle each marketing year. While the forecasts are published in the form of an interval, the probability with which the realized price is expected to fall within the forecast interval is not specified.

Descriptive statistics for WASDE interval price forecasts for corn, soybeans, and wheat over 1980/81-2004/05 are presented in Tables 1-3.[1] During the study period, the first (May prior to harvest) forecast intervals averaged $0.39/bushel for corn, $1.33/bushel for soybeans, and $0.46/bushel for wheat. In relative terms, the May forecast intervals for wheat were the most narrow representing about 14% of the average forecasted price,[2] compared to 17% for corn and 22% for soybeans. By November after harvest these average intervals narrowed to $0.36/bushel for corn, $0.90/bushel for soybeans, and $0.24/bu for wheat. The relative magnitude of post-harvest wheat forecast intervals was about half the size of corn and soybean price intervals, with a November average of $0.07/bushel and $0.15/bushel, respectively. These forecast intervals were usually collapsed to point estimates in May after harvest for wheat and soybeans and in August after harvest for corn. No trends in the magnitude of forecast intervals over time were detected. Thus, intervals in the same months did not become smaller (or larger) from the beginning to the end of the study period.

Interval forecast accuracy is typically described in terms of the hit rate, the proportion of time the forecast interval included the final value. Tables 1-3 demonstrate that hit rates for individual months ranged from 32 to 84 percent for corn, 28 to 84 percent for soybeans, and 36 to 88 percent for wheat. Prior to harvest, hit rates for corn price forecast intervals were the lowest, averaging 47 percent, compared to 61 and 69 percent for wheat and soybeans, respectively. This implies that, on average, corn price interval forecasts prior to harvest contained the final price estimate only 47 percent of the time. After harvest, the hit rates for all commodities increased, averaging 70 percent for corn, 66 percent for soybeans, and 67 percent for wheat price interval forecasts. All three commodities demonstrated some very low hit rates late in the forecasting cycle. For example, hit rates for corn price interval forecasts averaged 48 and 52 percent in August and September after harvest; soybean hit rates averaged 28, 44, and 52 percent from May through July after harvest, and wheat hit rates averaged 40 and 36 percent in May and June after harvest. This loss in accuracy late in the forecasting cycle is associated with prematurely collapsing intervals to point estimates.

Another issue is whether forecast intervals accurately reflect the shape of the underlying price distribution. Statistics on the proportion of misses above and below the forecast interval reported in Tables 1-3 provide insight on this issue. If the forecast intervals accurately reflected the shape of the underlying price distribution, one would expect equal probability of misses above and below the forecast interval. Table 2 demonstrates that for soybean price forecast intervals the proportion of misses above the interval was 2 times greater than the proportion of misses below the interval prior to harvest, and 2.8 times greater after harvest. Furthermore, the magnitude of misses in soybean forecast intervals tends to be much greater on the upside then the downside, averaging $0.77/bushel and $0.28/bushel, respectively, prior to harvest and

$0.15/bushel and $0.09/bushel, respectively, after harvest. The other two commodities do not exhibit such persistent tendencies.

The evidence presented in this section describes several major concerns regarding WASDE forecast intervals of corn, soybeans, and wheat prices: 1) these forecast intervals are characterized by relatively low hit rates; 2) in soybeans, the forecast intervals do not accurately reflect the shape of the underlying price distribution; and 3) confidence levels associated with these forecast intervals are not specified. The remainder of the paper discusses, applies and compares three ways of deriving empirical confidence intervals that may be used to improve WASDE price forecast intervals.

Empirical Confidence Intervals

Construction of empirical confidence limits for economic forecasts was first suggested by Williams and Goodman (1971). This approach consists of splitting the data in two parts and fitting the method or model to the first part in order to find forecast errors. The model is then refitted each year adding an additional observation in the first part and increasing the part of the sample used to estimate forecast errors. The key assumption of this method is that future forecast errors belong to approximately the same distribution as past forecast errors.[3] Williams and Goodman (1971) argue that this assumption is less restrictive than the standard assumption that the forecasting model describes the series adequately in the future. Therefore, by accumulating forecast errors through time one can obtain an empirical distribution of forecast errors and determine confidence limits for future forecasts by using the percentage points of the empirical distribution generated from past errors. The benefit of this method is that it can be applied in a straight forward manner to any type of error distribution, including fat-tailed and/or asymmetric distributions. This method is also particularly useful when the forecasting model is not fully identified and based on consensus or a combination of several sources, which makes the standard model-based methods for confidence limit calculation difficult to apply. According to Chatfield (1993), this method "…is attractive in principle, however, it seems to have been little used in practice, presumably because of the heavy computational demands." Chatfield (1993) also remarks that since computational demands have become much less of a burden, this method should "…be reexamined."

Another empirical approach was proposed by Gardner (1988), who applied the chosen forecasting model to all of the past data, finding within-sample forecast errors at 1, 2, 3, …-steps-ahead from all available time origins, and then finding the variances of these errors at each lead time. The model is not re-estimated each time, and the variances at different lead times are based on within-sample fitted errors, rather than post-sample forecast errors. Gardner (1988) argues that the advantage of this method of computing variances is that the validity of the model and the form of the generating function are irrelevant. Confidence intervals can then be based on the standard deviation of the k-steps-ahead errors and an assumption of normality.

A drawback of empirical methods is the requirement of enough historical data in order to estimate forecast error distributions. Taylor and Bunn (1999) argue that "…the number of forecast errors needed depends on the accuracy required, but it is probably fair to say that empirical methods need at least fifty observations to produce reasonable results." It has been shown that variance estimates using Gardner's approach are unreliable for small sample sizes and are based on model-fitting errors rather than true post-sample forecast errors (e.g., Bowerman and Koehler, 1989). At the same time William and Goodman (1971) demonstrate that empirical confidence intervals using 24 observations were satisfactory at the 80 percent level, but 90% and 95% levels improved when more observations were included.

In this study we apply several procedures based on William and Goodman's approach to derive empirical confidence intervals for WASDE corn, soybean, and wheat price forecasts because this approach does not assume normality of forecast error distributions. While the small sample properties of William and Goodman's approach have not been studied, this approach is not as likely to suffer from model-fitting errors.

