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The Impact of Public Information on Commodity Market Performance: The Response of Corn Futures to USDA Corn Production Forecasts

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Abstract

This paper examines the impact of the U.S. Department of Agriculture's (USDA) projections of annual corn output on the price of corn futures. We tested if output projections significantly drive responses to the futures market. We also tested if the accuracy of past projections influences market response to the current projections. For each month—from May (planting month) to October (harvesting month)—we estimated a system of equations representing the daily opening, closing, high-, and low-futures prices. These equations test the forecast's impacts on both price levels and daily variances. We found USDA's projection of annual corn production influenced future prices and daily variances. The projection moved the future price closer to the October harvest price, and its impact lingered for several days. We found errors in past output projections have only a small effect on the projection impacts on future prices.

Keywords: future prices, corn, corn output, corn futures, crop projections, uncertainty, USDA, *World Agricultural Supply and Demand Estimates, WASDE,* U.S. Department of Agriculture, Economic Research Service, ERS, futures contracts, market impact.

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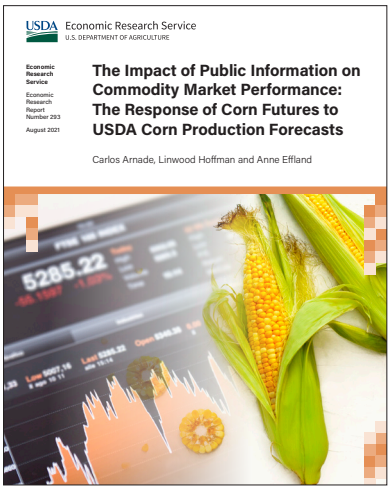

What Is the Issue?

The U.S. Department of Agriculture (USDA) releases its *World Agricultural Supply and Demand Estimates* (*WASDE*) report monthly, which contains projections of numerous agricultural variables, such as expected production and stocks. Over the past five decades, various studies have tested whether publicly releasing *WASDE* reports influences an agricultural commodity's futures price. Some previous studies have found *WASDE* reports can influence the expected volatility of a commodity's futures price, and most studies agree these reports do ultimately impact a commodity's futures price. Although these findings are important, these studies often fail to identify which variables projected by USDA are primarily responsible for futures market impacts. Currently, no study has attempted to determine how the accuracy of USDA projections can affect futures market prices. Another overlooked issue is whether USDA projections are a better or worse predictor of harvest prices for a particular commodity. This issue remains a concern for thousands of market participants using the futures price to make decisions. Finally, previously conducted studies evaluated projections from 1 or 2 specific months of the year. By doing so, these evaluations fail to relate the projections' impact to USDA's changing projections as information improves over the cropping season.

What Did the Study Find?

This study found USDA corn-output projections are a crucial variable in influencing corn futures. USDA corn-production projections significantly impact corn futures, even when accounting for the impact of other *WASDE* projections, such as projected stocks, consumption of the commodity, and season average prices. The magnitude of the projection's impact varies across the calendar year. August and September reports have a stronger influence on prices than reports from earlier in the cropping season. Additionally, this study found USDA corn-production projections influence the market's daily variance of corn futures, represented in this report as the differences between the daily high price and daily low price.

Errors in past USDA corn-output projections have had small yet statistically significant effects, which shape more recent USDA projections on corn futures prices. Notably, this study shows that USDA projections—on average—drive the futures price closer to the actual October harvest price. For example, over a 19-year period, corn futures in May are, on average, 1.01 percent closer to the harvest price than they would have been without the release of USDA's *WASDE* report. Additionally, USDA projections bring the futures price in June 4.18 percent closer to the October harvest price. In July, USDA projections have a neutral impact; in August, the projections bring corn futures 1.11 percent closer to the harvest price; and in September, the projections bring corn futures 3.56 percent closer to the harvest price.

Moreover, this report shows how the release of USDA's *WASDE* report dissimilarly influences different representations of the daily future prices. Impacts on the daily open price are distinct from the daily closing price. Notably, impacts on the daily high price are distinct from impacts on the daily low price. Finally, this study shows the USDA's influence on corn prices remains embodied in corn futures for several days after the release of USDA's *WASDE* report.

How was the Study Conducted?

