# The Informational Content of USDA Crop Reports: Impacts on Uncertainty and Expectations in Grain Futures Markets

**KEVIN P. McNEW**
**JUAN ANDRES ESPINOSA**

The current price of a futures contract conveys the expected price, as determined by the market, at the contract expiration date. However, futures prices do not indicate the degree of certainty that the market places on this price forecast. To obtain the market's certainty level about the price expectation, one must look at option prices. In fact, through option prices one can uncover the ex ante price probability distribution function.

One factor which influences the shape or moments of the price distribution is information. New information induces traders to reevaluate their current expectations about future economic conditions. If traders' expectations change, then one should observe changes in the moments of the distribution. For example, information that makes

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■ *Kevin P. McNew and Juan Andres Espinosa are Graduate Research Assistants in the Department of Agricultural and Resource Economics, North Carolina State University.*

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participants more certain about future economic conditions would result in a narrower distribution.

An extensive literature has developed that examines the impact that new information has on agricultural futures prices. However, by examining futures prices alone, this literature has determined only the effect that information has on the mean of this distribution and not the uncertainty level. An assessment of how information influences market expectations beyond the mean should yield a more robust interpretation of the informational content of specific news events.

This study investigates the influence of USDA crop production reports on market expectations in the corn and soybean futures markets. It is shown that the informational content of these reports, as measured by changes in the market's expected price and uncertainty level, can be inferred solely from changes in the standard deviation of the price probability distribution in the days surrounding the report. The empirical evidence suggests that USDA crop production reports lead to a lower level of uncertainty in both markets but do not significantly change the expected price in either the corn or soybean markets.

The next section reviews previous work that has evaluated the impact of USDA production information on commodity prices. Subsequent sections discuss the use of options in identifying the uncertainty level in the market, hypotheses tests concerning the informational content of USDA crop production reports, and the results from these tests.

## USDA INFORMATION IMPACTS ON COMMODITY FUTURES PRICES

The impact that economic information has on prices in efficient markets is well developed in the literature. As Fama (1970) points out, the arrival of new information is followed by price adjustments only when the information is unexpected or contrary to traders' previous beliefs. Information that is anticipated should be reflected in the current price while unanticipated information should lead to a new equilibrium price level.

These two characteristics of information, under the efficient market hypothesis, have motivated a number of empirical studies using futures prices. In examining agricultural futures prices, researchers traditionally concentrate on USDA production reports. The impact on commodity prices from these reports is usually addressed with one of the following two questions: (a) Do USDA production reports contain news to traders?

and (b) Do prices adjust in response to unanticipated but not to anticipated information in the USDA reports?

Fackler (1985); Milonas (1987); Sumner and Mueller (1989); and Fortenbery and Sumner (1993) investigate the first issue of whether USDA reports are newsworthy. In these studies, it is hypothesized that significant changes in futures prices are the result of a newly perceived supply situation as a consequence of the production report. The magnitude of the price change indicates how "surprised" traders are by the new information. Empirical tests of this hypothesis are conducted using a measure of absolute price change. Price adjustments significantly larger after the report, when compared to adjustments prior to the report or some other control period, imply that the report contains unanticipated information.

Most of these studies find that USDA production reports are newsworthy. Milonas, Fackler, and Sumner and Mueller find corn and soybean crop production reports lead to significant price adjustments.[1] However, Fortenbery and Sumner find that the influence of crop production reports from 1985 to 1989 is not significant on corn and soybean futures prices. They also report a similar finding for option prices during this period.

To reconcile their contradictory findings, Fortenbery and Sumner show that when futures prices are near the government loan rate for the commodity, price changes after a report are significantly smaller. They suggest that this may be a primary reason for the diminished report effect in post-1985 data. Also evident during the post-1985 period is the existence of options markets. As an alternative explanation, they argue that without options, traders may offset unattractive futures positions in light of new information inducing prices to overadjust in the short run. However, with options available, traders have a means of hedging existing futures positions and are not forced to liquidate. Thus, prices do not show significant adjustments.[2]

An alternative group of studies investigates price responsiveness to unanticipated and anticipated information [Miller (1979); Colling and Irwin (1990); Garcia and Leuthold (1992); Runkle (1992); Grunewald et al. (1993)]. Most of these studies use an average of forecasts

[1]The studies by Fackler and Sumner and Mueller consider the impact on the new-crop contract futures price, whereas Milonas considers the impact on the cash price.