Empirical analysis

A critical assumption of all empirical approaches to deriving confidence intervals is that the distribution of forecast errors remains stable over time. Several previous studies (e.g., Smith and Sincich, 1988; Stoto, 1983) have evaluated this assumption and found that the distribution of population forecast errors remained relatively stable over time and data on past forecast errors provided very useful predictions of future forecast errors. Within the present study we test the validity of this assumption by dividing the sample in two parts, from 1980/81 through 1994/95 and from 1995/96 through 2004/05 and examining whether the first two moments of forecast error distribution differed between two sub-periods. Forecast errors were calculated as the difference between the final (November for corn and soybeans and September for wheat) estimate and the midpoint of the forecast interval. Independent sample t-tests showed no statistically significant difference at the 5% level in mean forecast errors for each forecasting month between the two sub-periods. Levene's F-statistic showed no statistically significant difference at the 5% level in forecast error variances for each forecasting month between the two sub-periods.[4] Therefore, forecast error distributions of monthly WASDE corn, soybean, and wheat price forecasts appear stable over time.

Williams and Goodman's (1971) approach to calculating confidence intervals consists of splitting the data in two parts and fitting the method or model to the first part in order to find the forecast error distribution which is then used to provide confidence limits for the forecast intervals in the second part of the sample. In this study we also divide the sample in two parts, from 1980/81 through 1994/95 and from 1995/96 through 2004/05. Such split provides us with a minimum of 15 years of data to estimate forecast error distributions and 10 years of out-of-sample data to evaluate the performance of the proposed approaches. It is important to keep in mind that the objective of this study is limited to examining empirical approaches to calculating confidence intervals for WASDE forecasts of corn, soybeans, and wheat prices. We do not analyze the validity of the forecasting method currently used by the USDA, but rather try to suggest the procedure that will provide correct confidence intervals for these forecasts. Therefore, rather than fitting a forecasting model to the first part of the sample (as was done by Williams and Goodman, 1971), we rely on the forecasting method that has been used by the USDA and employ actual forecast errors from the first part of the sample to estimate forecast error distributions. In this study we calculate empirical limits for a 90% confidence level (a conventional confidence level for published forecast intervals), however, the procedure will be the same for any other selected confidence level.

The simplest procedure for estimation of forecast error distributions is via histograms. Figure 1 gives an example of such histograms for November soybean price forecasts based on the first 15 and the first 24 observations. These histograms demonstrate that the distribution of soybean price forecast errors remained stable over time with relatively unchanged extreme values. The 90% confidence intervals based on the histograms for this sample are constructed by dropping the largest positive and the largest negative error. Thus, the second largest positive and negative error is added to the midpoint of the next published forecast to construct a prediction interval. This procedure provides prediction intervals that are based on 13 out of 15 observations (87% confidence level) for the first prediction (16th observation) of the second part of the sample (1995/96 - 2004/05). The histograms are then refitted by adding an additional observation each year in the first part with the prediction interval for the last forecast (25th observation) being based on 22 out of 24 observations (92% confidence level). While this non-parametric procedure is straightforward, several drawbacks should be pointed out: 1) the discrete nature of the histograms limits the flexibility of selecting a specific confidence level (a 90% confidence interval based on a histogram with 15 observations has to be approximated using 13 out of 15 observations, an 87% confidence level); 2) this procedure concentrates on the tails of the distribution (its extreme values in this case), without taking into account the complete shape of the probability distribution.

The limitations of the non-parametric histogram-based procedure can be overcome by fitting a parametric probability distribution to forecast errors from the first part of the sample. This can be done easily using the @Risk for Excel analysis tool. This software fits 10 common distributions to the selected data set and ranks them using a chi-square test. Figure 2 presents the best fitting (according to chi-square value) probability distributions for November soybean price forecasts based on the first 15 and the first 24 observations. The prediction intervals can be calculated by adding the 90% confidence limits from the best fitting distribution to the midpoint of the next published forecast. Similar to the procedure used for construction of histogram-based confidence intervals, the distributions will be refitted each year by adding an additional observation. This procedure allows for precise confidence levels and takes into account the complete shape of the probability distribution. These features are observable in figure 2, where the distribution, which includes 24 observations (bottom panel) places less weight on the extreme values and provides a 90% confidence interval that is narrower than the one derived from a distribution based on 15 observations (top panel). The drawback of this procedure is that a different best-fitting distribution may be chosen from one year to the next as more observations are added.

Allowing distributions to vary over time can be viewed as a violation of the underlying assumption of the empirical approach that future forecast errors belong to approximately the same distribution as past forecast errors. To avoid this shortcoming the probability distribution that is most often ranked as the best fitting distribution is selected. For example, Williams and Goodman (1971) report that forecast errors from their data set approximately followed a gamma distribution. We found that the forecast errors from the data set used in this study most often followed a logistic distribution. Therefore, confidence intervals calculated by adding 90%

confidence limits from a logistic distribution to the midpoint of the next published forecast were constructed as an alternative to the previous approach.

The next step of the empirical analysis is to compare the performance of the empirical confidence intervals derived using the three procedures described above. Accuracy of forecast intervals is traditionally examined in terms of hit rates and forecast coverage. Hit rates describe the proportion of times forecast intervals contain the final or "true" value (y_t) and may be defined as the expectation of an indicator variable, I_t^k :

$$I_t^k = \begin{cases} 1, & \text{if } \quad y_t \in \left[l_{t/k}(\alpha), u_{t/k}(\alpha) \right] \\ 0, & \text{if } \quad y_t \notin \left[l_{t/k}(\alpha), u_{t/k}(\alpha) \right] \end{cases} \tag{1}$$

where $\left[l_{t/k}(\alpha), u_{t/k}(\alpha) \right]$ are the lower and upper limits of the interval forecast for y_t made at time k with coverage probability α. Forecast coverage examines whether the proportion of times the forecast interval includes the true value corresponds to a stated confidence level, or, in other words, if the interval hit rate is equal to the coverage probability. Thus, forecast coverage may be examined by testing the hypothesis H_0: $E(I_t^k)=\alpha$ against H_1: $E(I_t^k)\neq\alpha$. If H_0 is not rejected and the interval hit rate is equal to the coverage probability, forecasts are said to be calibrated. The likelihood function for the indicator variable I_t^k, which has a binomial distribution, is (Christoffersen, 1998)

$$L(\alpha) = (1-\alpha)^{n_0} \alpha^{n_1} \tag{2}$$

under the null hypothesis and

$$L(p) = (1-p)^{n_0} p^{n_1} \tag{3}$$

under the alternative hypothesis, where n_1 and n_0 are the number of times an interval was "hit" (1) or "missed" (0) in the indicator sequence I_t^k, and L is a likelihood function. Then, forecast coverage may be tested via the likelihood ratio test,

$$LR_c = -2\ln\left(\frac{L(\alpha)}{L(\hat{p})}\right) \xrightarrow{asy} \chi^2(1) \tag{4}$$

where $\hat{p} = n_1/(n_0+n_1)$ is the maximum likelihood estimator of p. This test is described by Christoffersen (1998) as an unconditional coverage test.[5] The remainder of the paper discusses the characteristics of empirical confidence intervals generated using the histogram-based method, the changing distribution-based method and the fixed distribution-based method and compares their performance using accuracy tests described in this section.