Daily corn futures were regressed on several explanatory variables. Two explanatory variables were used to represent USDA projections. These included a dummy variable set equal to zero for most days of a month and one variable on the day of USDA's *WASDE* announcement. There were other variables—such as daily lags—which included a second, third, and fourth zero/one variable to test impacts over several days after the report's release.[1]

The regressions estimated in this report differed from previous literature by including a second variable to represent USDA projections: USDA projected corn output. The USDA projection variable was also set equal to zero until the day of the release and was then represented by the difference between the new USDA projection and the projection issued in the previous month. For example, in testing the impact of the August projection on corn futures, we used the difference between USDA's August projection of annual corn output and the projection made in July. In effect, we tested the impact of new USDA information on corn's futures-price projections.

Data for each month were used to estimate a separate model; that is, separate models were estimated for the days in May, separate models were estimated for the days in June, and so on, through October. Creating specific monthly models is consistent with methods used in previous studies. Each of the 6 month-specific models consisted of daily data from 1999 to 2017.[2] We also analyzed subperiods of fewer years. By deriving the relationship between corn futures and USDA's corn output projections, we estimated which of the projections' impact makes corn futures a better or worse predictor of the October harvest price.

We also included a 3-year weighted average of output projection errors from preceding years in our model (e.g., for our 2004 observation, we used errors from 2001, 2002, and 2003). These errors represented the difference between USDA projections from the month in question and that year's actual output of corn. This setup allowed us to test if the accuracy of past errors influenced the impact that current projections have on corn futures.

Unlike earlier USDA impact studies, this study measured the difference in USDA's impact on the daily high futures price and daily low futures price to calculate USDA impacts on the variability of the daily futures price. In one trial we conducted, the model tested and measured USDA's impact on both the level of corn futures and the daily variability of corn futures.

[1]Two months of model data were pretested for random breaks in futures prices. In doing so, ERS found no indication that markets anticipate a *WASDE* release.

[2]One table in this report uses data from 1992 to 2017.

The Impact of Public Information on Commodity Market Performance: The Response of Corn Futures to USDA Corn Production Forecasts

Introduction

Throughout each year, the U.S. Department of Agriculture (USDA) releases a monthly report called the *World Agriculture Supply and Demand Estimates* (*WASDE*). This report provides projections on numerous economic and agricultural variables, including USDA's production forecasts for a number of U.S. crops. Given the wide availability of information on the farm economy from local, State, and private sources, we want to gauge whether *WASDE* reports provide useful information to participants in agricultural markets. In our estimations, if markets react to the *WASDE* report, then its content could be considered useful. A number of studies have previously tested whether USDA projections of crop production and other agricultural data influence commodity future prices (Adjemian, 2012; Bunek and Janzen, 2015; Lehecka et al., 2014; Falk and Orazem, 1989; Fortenbery and Sumner, 1993; Sumner and Mueller, 1989; Ying et al., 2019). Most of these studies found *WASDE* reports have an immediate impact on commodity futures prices. Both Isengildina-Massa et al. (2008) and Lehecka (2014) found the financial impact of *WASDE* reports grew over time and speculated that uncertainty over USDA policy may have been a contributing factor. Recently, Ying et al. (2019) also found the impact of a variety of USDA reports has grown over time, leading to speculation that the emergence of the internet may have enhanced USDA's ability to influence commodity futures prices.

Past studies measured USDA's impact on market prices in a variety of ways to essentially test whether futures markets react to USDA's information release. Orazem and Falk (1989) developed a regression analysis of soybean futures, as influenced by USDA's August projection of soybean production. Orazem and Falk (1989) additionally addressed the more complex issue of Government revisions and rational market behavior. Adjemian (2012) measured the absolute value of the difference in corn, soybean, and wheat futures the day before and the morning after USDA's publication of *WASDE* reports. Both studies revealed the difference between futures prices was significantly larger than average differences. Using data from 1965 to 1989, Fortenbery and Sumner (1993) obtained similar results for corn and soybean futures after controlling for the existence of the options market. However, Fortenbery and Sumner found no USDA impact using monthly data for 1985–89.

Additionally, a number of studies have tested the impact of USDA forecasts on implied volatility. This volatility is a measure derived from option prices, which can serve as an indicator of expected market price volatility in futures market transactions (Adjemian et al., 2018; Bunek and Janzen, 2015; McNew and Espinosa, 1994; Isengildina-Massa et al., 2008). These studies showed USDA's crop production reports—which include forecasts and estimates, depending on the month of the year—reduced the implied volatility of corn and soybean futures prices on the day a *WASDE* report was released. Ultimately, these studies have shown USDA's release of information into the public domain reduces uncertainty about futures prices.