[2]This leads one to the question of whether the informational content of the reports has changed or whether significant price adjustments prior to 1985 were an artifact of inadequate risk management tools. Fortenbery and Sumner discuss how the latter hypothesis could be supported by negatively correlated price changes on successive days immediately following the report and an increase in volume in the options market on days surrounding the report date.

published by private firms as a proxy for the market's expectation or the anticipated information in the USDA report.[3] These private forecasts are released by firms to their clients prior to the government report. Thus, if markets are efficient, the private forecast should be incorporated in the prereport price and any price movement must be attributable to the difference between the government and private forecast.

This residual between the USDA forecast and private forecast is used to measure unanticipated information. This allows for testing the hypothesis that prices adjust to unanticipated but not to anticipated information. Colling and Irwin find that live hog futures prices do not react to information that is anticipated in the Hogs and Pigs Report but do show significant adjustments (and in the expected direction) to unanticipated information. Grunewald et al. find similar results for the Cattle On-Feed Report. Runkle finds that live hog futures prices only react to the unanticipated component in the forecast errors of the USDA Hogs and Pigs Report. In all, these findings support market efficiency as anticipated information does not influence the price.

Carter and Galopin (1993) address the issue of whether report information is valuable. They hypothesize that a report has economic value if positive returns from trading can be earned using the report's information prior to the release data. They find that the USDA Hogs and Pigs Report, when used in conjunction with a private forecast, has little or no economic value as a trader would not expect to earn positive returns from a hypothetical trading strategy.

However, using positive returns to assign economic value to a report may not be a suitable criteria in a market where individuals are concerned with risk. Agents which make decisions based on both expected return and risk would find economic value in information that changes their risk perception but not their expected return. Thus, assessing economic value to information can not be based solely on whether the information alters the mean expectation in the market. A further look at the information's impact on risk perceptions or uncertainty in the market is needed. The next section discusses how to measure the degree of uncertainty in the market using option prices.

[3]There may not be any reason to believe that private crop forecasts do in fact represent the true market expectation of the USDA forecasts. However, Colling and Irwin and Grunewald et al. show that the private forecasts are unbiased predictors of the USDA Hogs and Pigs Report and the Cattle On-Feed Report, respectively. Also, Colling et al. (1992) demonstrate that the former report satisfies both weak- and strong-form rational expectations criteria.

## THE ROLE OF OPTIONS IN INTERPRETING INFORMATION

Option prices reflect the uncertainty about the current expected price or futures price. Furthermore, the price of an option can be used to find an artificial price probability distribution function. The identification of the distribution function requires an assumption of no-arbitrage possibilities which guarantees that the option's price equals the stream of discounted expected returns from the option [Cox and Ross (1976)].

Denote the probability distribution function by $P(F_T)$, where the futures price at time $t$ is $F_t$, and $T$ is the expiration date of the option. The return on a call option is $\max(0, F_T - x)$, where $x$ is the exercise price of the option. The no-arbitrage condition assures that the current price of a call option ($V_c(x)$) has the following representation:

$$V_c(x) = b(T) \int_0^{\infty} \max(0, F_T - x)\, dP(F_T) \qquad (1)$$

where $b(T)$ is the current price of a risk-free bond paying \$1 at time $T$. Similarly, a put option has a return of $\max(0, x - F_T)$ and the price of a put option ($V_p(x)$) can be expressed as:

$$V_p(x) = b(T) \int_0^{\infty} \max(0, x - F_T)\, dP(F_T) \qquad (2)$$

Knowledge of the distribution function, $P(F_T)$, and the price of a risk-free bond, $b(T)$, is sufficient to calculate the theoretical option values for different strike prices. Conversely, observance of option premiums can be used to deduce information about $P(F_T)$ [Breeden and Litzenberger (1978)].

To identify the probability distribution function, $P(F_T)$ is assumed to be log-normal in this study. There are several reasons for choosing this distribution function. First, as will be shown below, the mean and standard deviation for this distribution can be found easily. Secondly, log-normality rules out negative prices. Finally, although the log-normal distribution function may be viewed as yielding restrictive shapes, it has been found to perform well when compared to alternative distributions that are more flexible [Fackler and King (1990); Sherrick et al. (1990)].