Results

Tables 4-6 compare descriptive statistics for empirical confidence intervals calculated using the three methods described above and published WASDE forecast intervals of corn, soybean, and wheat prices over 1995/96 through 2004/05. Because of the generally low hit rates of the published forecasts shown in Tables 1-3, it was expected that the empirical prediction intervals calibrated at the 90% confidence level would be wider than published intervals. Table 4 demonstrates that prior to harvest, histogram-based intervals were about 2 times wider and distribution-based intervals were about 2.5 times wider on average than published forecast intervals of corn prices.[6] After harvest, the difference was not as dramatic with histogram-based intervals about 30% wider, and distribution-based intervals 60% wider on average than published intervals. A similar pattern is observed for soybean price forecast intervals in Table 5 with histogram-based intervals about 2 times wider and distribution-based intervals about 2.3 times wider on average than published forecast intervals prior to harvest. After harvest, histogram-based intervals of soybean price forecasts were about 50% wider and distribution-based intervals were 72-80% wider on average than published intervals. The difference between the published and empirical forecast intervals prior to harvest was the smallest for wheat with histogram-based intervals about 70% wider and distribution-based intervals 90% wider on average than published intervals, as shown in Table 6. However, after harvest, the difference between the published and empirical forecast intervals of wheat prices was the largest among commodities considered in this study with histogram-based intervals about 58% wider and distribution-based intervals 83% wider on average than published intervals.

Another issue with the WASDE price forecasts was whether the symmetric forecast intervals accurately reflect the distributions of the underlying commodity prices. Because empirical confidence intervals are calculated using actual forecast errors, they take into account the asymmetries of error distributions. These asymmetries are reflected in the average interval magnitudes below and above the mean for empirical confidence intervals reported in Tables 4-6.[7] Based on these statistics it is hard to judge if there were any consistent asymmetries in these error distributions. Average interval magnitude above the mean is greater than average magnitude below the mean prior to harvest in changing distribution-based intervals for all three commodities. But this difference becomes very small or disappears in histogram-based intervals and logistic distribution-based intervals (except histogram-based intervals for wheat price forecasts). After harvest, the downside price risk (average magnitude below relative to magnitude above the mean) is greater for corn price forecasts according to distribution-based intervals; the upside price risk is greater for soybean price forecasts according to histogram- and changing distribution-based intervals, and relatively symmetric for wheat price forecasts. Thus, while there is some evidence of greater upside price risk for soybeans, the evidence is inconsistent for other commodities.

Tables 7-9 present results of the accuracy tests of published WASDE forecast intervals and empirical confidence intervals for corn, soybean, and wheat prices over 1995/96 through 2004/05. As was observed in Tables 1-3 for the whole sample, published forecasts had relatively low hit rates in the prediction part of the sample, 1995/96 through 2004/05, although significant improvement in forecast accuracy was observed in corn price forecast intervals after harvest. Tables 7-9 allow comparison of the three methods of empirical confidence interval estimation based on their accuracy. Confidence levels of histogram-based intervals ranged from 87% to 92% depending on the number of observations included in histograms, while the confidence level of distribution-based forecasts was set at 90%. Table 7 reveals that histogram-based intervals for corn price forecasts under-performed the distribution-based intervals with average hit rates of 82% and 88%, respectively, prior to harvest and 88% and 93%, respectively, after harvest. According to Table 8, all three methods performed equally well both before and after harvest in soybeans with hit rates averaging 87% before harvest and 80% after harvest. Table 9 shows that in wheat, while all three methods performed equally well before harvest (80%

average hit rates), after harvest, distribution-based intervals outperformed histogram-based intervals (91% and 81% hit rates, respectively).

Coverage tests revealed that confidence levels of published forecast intervals of corn prices were significantly different from 90% in 5 out of 6 cases prior to harvest and 2 out of 11 cases after harvest. In soybeans, confidence levels of published forecast intervals were significantly different from 90% in 2 out of 6 cases prior to harvest and 5 out of 11 cases after harvest. Confidence level of published forecast intervals of wheat prices was significantly different from 90% in 2 out of 6 cases prior to harvest and 2 out of 8 cases after harvest. Coverage tests failed to reject the null hypothesis of the confidence level of the empirical forecast intervals being equal to 90% in all cases except May wheat histogram-based and changing distribution-based intervals and April soybean changing distribution-based intervals. The low hit rates of May wheat prediction intervals may be explained by several small misses ($0.01 outside the prediction interval), while the low accuracy of April soybean prediction interval is likely the result of over-fitting as the shapes of the fitted distributions were allowed to change from one year to the next.

Based on the results presented in this section, it appears that the fixed distribution-based approach was the most successful in estimating empirical confidence intervals for WASDE corn, soybean and wheat price forecasts. This approach generated empirical confidence intervals based on assuming that forecast errors approximately followed a logistic distribution. Logistic distribution-based intervals were about 2.5 times wider prior to harvest and 69% wider after harvest than published intervals in corn, 2.3 times wider prior to harvest and 72% wider after harvest than published intervals in soybeans and 90% wider prior to harvest and 83% wider after harvest than published intervals in wheat. Hit rates of logistic distribution-based intervals ranged from 70% to 100% and were not statistically different from the 90% level in all cases.

Summary and Conclusions

WASDE price forecasts (unlike all other WASDE estimates) are published in the form of an interval to reflect uncertainty associated with prices in the future. Several major concerns regarding WASDE forecast intervals of corn, soybeans, and wheat prices include: 1) these forecast intervals have relatively low hit rates; 2) in soybeans, the forecast intervals do not accurately reflect the shape of the underlying price distribution; and 3) confidence levels associated with these forecast intervals are not specified.