Given that $P(F_T)$ is assumed to be log-normal (i.e., $\ln(F_T)$ is $N(\tilde{\mu}, \tilde{\sigma}^2)$) it can be characterized by the first two moments, $\tilde{\mu}$ and $\tilde{\sigma}^2$. Under the log-normal assumption, eqs. (1) and (2) can be expressed as:

$$V_c(x) = b(T)\left[F_t\Phi\left(z + \frac{\tilde{\sigma}}{2}\right) - x\Phi\left(z - \frac{\tilde{\sigma}}{2}\right)\right] \quad (3)$$

$$V_p(x) = b(T)\left[x\Phi\left(z + \frac{\tilde{\sigma}}{2}\right) - F_t\Phi\left(z - \frac{\tilde{\sigma}}{2}\right)\right] \quad (4)$$

where $z = \ln(x/F_t)/\tilde{\sigma}$, $F_t$ is the futures price in period $t$ and $\Phi(\,)$ is the standard normal distribution function. In this case there is one free parameter, $\tilde{\sigma}$, and estimation of $\tilde{\sigma}$ will give the value of $\tilde{\mu} = \ln(F_t) - \tilde{\sigma}^2/2$ [Fackler and King (1990)]. Equations (3) and (4) are the common option pricing formulas derived by Black (1976).[4]

For interpretive reasons it is beneficial to transform $\tilde{\mu}$ and $\tilde{\sigma}^2$, the mean and variance of $\ln(F_T)$, to $\mu$ and $\sigma^2$ which represent the mean and variance of $F_T$. These transformations are [Cox and Rubinstein (1985, p. 204)]:

$$E(F_T) = \mu = e^{(\tilde{\mu}+\tilde{\sigma}^2/2)}, \qquad \mathrm{Var}(F_T) = \sigma^2 = \left[e^{(2\tilde{\mu}+\tilde{\sigma}^2)}\right]\left[e^{\tilde{\sigma}^2} - 1\right]$$

Substituting in the definition of $\tilde{\mu}$ in the equation for $\mu$ yields $\mu = F_t$. Thus, this parameterization assumes that the mean of the distribution is the current futures price, $F_t$. In the analysis that follows, $\mu$ and $\sigma$ are used and can be interpreted as the conditional mean and standard deviation of $F_T$ in period $t$.

In the terminology of options studies, $\sigma$ is referred to as the implied volatility.[5] It measures the uncertainty that market participants have concerning the futures price at the expiration of the option. Informational events may affect either $\mu$ or $\sigma$ depending on whether the information is unanticipated or anticipated. Unanticipated information should lead to a change in either $\mu$ or $\sigma$, or both. Anticipated informton should be fully reflected in option prices and therefore should not influence $\mu$ or $\sigma$ [Wilson and Fung (1990)]. Thus, information that is always anticipated has no impact on market beliefs and should be of no value to traders.

[4]One difference between the formulation presented here and that of Black's concerns the interpretation of the volatility parameter. In Black's work, the volatility parameter refers to the daily variance, while here it represents the variance parameter of the expiration date price distribution. An advantage of the no-arbitrage model used here is it that no assumptions are made about the time path of the volatility. In contrast, the formulation of Black assumes that the volatility process is a deterministic function of time.

[5]Both the variance parameter, $\sigma^2$, used in this study and the daily variance used in Black's model have been referred to as the implied volatility.

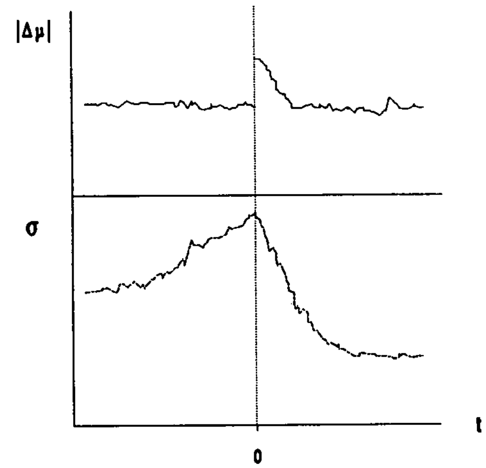


FIGURE 1
Impact of unanticipated information around report data.