This study applies and compares three procedures for calculating empirical confidence intervals for WASDE forecasts of corn, soybean, and wheat prices. The basic approach was first introduced by Williams and Goodman (1971), and is based on the notion that by accumulating forecast errors through time one can obtain an empirical distribution of forecast errors. If the key assumption of this method is satisfied and future forecast errors belong to approximately the same distribution as past forecast errors, confidence limits for future forecasts can be determined by using the percentage points of the empirical distribution generated from past errors.

Based on the results of independent sample *t*-tests and Levene's F-tests, forecast error distributions of monthly WASDE corn, soybean and wheat forecasts appear stable over time.

Three procedures were used to estimate forecast error distributions, including histograms, changing distributions, and a fixed distribution. The procedures are compared based on out-of-sample performance, where the first 15 observations (1980/81-1994/95) are used to generate confidence limits for the 16th year (1995/96); the first 16 observations are used to generate confidence limits for the 17th year (1996/97) and so on.

Based on the results of the accuracy tests of the empirical 90% confidence intervals for WASDE corn, soybean and wheat price forecasts over 1995/96 through 2004/05, the fixed distribution-based approach was the most successful in estimating forecast error distributions. This approach generated empirical confidence intervals based on assumption that forecast errors approximately followed a logistic distribution. Logistic distribution-based intervals were about 2.5 times wider prior to harvest and 69% wider after harvest than published intervals in corn, 2.3 times wider prior to harvest and 72% wider after harvest than published intervals in soybeans and 90% wider prior to harvest and 83% wider after harvest than published intervals in wheat. Hit rates of logistic distribution-based intervals ranged from 70% to 100% and were not statistically different from 90% level in all cases.

The results of this study can be used by WASDE forecast providers to estimate the confidence intervals for corn, soybean, and wheat price forecasts. The distributions of errors of these forecasts appear stable over time. Therefore, confidence limits for the future forecasts can be calculated based on percentage points of logistic distribution of past forecast errors. The use of an empirical approach to confidence interval calculation provides accurate intervals that reflect the properties of the underlying price distributions. While this study reports the results for 90% confidence level, other confidence level may be selected by USDA analysts in order to improve informativeness of these forecasts. However, it is important that the confidence level associated with these forecasts is stated in published reports. Thus, the resulting forecasts might be published in the following format:

Avg. farm price ($/bu)	expected value of the forecast
90% conf. interval	empirical confidence interval

While this format will add an extra line to the existing WASDE reports, it will provide complete information about these forecasts and significantly aid in their interpretation and use.

Finally, a caveat of this study should be mentioned. The empirical confidence intervals presented in this study are based on relatively few observations. Even though the accuracy of the confidence intervals generated using logistic-distribution of past errors was not significantly different from 90%, the hit rates ranged from 70% to 100%, suggesting that there is still room for improvement. Quantile regression procedures may improve accuracy of forecast error distribution estimation by pooling the data across months and across marketing years (Taylor and Bunn, 1999). This approach relaxes the assumption that error distributions for each forecasting month are independent as forecast errors tend to decline from the beginning to the end of the forecasting cycle as more information becomes available. While this approach has a potential to improve accuracy of error distribution estimation, it's major drawback is the substantial computational burden. Research on accuracy gains of error distribution estimation using the quantile regression procedure is currently under way.

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Endnotes

[1] Tables 1-2 present descriptive statistics for 17 monthly forecasts of corn and soybean prices and Table 3 presents descriptive statistics for 16 monthly forecasts of wheat prices because the remaining forecasts provide the final estimates for each commodity.

[2] Isengildina, Irwin, and Good (2004) provide evidence that WASDE price forecasts are symmetric. Therefore, average forecast price is computed by taking an average of midpoint forecast prices for each month.

[3] It is worth noting that most theoretical variance expressions are based on the same assumption.

[4] Results not presented here but available from the authors upon request.

[5] Christoffersen (1998) also proposed additional tests that examine interval forecast independence and forecast coverage conditional on independence. However, due to a small number of observations, these tests cannot be applied to the prediction part of the sample (1995/96-2004/05).

[6] It is important to keep in mind that these interval widths are conditional on the selected confidence level (90%). The widths of the empirical confidence intervals would be smaller if, for example, an 80% confidence level was selected. If the selected confidence level was equal to the actual hit rates, the widths of the empirical confidence intervals would be approximately equal to that of published intervals.

[7] Since the published intervals are symmetric according to Isengildina, Irwin, and Good (2004), the magnitudes above and below the mean would be equal to half of the interval.

Table 1. Descriptive Accuracy Statistics for Corn Price Interval Forecasts, 1980/81-2004/05 Marketing Years.

Month	Mean Forecast Price ($/bu)	Average Interval ($/bu)	Hit Rate (%)	Misses Above (%)	Misses Below (%)	Avg. Miss Above ($/bu)	Avg. Miss Below ($/bu)
Prior to harvest							
May	2.31	0.39	0.40	0.40	0.20	0.25	0.27
June	2.33	0.39	0.32	0.40	0.28	0.22	0.23
July	2.37	0.39	0.44	0.32	0.24	0.17	0.26
August	2.41	0.38	0.56	0.16	0.28	0.16	0.15
September	2.42	0.37	0.56	0.16	0.28	0.16	0.14
October	2.39	0.36	0.56	0.20	0.24	0.11	0.11
Average	2.37	0.38	0.47	0.27	0.25	0.18	0.19
After harvest							
November	2.37	0.36	0.72	0.16	0.12	0.13	0.18
December	2.37	0.34	0.80	0.12	0.08	0.14	0.15
January	2.37	0.29	0.84	0.08	0.08	0.20	0.10
February	2.37	0.25	0.80	0.12	0.08	0.10	0.10
March	2.37	0.19	0.72	0.16	0.12	0.06	0.05
April	2.37	0.14	0.72	0.16	0.12	0.06	0.04
May	2.37	0.10	0.68	0.12	0.20	0.05	0.06
June	2.37	0.07	0.68	0.12	0.20	0.05	0.05
July	2.37	0.05	0.76	0.08	0.16	0.06	0.05
August	2.37	0.01	0.48	0.20	0.32	0.03	0.03
September	2.37	0.00	0.52	0.16	0.32	0.03	0.02
Average	2.37	0.16	0.70	0.13	0.16	0.08	0.08

Note: Mean forecast price is calculated by averaging the midpoints of forecast intervals. Hit rate is the proportion of times the interval contained the final (November) estimate. Misses above and below describe cases when the final estimate fell above or below the forecast interval.