To illustrate how unanticipated information influences $\mu$ or $\sigma$, consider the following example (depicted in Fig. 1). Suppose that traders are aware that information will become available at time 0. Prior to time 0, the absolute change in the conditional mean, $|\Delta\mu|$, is at a normal level, reflecting common trading activity. If, during this interval, traders expect the arriving information to alter their perceptions about $\mu$ (although the direction of the change is uncertain) then $\sigma$, the conditional volatility in period $t$, will increase up until time 0. This reflects the likelihood of a large price change in futures (i.e., a large $|\Delta\mu|$) at time 0. This is demonstrated in the lower graph of Figure 1 to the left of $t = 0$.

At the time the information is released, the mean will change significantly reflecting the new information. Also, the adjustment to a new equilibrium level may not be instantaneous. This is shown in the top graph of Figure 1. However, after time 0, $\sigma$ will decrease as the adjustment in the mean decays. If the information makes participants more certain about future economic conditions then $\sigma$ should decline to a lower level then before the rise occurred, prior to time 0. In principle, if information is always anticipated, then both the change in the mean and the implied volatility should remain constant.[6]

This example suggests that observance of $\sigma$ before and after a report date is sufficient to draw conclusions about the informational content of

[6]In Figure 1, the time window for this example is arbitrary and unspecified. However, in practice, it should be short enough so that the natural decay in $\sigma$ over time (as $t$ approaches $T$) is not significant.

the report. That is, increases in $\sigma$ prior to the report date are indicative of information that changes the mean expectation in the market while a lower level of $\sigma$ after the report suggests that the information resolves uncertainty.

Patell and Wolfson (1979) find a similar pattern as depicted in Figure 1 for the implied volatility in stock options around annual earnings announcements. Their results indicate that for the near-term option, the implied volatility increases up until the announcement date and then decreases. In contrast, Monroe (1992) finds that 8 out of 15 economic reports considered lead to significant changes in $\sigma$ in the treasury bond futures markets. Of the 8 informational sources that have significant impacts, 7 resulted in higher values of $\sigma$. Monroe's findings should be viewed with caution, however. This is because her results are based only on a comparison of the value of $\sigma$ prior to an announcement with a value of $\sigma$ that is calculated using the average of the opening price range after an economic announcement. The use of the opening range in the analysis may give misleading results as it is unlikely that a long-run equilibrium is reached during this period. If one is concerned with a long-run interpretation of the impact on $\sigma$, more distant trading periods should be examined.

An approach comparable to that of Patell and Wolfson is used in this article to analyze the impact that USDA crop reports have on market expectations. The time path of $\sigma$ in the days prior to and after the report is examined to more fully gauge the informational content of these reports. The next section presents the methodology and testing procedures.

## EMPIRICAL METHODOLOGY

The above discussion illustrates how the informational content of USDA production reports can be inferred from specific patterns of $\sigma$ around the report date. If the information is anticipated, then $\sigma$ should be constant over the period before and after a report. However, if $\sigma$ changes before or after the production report, then the informaton is unanticipated.

The two specific hypotheses considered in this study relate to how unanticipated information can be detected from the time path of $\sigma$. First, if the information leads to significant changes in $\mu$, on average, then $\sigma$ should rise prior to the report date. Secondly, if the information resolves uncertainty in the market, then $\sigma$ should be lower after the report date in comparison to earlier days. Also, the adjustment in $\sigma$ to a lower level should occur rapidly.

These hypotheses about $\sigma$ are used to interpret the informational content of USDA crop production reports in the corn and soybean markets. The study period encompasses the years 1985 to 1991. The specific futures and options contracts considered are the December corn and January soybean contracts. These are selected because the crop reports should have an immediate impact on these new-crop contracts.

The data consist of daily observations on the closing futures price and the prices for a call and a put option with strike prices closest to the current futures price. The near-the-money option tends to be actively traded and should reflect changes in the market price expectations. Interest rate data are from the *Wall Street Journal*, using the average of the bid–ask interest rates for treasury bills that matured on the date of expiration of the option contracts. This interest rate is then used to calculate $b(T)$.