Table 2. Descriptive Accuracy Statistics for Soybean Price Interval Forecasts, 1980/81-2004/05 Marketing Years.

Month	Mean Forecast Price ($/bu)	Average Interval ($/bu)	Hit Rate (%)	Misses Above (%)	Misses Below (%)	Avg. Miss Above ($/bu)	Avg. Miss Below ($/bu)
Prior to harvest							
May	5.75	1.29	0.52	0.28	0.20	0.76	0.31
June	5.75	1.24	0.56	0.28	0.16	0.76	0.36
July	5.79	1.21	0.68	0.24	0.08	0.75	0.29
August	5.90	1.20	0.84	0.12	0.04	1.07	0.05
September	6.00	1.08	0.80	0.12	0.08	0.87	0.39
October	5.97	0.97	0.72	0.16	0.12	0.42	0.30
Average	5.86	1.17	0.69	0.20	0.11	0.77	0.28
After harvest							
November	5.95	0.90	0.72	0.16	0.12	0.48	0.35
December	5.96	0.79	0.80	0.12	0.08	0.42	0.15
January	5.93	0.68	0.76	0.20	0.04	0.20	0.10
February	5.91	0.59	0.80	0.20	0.00	0.19	n/a
March	5.88	0.44	0.80	0.20	0.00	0.17	n/a
April	5.90	0.26	0.76	0.20	0.04	0.14	0.06
May	5.92	0.00	0.28	0.48	0.24	0.10	0.11
June	5.93	0.00	0.44	0.40	0.16	0.09	0.14
July	5.94	0.00	0.52	0.32	0.16	0.06	0.09
August	5.94	0.00	0.68	0.20	0.12	0.05	0.05
September	5.94	0.00	0.72	0.20	0.08	0.03	0.01
Average	5.93	0.33	0.66	0.24	0.09	0.18	0.12

Note: Mean forecast price is calculated by averaging the midpoints of forecast intervals. Hit rate is the proportion of times the interval contained the final (November) estimate. Misses above and below describe cases when the final estimate fell above or below the forecast interval.

Table 3. Descriptive Accuracy Statistics for Wheat Price Interval Forecasts, 1980/81-2004/05 Marketing Years.

Month	Mean Forecast Price ($/bu)	Average Interval ($/bu)	Hit Rate (%)	Misses Above (%)	Misses Below (%)	Avg. Miss Above ($/bu)	Avg. Miss Below ($/bu)
Prior to harvest							
May	3.31	0.46	0.44	0.20	0.36	0.46	0.19
June	3.31	0.45	0.40	0.20	0.40	0.39	0.15
July	3.26	0.43	0.60	0.16	0.24	0.33	0.07
August	3.27	0.42	0.68	0.16	0.16	0.23	0.07
September	3.27	0.35	0.76	0.16	0.08	0.18	0.09
October	3.28	0.29	0.76	0.16	0.08	0.12	0.12
Average	3.29	0.40	0.61	0.17	0.22	0.28	0.11
After harvest							
November	3.29	0.24	0.64	0.20	0.16	0.06	0.10
December	3.30	0.20	0.68	0.16	0.16	0.05	0.06
January	3.30	0.16	0.68	0.16	0.16	0.03	0.04
February	3.30	0.12	0.68	0.16	0.16	0.03	0.03
March	3.29	0.10	0.76	0.16	0.08	0.03	0.04
April	3.29	0.08	0.68	0.20	0.12	0.04	0.03
May	3.29	0.00	0.40	0.28	0.32	0.03	0.03
June	3.29	0.00	0.36	0.28	0.36	0.03	0.03
July	3.30	0.00	0.88	0.00	0.12	n/a	0.03
August	3.30	0.00	0.92	0.00	0.08	n/a	0.03
Average	3.30	0.09	0.67	0.16	0.17	0.04	0.04

Note: Mean forecast price is calculated by averaging the midpoints of forecast intervals. Hit rate is the proportion of times the interval contained the final (September) estimate. Misses above and below describe cases when the final estimate fell above or below the forecast interval.

Table 4. Descriptive Statistics for Corn Empirical Price Forecast Intervals, 1995/96-2004/05 Marketing Years.

Month	Published Intervals	Histogram Intervals			Changing Distribution Intervals			Logistic Distribution Intervals		
	Average Interval	Average Interval	Average Below	Average Above	Average Interval	Average Below	Average Above	Average Interval	Average Below	Average Above
Prior to harvest										
May	0.40	1.12	-0.43	0.69	1.26	-0.42	0.84	1.31	-0.51	0.80
June	0.40	1.01	-0.43	0.58	1.33	-0.44	0.89	1.31	-0.54	0.77
July	0.40	0.87	-0.42	0.45	1.24	-0.57	0.67	1.14	-0.56	0.58
August	0.40	0.72	-0.44	0.28	0.91	-0.51	0.39	0.89	-0.51	0.38
September	0.40	0.71	-0.41	0.31	0.85	-0.46	0.38	0.85	-0.52	0.33
October	0.40	0.61	-0.30	0.31	0.73	-0.39	0.34	0.73	-0.47	0.27
Average	0.40	0.84	-0.40	0.44	1.05	-0.47	0.59	1.04	-0.52	0.52
After harvest										
November	0.40	0.62	-0.40	0.22	0.67	-0.39	0.28	0.67	-0.39	0.28
December	0.38	0.39	-0.20	0.19	0.53	-0.31	0.22	0.52	-0.30	0.22
January	0.34	0.31	-0.14	0.17	0.43	-0.26	0.17	0.43	-0.26	0.17
February	0.27	0.34	-0.15	0.19	0.38	-0.21	0.16	0.37	-0.21	0.16
March	0.20	0.29	-0.10	0.19	0.32	-0.16	0.16	0.31	-0.17	0.14
April	0.13	0.20	-0.10	0.10	0.26	-0.13	0.13	0.23	-0.14	0.09
May	0.10	0.13	-0.07	0.06	0.24	-0.10	0.14	0.18	-0.12	0.06
June	0.08	0.11	-0.05	0.06	0.15	-0.08	0.07	0.15	-0.10	0.05
July	0.06	0.09	-0.05	0.04	0.10	-0.06	0.04	0.10	-0.07	0.03
August	0.00	0.07	-0.05	0.02	0.07	-0.05	0.02	0.07	-0.05	0.02
September	0.00	0.06	-0.05	0.01	0.07	-0.05	0.02	0.06	-0.04	0.02
Average	0.18	0.24	-0.12	0.11	0.29	-0.16	0.13	0.28	-0.17	0.11

Table 5. Descriptive Statistics for Soybean Empirical Price Forecast Intervals, 1995/96-2004/05 Marketing Years.