Under the assumption of a log-normal price distribution, eqs. (3) and (4) can be used to obtain values of $\tilde{\sigma}$ which are consistent with the observed option premiums. This involves a numerical search technique because no analytical solution exists. Separate grid searches are performed on eqs. (3) and (4) to find the values of $\tilde{\sigma}$ which solved the arbitrage conditions for the put and call options. The two values of $\tilde{\sigma}$ for the put and call are averaged and used to calculate $\sigma$. Also, as implied by the formulation of the previous section, $\mu$ is set equal to the current futures price, $F_t$.

The dates studied are those surrounding the USDA crop production report. These reports are released after the futures markets have closed, usually around the 10th of the month, from August through November. Eight trading days surrounding the report date are sampled to examine the impact of information. Consideration of more trading days would create interpretive difficulties because of other information influencing price behavior either prior to or after the report.

To distinguish the days surrounding the report date, a time subscript, $t$, is used. That is, $t = -3, -2, -1, 0, 1, 2, 3, 4$ are the dates studied. For example, day 0 is the date the report is released, $-3$ refers to three trading days prior to the report, and 4 represents four trading days after the report is released. Although day 0 is the report date, the information is not released until after the markets have closed. Therefore, day 0 should be viewed as preceding the report and any impacts should be observed after day 0.

Using the 7 years of data for the 4 crop report months yields 28 observations for each day, $t$. For corn, however, the month of November is not used because the December option contract expires approximately one week after the report.[7] Thus, for corn there are 21 observations while for soybeans there are 28 observations for each day $t$.

Because the implied volatility estimates decrease as the time to expiration declines, a correction of $\sigma$ is made prior to performing hypotheses tests. Each implied volatility estimate is divided by the day 0 estimate for the corresponding month and year. Thus, in this analysis, day 0 always has a standardized volatility estimate of 1. This normalization removes any monthly or yearly effect that may exist in the implied volatility and makes the testing procedures more valid.

## RESULTS

Table I presents the normalized implied volatility ($\sigma$) averaged for each crop report month. These values are interpreted as the average proportion of the implied volatility in comparison to day 0.

For both corn and soybeans, the implied volatility drops after day 0. On average, over all crop report months, the implied volatility for corn

**TABLE I**

Average Implied Standard Deviation as a Proportion of Day 0

| | | | Corn | | | | |
|---|---|---|---|---|---|---|---|
| $t^a$ | −3 | −2 | −1 | 1 | 2 | 3 | 4 |
| Month | | | | | | | |
| Aug. | 0.984 | 1.005 | 0.962 | 0.940 | 0.908 | 0.910 | 0.974 |
| Sept. | 0.979 | 0.991 | 1.010 | 0.920 | 0.900 | 0.909 | 0.879 |
| Oct. | 1.023 | 1.003 | 0.974 | 0.908 | 0.923 | 0.882 | 0.828 |
| Avg. | 0.995 | 0.999 | 0.982 | 0.923 | 0.910 | 0.900 | 0.894 |
| | | | Soybeans | | | | |
| $t$ | −3 | −2 | −1 | 1 | 2 | 3 | 4 |
| Month | | | | | | | |
| Aug. | 1.034 | 0.986 | 1.012 | 0.981 | 0.931 | 0.954 | 0.926 |
| Sept. | 1.012 | 0.995 | 0.985 | 0.943 | 0.968 | 0.913 | 0.905 |
| Oct. | 1.030 | 1.030 | 1.021 | 0.954 | 0.935 | 0.937 | 0.925 |
| Nov. | 1.003 | 1.028 | 1.008 | 0.948 | 0.927 | 0.919 | 0.918 |
| Avg. | 1.020 | 1.010 | 1.007 | 0.957 | 0.940 | 0.931 | 0.918 |

[a]Day 0 is not reported because it is standardized to 1 for all observations. The monthly averages are based on 7 observations for the years 1985–1991.

[7]The implied volatility for corn decreases dramatically during the month of November. This is most likely due to the short time to expiration and not the result of the report information. Note that deleting the month of November removes an observation that unjustly favors the alternative hypothesis of a declining implied volatility after the report.

decreases by 7.7% (about 2¢ per bushel) between day 0 and day 1 while the decrease in soybeans is 4.3% (or 2¢ per bushel) during the same period. By day 4, the implied volatility for corn decreases by 10.6% (3¢) while soybeans decreases by 8.2% (5¢).

Not only on average, but in all crop report months, there is a drop in implied volatility for corn and soybeans. However, the magnitude of this decline depends upon which month is examined. For both commodities, the decline after day 0 is less dramatic earlier in the crop year. This may be attributable to traders being more confident in later crop reports as opposed to the initial report released in August. However, one should view these comparisons across crop report months with caution as they are based on only 7 observations.

Prior to the report there does not appear to be a strong upward trend present in the implied volatility for either corn or soybeans. Although the implied volatility for corn in the day preceding the report is less than day 0, the implied volatility for soybeans is higher preceding the report.

To perform hypotheses tests about the informational content of USDA crop reports, values of $\sigma$ are compared for all possible daily combinations during the eight-day period. That is, the data are pooled across months and years yielding 28 observations for soybeans and 21 observations for corn for each date $t$. Although disaggregating the tests by month might be informative, with only seven years (observations) of data the monthly tests are likely to have very low power.

The Van der Waerden and Wilcoxon (Kruskal–Wallis) nonparametric test statistics are used to conduct hypotheses tests. Both tests can be used to detect differences in the location between two sets of data. These tests are linear rank statistics and have the general form [Hajek (1969, p. 45)]:

$$S = \sum_{i=1}^{N} c_i a(R_i)$$

where $N = N_1 + N_2$ is the total number observations in the pooled sample, $c_i$ is the weight associated with observation $i$ and $a(R_i)$ is a score function dependent upon the ranking $(R_i)$ of observation $i$.

For both statistics the weight, $c_i$, is 1 for observations in the first sample and 0 for the second sample. In the Wilcoxon test, an ordinal ranking of all the data [e.g., $a(R_i) = i$] is used while the Van der Waerden test uses the standard normal quantile function based on the ordinal ranking normalized by the sample size (e.g., a $(R_i) = \Phi^{-1}[i/(N + 1)]$ where $\Phi(\ )$ is the standard normal distribution

**TABLE II**
Probability Values for the Van der Waerden Test Statistic on the Implied Standard Deviation of Corn

| | *Ha*: $\sigma_i < \sigma_j$[a] | | | *Ha*: $\sigma_i > \sigma_j$ | | | |
|---|---|---|---|---|---|---|---|
| *j* | −2 | −1 | 0 | 1 | 2 | 3 | 4 |
| *i* | | | | | | | |
| 3 | | | | | | | 0.200 |
| 2 | | | | | | 0.417 | 0.171 |
| 1 | | | | | 0.301 | 0.261 | 0.088 |
| 0 | | | | 0.001 | 0.001 | 0.001 | 0.001 |
| −1 | | | 0.055 | 0.002 | 0.005 | 0.002 | 0.004 |
| −2 | | 0.769 | 0.751 | 0.001 | 0.002 | 0.001 | 0.001 |
| −3 | 0.340 | 0.746 | 0.411 | 0.001 | 0.003 | 0.002 | 0.002 |

[a]The tests are conducted under the null hypothesis that $\sigma_i = \sigma_j$. Small *p*-values indicate rejection of the null in favor of the respective alternative hypothesis. These tests are based on 21 observations.

function). Both test statistics converge asymptotically to a standard normal distribution and are usually reported as chi-squared with one degree of freedom. Only the Van der Waerden tests results are presented as both tests yield almost identical results in this application.

Tests for $\sigma$ are presented in Tables II and III for corn and soybeans, respectively. These tables give the probability values for the null hypothesis that $\sigma_i = \sigma_j$ where $i$ is the column and $j$ is the row. For example, the null hypothesis that the implied volatility for corn on day 0 is equal to the implied volatility on day −3 has a $p$-value of 0.411.

The first hypothesis tested is whether USDA reports have unanticipated information which changes $\mu$ significantly. If this hypothesis is true, then $\sigma$ should rise prior to day 0 in anticipation of a change in the mean after day 0 (i.e., $\sigma_i < \sigma_j$ for $j > i$). The test that $\sigma$ increases on days prior to the report is given in the left-hand side of these tables. With one exception in corn, the comparisons prior to day 0 indicate that there is not a significant rise in the implied volatility during this four-day period. However, the low $p$-value (0.055) between day −1 and day 0 for corn does present some evidence of an increase in the implied volatility the day before the report. This evidence is marginal, however, as the implied volatilities in days −3 and −2 are not significantly different from day 0. This indicates no upward movement in $\sigma$ prior to day 0. For soybeans there is strong evidence of no unanticipated information that will influence the mean as there is no statistical evidence of a rise in $\sigma$ prior to day 0.