Month	Published Intervals	Histogram Intervals			Changing Distribution Intervals			Logistic Distribution Intervals		
	Average Interval	Average Interval	Average Below	Average Above	Average Interval	Average Below	Average Above	Average Interval	Average Below	Average Above
Prior to harvest										
May	1.11	2.65	-1.40	1.25	2.98	-1.20	1.78	2.95	-1.18	1.76
June	1.09	2.66	-1.40	1.26	2.92	-1.22	1.70	2.90	-1.18	1.72
July	1.06	2.06	-0.80	1.26	2.38	-1.05	1.34	2.38	-1.14	1.24
August	1.03	1.55	-0.75	0.80	2.02	-0.92	1.10	1.85	-1.00	0.85
September	0.91	1.92	-1.15	0.77	1.96	-1.14	0.82	1.85	-1.18	0.67
October	0.82	1.52	-0.99	0.53	1.89	-1.05	0.84	1.81	-1.05	0.75
Average	1.00	2.06	-1.08	0.98	2.36	-1.10	1.26	2.29	-1.12	1.17
After harvest										
November	0.79	1.77	-0.99	0.78	1.74	-0.93	0.81	1.69	-0.92	0.76
December	0.73	1.27	-0.65	0.62	1.36	-0.71	0.65	1.26	-0.70	0.56
January	0.67	0.81	-0.35	0.46	0.88	-0.41	0.47	0.88	-0.50	0.38
February	0.59	0.61	-0.27	0.34	0.74	-0.31	0.43	0.73	-0.39	0.34
March	0.40	0.35	-0.10	0.25	0.51	-0.09	0.41	0.48	-0.19	0.29
April	0.30	0.16	-0.06	0.11	0.35	-0.06	0.28	0.32	-0.11	0.21
May	0.00	0.18	-0.06	0.12	0.28	-0.09	0.18	0.27	-0.10	0.17
June	0.00	0.17	-0.06	0.11	0.26	-0.09	0.17	0.23	-0.08	0.14
July	0.00	0.11	-0.03	0.08	0.15	-0.04	0.12	0.12	-0.04	0.08
August	0.00	0.06	0.00	0.06	0.09	-0.01	0.09	0.07	-0.03	0.04
September	0.00	0.03	0.00	0.03	0.07	0.00	0.07	0.03	-0.01	0.02
Average	0.32	0.50	-0.23	0.27	0.58	-0.25	0.34	0.55	-0.28	0.27

Table 6. Descriptive Statistics for Wheat Empirical Price Forecast Intervals, 1995/96-2004/05 Marketing Years.

Month	Published Intervals	Histogram Intervals			Changing Distribution Intervals			Logistic Distribution Intervals		
	Average Interval	Average Interval	Average Below	Average Above	Average Interval	Average Below	Average Above	Average Interval	Average Below	Average Above
Prior to harvest										
May	0.54	1.24	-0.53	0.71	1.40	-0.67	0.73	1.39	-0.78	0.61
June	0.54	1.09	-0.48	0.61	1.31	-0.63	0.68	1.32	-0.74	0.57
July	0.54	0.85	-0.25	0.60	0.91	-0.34	0.57	0.89	-0.48	0.41
August	0.54	0.80	-0.31	0.49	0.83	-0.30	0.53	0.82	-0.39	0.44
September	0.44	0.59	-0.20	0.39	0.61	-0.20	0.41	0.60	-0.27	0.33
October	0.36	0.49	-0.20	0.29	0.52	-0.21	0.30	0.51	-0.25	0.26
Average	0.49	0.84	-0.33	0.51	0.93	-0.39	0.54	0.92	-0.48	0.44
After harvest										
November	0.28	0.40	-0.21	0.20	0.43	-0.20	0.23	0.44	-0.20	0.23
December	0.22	0.31	-0.15	0.16	0.35	-0.15	0.20	0.33	-0.16	0.18
January	0.17	0.22	-0.10	0.12	0.25	-0.12	0.13	0.26	-0.15	0.11
February	0.12	0.18	-0.09	0.09	0.23	-0.11	0.12	0.22	-0.13	0.09
March	0.10	0.13	-0.05	0.08	0.16	-0.05	0.11	0.16	-0.08	0.08
April	0.07	0.12	-0.05	0.07	0.14	-0.04	0.10	0.15	-0.06	0.08
May	0.00	0.10	-0.05	0.05	0.10	-0.05	0.06	0.10	-0.05	0.05
June	0.00	0.10	-0.05	0.05	0.11	-0.05	0.06	0.10	-0.05	0.05
Average	0.12	0.19	-0.09	0.10	0.22	-0.10	0.13	0.22	-0.11	0.11

Table 7. Accuracy Statistics for Corn Empirical Price Forecast Intervals, 1995/96-2004/05 Marketing Years.

Month	Published Intervals		Histogram Intervals		Changing Distribution Intervals		Logistic Distribution Intervals	
	Hit Rate (%)	Unconditional Coverage	Hit Rate (%)	Unconditional Coverage	Hit Rate (%)	Unconditional Coverage	Hit Rate (%)	Unconditional Coverage
Prior to harvest								
May	0.50	10.22 **	0.80	0.89	0.90	0.00	0.90	0.00
June	0.40	15.01 **	0.80	0.89	0.80	0.89	0.90	0.00
July	0.50	10.22 **	0.80	0.89	1.00	n/a	1.00	n/a
August	0.60	6.22 *	0.80	0.89	0.80	0.89	0.80	0.89
September	0.70	3.07	0.80	0.89	0.80	0.89	0.80	0.89
October	0.60	6.22 *	0.90	0.00	0.90	0.00	0.90	0.00
Average	0.55		0.82		0.87		0.88	
After harvest								
November	0.90	0.00	0.90	0.00	0.90	0.00	0.90	0.00
December	0.90	0.00	0.90	0.00	0.90	0.00	0.90	0.00
January	1.00	n/a	0.90	0.00	1.00	n/a	1.00	n/a
February	0.90	0.00	1.00	n/a	1.00	n/a	1.00	n/a
March	0.90	0.00	1.00	n/a	1.00	n/a	1.00	n/a
April	0.60	6.22 *	0.90	0.00	1.00	n/a	1.00	n/a
May	0.70	3.07	0.80	0.89	0.90	0.00	0.90	0.00
June	0.70	3.07	0.70	3.07	0.90	0.00	0.80	0.89
July	0.90	0.00	0.80	0.89	0.80	0.89	0.80	0.89
August	0.50	10.22 **	0.90	0.00	0.80	0.89	0.80	0.89
September	0.70	3.07	0.90	0.00	1.00	n/a	1.00	n/a
Average	0.79		0.88		0.93		0.92	

Note: Confidence level of histogram-based forecasts range from 87% to 92% depending on the number of observations included in histograms. Confidence level of distribution-based forecasts is 90%. One asterisk indicates significance at 5% level, two asterisks indicate significance at 1% level.