Whether the USDA reports have unanticipated information which resolves uncertainty requires testing whether $\sigma$ is lower after the report than it is prior to the report (i.e., $\sigma_i > \sigma_j$ for $j > i$). Results form these tests are given in the lower right-hand quadrant of Tables II and III. In all cases, the implied volatility is lower after the report when compared to days prior to the report for both corn and soybeans. Also, this drop occurs immediately following the report as both corn and soybeans have low $p$-values (0.001) on day 1 when compared to day 0. Thus, for both corn and soybeans, there is strong evidence that USDA production reports contain unanticipated information which reduces the uncertainty level in the market.

To see if a residual effect on $\sigma$ exists after the report has been released, tests are conducted on the four days following the report. These results are given in the upper right-hand quadrant of Tables II and III. By day 4, the implied volatility for soybeans appears to decrease to a lower level beyond day 1 as the $p$-value is 0.037. In corn, this result is not as convincing as the $p$-value is 0.088. Also, for both corn and soybeans this decay in implied volatility must be gradual as the $p$-values between consecutive days, given on the diagonal, are all highly insignificant.

The results for $\sigma$, taken collectively, convey several implications concerning the informational content of USDA crop reports. First, because $\sigma$ does not appear to increase prior to the report for soybeans, USDA reports must not contain unanticipated information that influences the mean. For corn, this conclusion is not as strong as the day

**TABLE III**
Probability Values for the Van der Waerden Test
Statistic on the Implied Standard Deviation of Soybeans

| | *Ha*: $\sigma_i < \sigma_j$[a] | | | *Ha*: $\sigma_i > \sigma_j$ | | | |
|---|---|---|---|---|---|---|---|
| $j$ | −2 | −1 | 0 | 1 | 2 | 3 | 4 |
| $i$ | | | | | | | |
| 3 | | | | | | | 0.328 |
| 2 | | | | | | 0.271 | 0.116 |
| 1 | | | | | 0.309 | 0.099 | 0.037 |
| 0 | | | | 0.001 | 0.001 | 0.003 | 0.001 |
| −1 | | | 0.208 | 0.004 | 0.003 | 0.001 | 0.001 |
| −2 | | 0.543 | 0.500 | 0.008 | 0.003 | 0.001 | 0.001 |
| −3 | 0.757 | 0.282 | 0.722 | 0.003 | 0.001 | 0.001 | 0.001 |

[a]The tests are conducted under the null hypothesis that $\sigma_i = \sigma_j$. Small $p$-values indicate rejection of the null in favor of the respective alternative hypothesis. These tests are based on 28 observations.

prior to a report shows a significant increase in $\sigma$ at the 10% level. Secondly, USDA reports tend to make market participants more certain about future supply conditions as $\sigma$ is significantly lower after the report than it is prior to the report. Finally, there is evidence of under-reaction in $\sigma$ as there is a significant decline in the implied volatility beyond the first day.[8]

Although no further tests are necessary, it is useful to validate the results from the tests on $\sigma$ prior to the report with direct tests on $\mu$ after the report. Because $\sigma$ does not appear to increase prior to the report in the case of soybeans and increases only marginally in corn, one would not expect to find significant changes in $\mu$ after the report.

To test for significant changes in the mean after the report is released, the average absolute daily change in the mean prior to the report is compared to the daily changes after the report. The three-day average change prior to the report is used as an indication of normal absolute changes in the mean.[9] If the information is unanticipated in the mean, then the absolute daily changes after the report should be larger than the three-day average prior to the report. Also, if the information is unanticipated, it should be incorporated quickly so that changes immediately following the report should be more significant than changes occurring in more distant periods after the report.

These test results are presented in Table IV for both commodities. For corn and soybeans, the absolute change in the mean for the two days following the report does not appear to be significantly larger than the average change prior to the report. Thus, it appears that the mean does not change significantly because of the USDA report.

However, a somewhat puzzling result is the finding of a significantly larger change in day 3 for corn and day 4 for soybeans. This is most likely not a result of information from the report, given that earlier days show no significant changes. One possible explanation for the significance of these lagged changes is that traders may be reentering the market after the information has been incorporated. For example, traders may choose to exit the market prior to the report so as not to expose themselves to

[8]An extension of the time window after the report release may give more insight regarding the degree of the under-reaction.

[9]The results presented here are not sensitive to the use of the three-day average prior to the report. The same analysis is performed using the two-day average prior to the report as well as the absolute change the day before the report as benchmarks. Both procedures give similar results to those presented using the three-day average.

**TABLE IV**
Probability Values for the Van der Waerden Test of an Increase in the Absolute Daily Change of the Implied Means

| | | | | |
|---|---|---|---|---|
| | | *Corn* | | |
| Daily change[a] | (0, 1) | (1, 2) | (2, 3) | (3, 4) |
| | 0.280 | 0.119 | 0.066 | 0.130 |
| | | *Soybean* | | |
| Daily change | (0, 1) | (1, 2) | (2, 3) | (3, 4) |
| | 0.121 | 0.200 | 0.101 | 0.039 |

[a]The notation $(i,j)$ represents the null hypothesis that $|\mu_j - \mu_i|$ is equal to the three-day average of daily changes prior to the report against the alternative that it is greater than the average.

any short-term price risk and only reenter the market after the report information has been incorporated.[10]

The tests on $\mu$ along with the finding that $\sigma$ does not rise prior to the report suggest that USDA crop reports do not contain unanticipated information that changes the mean expectation for either corn or soybeans. This finding is consistent with Fortenbery and Sumner's result that crop reports do not influence corn and soybean futures prices during 1985 to 1989.

Fortenbery and Sumner's finding of insignificant changes in option prices may appear to be at odds with the result that $\sigma$ decreases significantly after the report. However, a direct comparison between the two is not insightful because changes in option prices reflect changes in futures prices and changes in $\sigma$. Depending on whether the futures price increases or decreases and whether a put or call is examined, option price changes may overstate or understate the impact from a change in $\sigma$. Thus, using $\sigma$ directly, as opposed to option prices, removes any ambiguity as a result of futures price changes.[11]

[10]Such an explanation would be supported by increases in open interest at some point beyond day 0. Open interest in the January soybean futures contract over this period shows such a pattern as the number of positions held in the market increases by 13% on day 4 in comparison to day −3. However, this result is not evident in corn. Similarly, significant increases in volume for day 3 for corn and day 4 for soybeans are not evident in the data.

[11]For example, an increase in the futures price and a decrease in $\sigma$ will influence the price of a call and a put differently. For the call, an increase in the futures price will increase the price of the call while the decrease in $\sigma$ will decrease its price. Thus, the price change for the call price understates the change in $\sigma$. Similarly, the price change for the put overstates the change in $\sigma$ as both effects decrease the price of a put.

## CONCLUSIONS

This study argues that when assessing the role of new information on market expectations, analyzing price deviations around an announcement date may neglect the benefit that information has on the uncertainty level in the market. By combining futures and options prices, a more effective interpretation can be given to the impact that USDA crop reports, and other informational sources, have on market expectations.

It is shown in this study how the informational content can be inferred from variations in the standard deviation of an artificial probability distribution derived from option and futures prices. Hypotheses tests are presented to detect whether USDA crop reports have unanticipated information that alters the market's beliefs about the mean of this distribution or made these beliefs more certain by reducing the standard deviation.

The results of these tests have several interesting implications. First, it appears that there is a large reduction in uncertainty in the day following the production report. Also, a residual decline in the implied volatility occurs beyond the first day after the report. Thus, USDA information has unanticipated information which makes the market more certain about future supply conditions. Secondly, there does not appear to be any strong evidence in either the corn or soybean market that the crop reports significantly impact the mean expectation of the market participants. Finally, the fact that USDA crop reports significantly influence the uncertainty present in the market leads one to the conclusion that the reports have economic value.

Although the value of this uncertainty reduction is not addressed, the average uncertainty reduction for corn is 3¢ per bushel and for soybeans it is 5¢ per bushel by the fourth day following a report. However, it is unclear whether this magnitude of uncertainty reduction warrants the government expenditures on production forecasts.

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