Table 8. Accuracy Statistics for Soybean Empirical Price Forecast Intervals, 1995/96-2004/05 Marketing Years.

Month	Published Intervals		Histogram Intervals		Changing Distribution Intervals		Logistic Distribution Intervals	
	Hit Rate (%)	Unconditional Coverage	Hit Rate (%)	Unconditional Coverage	Hit Rate (%)	Unconditional Coverage	Hit Rate (%)	Unconditional Coverage
Prior to harvest								
May	0.60	6.22 *	0.90	0.00	0.90	0.00	0.90	0.00
June	0.70	3.07	0.90	0.00	0.90	0.00	0.90	0.00
July	0.70	3.07	0.90	0.00	0.90	0.00	0.90	0.00
August	0.80	0.89	0.80	0.89	0.90	0.00	0.80	0.89
September	0.70	3.07	0.80	0.89	0.80	0.89	0.80	0.89
October	0.60	6.22 *	0.90	0.00	0.90	0.00	0.90	0.00
Average	0.68		0.87		0.88		0.87	
After harvest								
November	0.70	3.07	0.90	0.00	0.80	0.89	0.80	0.89
December	0.70	3.07	0.80	0.89	0.90	0.00	0.80	0.89
January	0.70	3.07	0.80	0.89	0.80	0.89	0.80	0.89
February	0.80	0.89	0.80	0.89	0.80	0.89	0.80	0.89
March	0.80	0.89	0.80	0.89	0.90	0.00	0.90	0.00
April	0.80	0.89	0.80	0.89	0.50	10.22 **	0.80	0.89
May	0.20	27.25 **	0.80	0.89	0.80	0.89	0.80	0.89
June	0.30	20.65 **	0.90	0.00	0.90	0.00	0.90	0.00
July	0.30	20.65 **	0.70	3.07	0.90	0.00	0.70	3.07
August	0.50	10.22 **	0.70	3.07	0.70	3.07	0.80	0.89
September	0.50	10.22 **	0.80	0.89	0.80	0.89	0.80	0.89
Average	0.57		0.80		0.80		0.81	

Note: Confidence level of histogram-based forecasts range from 87% to 92% depending on the number of observations included in histograms. Confidence level of distribution-based forecasts is 90%. One asterisk indicates significance at 5% level, two asterisks indicate significance at 1% level.

Table 9. Accuracy Statistics for Wheat Empirical Price Forecast Intervals, 1995/96-2004/05 Marketing Years.

Month	Published Intervals		Histogram Intervals		Changing Distribution Intervals		Logistic Distribution Intervals	
	Hit Rate (%)	Unconditional Coverage	Hit Rate (%)	Unconditional Coverage	Hit Rate (%)	Unconditional Coverage	Hit Rate (%)	Unconditional Coverage
Prior to harvest								
May	0.40	15.01 **	0.50	10.22 **	0.60	6.22 **	0.70	3.07
June	0.40	15.01 **	0.80	0.89	0.80	0.89	0.70	3.07
July	0.70	3.07	0.90	0.00	0.80	0.89	0.80	0.89
August	0.80	0.89	0.80	0.89	0.80	0.89	0.80	0.89
September	0.90	0.00	0.90	0.00	0.90	0.00	0.90	0.00
October	0.90	0.00	0.90	0.00	1.00	n/a	0.90	0.00
Average	0.68		0.80		0.82		0.80	
After harvest								
November	0.70	3.07	0.80	0.89	0.90	0.00	0.90	0.00
December	0.70	3.07	0.70	3.07	0.80	0.89	0.70	3.07
January	0.70	3.07	0.90	0.00	0.90	0.00	0.90	0.00
February	0.70	3.07	0.90	0.00	1.00	n/a	0.90	0.00
March	0.80	0.89	0.80	0.89	0.90	0.00	0.80	0.89
April	0.70	3.07	0.80	0.89	0.90	0.00	1.00	n/a
May	0.40	15.01 **	0.80	0.89	1.00	n/a	1.00	n/a
June	0.40	15.01 **	0.80	0.89	1.00	n/a	1.00	n/a
Average	0.64		0.81		0.93		0.90	

Note: Confidence level of histogram-based forecasts range from 87% to 92% depending on the number of observations included in histograms. Confidence level of distribution-based forecasts is 90%. One asterisk indicates significance at 5% level, two asterisks indicate significance at 1% level.

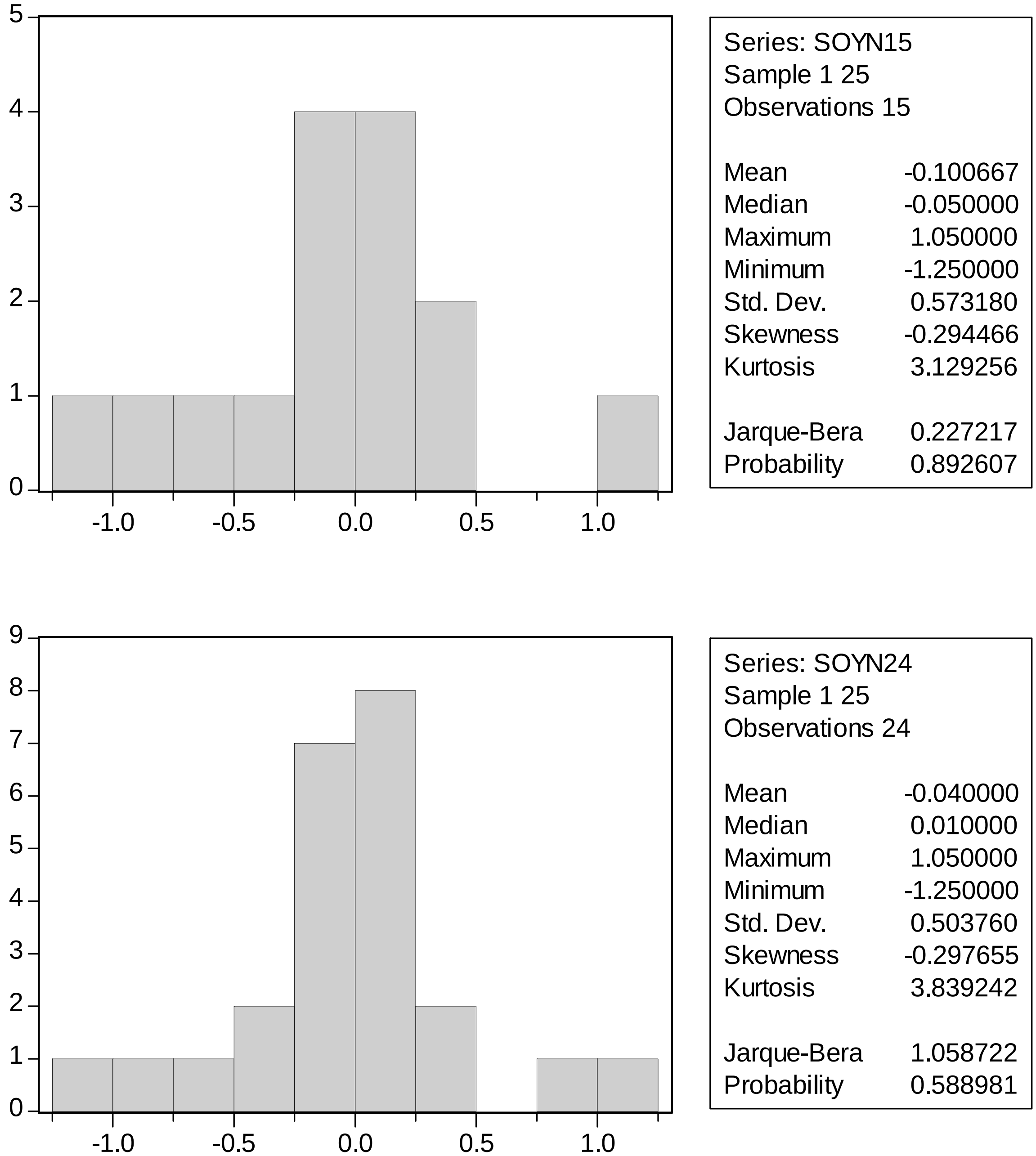
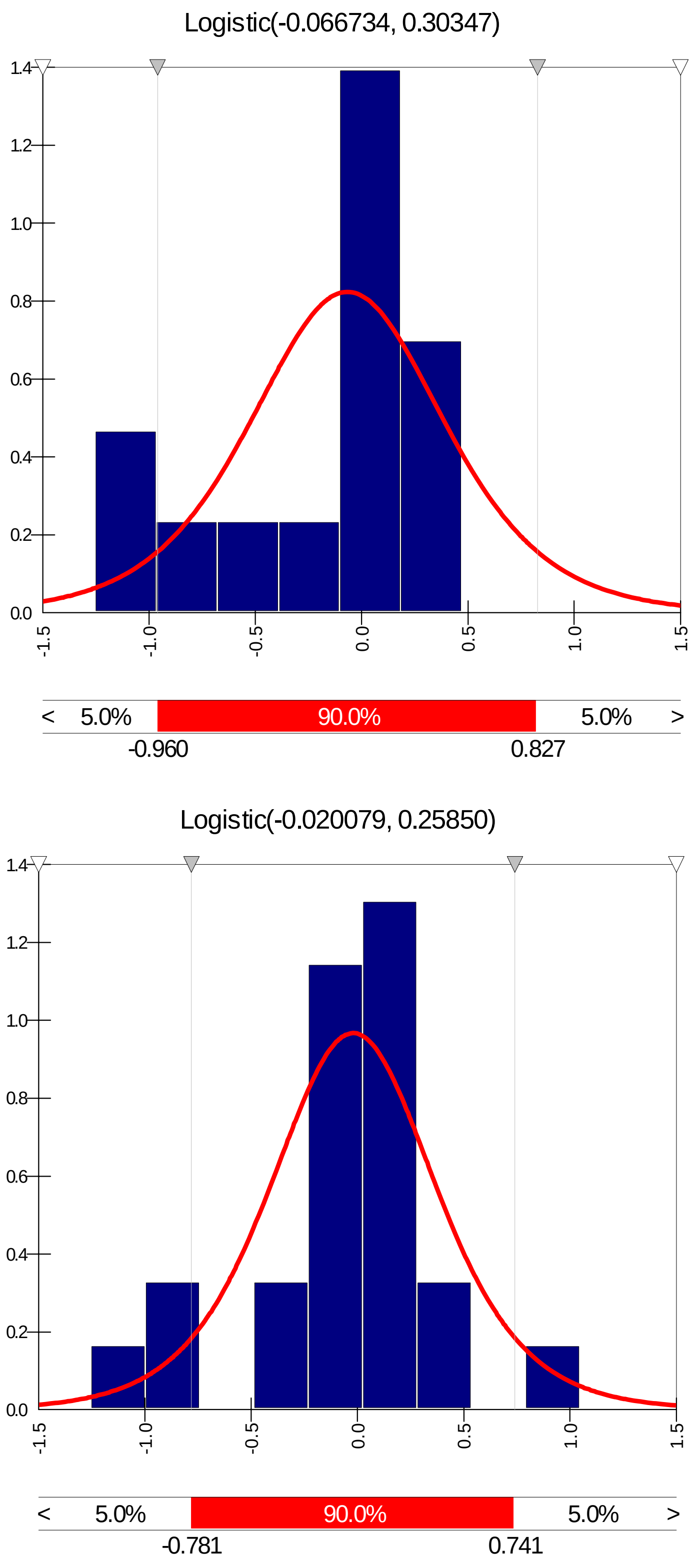


Figure 1. Forecast error histograms for November soybean forecasts based on 15 and 24 observations.



N=15

N=24

Figure 2. Forecast error distribution for November soybean forecasts based on 15 and 24 observations.