Each of these studies has helped to address the broader issue concerning the interaction between public information and agricultural commodity markets. Overall, this research suggests widely disseminated public information can influence commodity prices.[3] In particular, USDA analyses can contribute to the price discovery process.[4] Despite the wide range of topics addressed by these studies, several matters remain unaddressed that could help USDA obtain a fuller understanding of the impact its reports have on commodity futures prices.

USDA's Impact: Issues that Remain To Be Addressed

Most preceding studies found USDA projections—also known as forecasts in the literature—can influence commodity prices. So then, what specific information within the *WASDE* report drives the reaction of futures markets? To represent USDA's forecasts, many researchers create a zero-one variable, set to equal one on the date when USDA information is publicly circulated. Researchers have used the zero-one variable as an explanatory variable in their models (Adjemian, 2012)**.** Other researchers tested the impact of a specific forecast, such as an inventory forecast or crop production forecast. For example, Hoffman (1980) tested the impact of USDA's livestock inventory forecasts on cattle and hog prices. Milonas (1987) found that USDA production forecasts influence cash prices for several agricultural commodities. Sumner and Mueller (1989) tested the impact of USDA's production forecast on soybean and corn futures. Karali et al. (2019) and Adjemian and Arnade (2017) tested if the difference in USDA's crop forecast and previous private sector forecasts can affect the futures markets of various foreign markets.

A second question is how long does the impact of USDA forecasts last? A few studies have measured the duration of USDA's impact on futures markets. Using high frequency (i.e., capturing minute changes in price, also known as "tic") data—which can amount to more than a thousand observations per day—Lehecka et al. (2014) provided evidence that the impact of *WASDE* reporting immediately dissipates within an hour. In contrast, Ying et al. (2019) used daily data and found the impact of USDA reports can linger for several days after the *WASDE*'s release. The disparity in results suggests additional research on this topic is needed.

The third issue that remains to be addressed is whether USDA's forecasts benefit market participants. Milacek and Brorsen (2013) measured the profits that traders in corn and soybean markets would have earned if they had received advanced knowledge of USDA forecasts for ending corn and soybean stocks. In Milacek and Brorsen's (2013) article, benefits were based on a hypothetical situation rather than real-world profits—which were likely unavailable. However, just by raising the subject, Milacek and Brorsen illustrated the importance of understanding what economic impacts USDA forecasts could have on commodity market participants.

The fourth issue needing to be addressed is the relation between the accuracy of USDA forecasts and their impact on commodity prices. To our knowledge, there is no peer-reviewed research considering this relationship, although Macdonald (1992) evaluated the accuracy of USDA forecasts and found that forecast errors can vary considerably.

Finally, a fifth issue requiring a more systematic assessment is whether the market impact of the *WASDE* report changes as a crop moves from planting to harvest. Past studies evaluated various monthly forecasts that focused on a period of 2 or 3 months during and immediately prior to harvest, while other evaluations focused on impacts before planting or after harvest (Adjemian, 2012; Fortenbery and Sumner, 1993). Few studies evaluated the impacts of USDA forecasts from the first month of planting (May for corn) through the late harvest price (October for corn).

[3]Arguably, private sector markets are not efficient in the Fama (1970) sense if government forecasts influence that market.

[4]Price discovery plays a role in the formation of the market price.

Evaluating the Impact USDA's Projections of Corn Production: What We Do

This paper addresses each of the issues mentioned above by testing if the *WASDE* report's monthly projection of corn production (from May through October) influences the level and daily variability of the December corn futures contract. The December contract is often viewed as a predictor of the harvest season price.

Our paper makes several contributions to the literature. To partially address the first question,[5] we tested the impact of one key variable: *WASDE*'s projection of the upcoming crop output. We compared the estimated impacts of the crop production forecast and the impacts of the commonly used zero-one variable to represent USDA announcements.[6] To address the second question,[7] we included both a lag of the *WASDE* release date and a lagged-dependent variable. Consequently, we estimated both the duration and magnitude of USDA production forecasts' impact on the futures price of corn. We compared the impacts of the crop production forecast on the daily opening price, daily high price, and daily low price—with the impact on the daily closing price. This comparison allowed us to determine if *WASDE* projections can influence the spread between the daily high and low prices.

To address the third question,[8] we used the estimated impact coefficients to simulate future price changes with and without a *WASDE* announcement. This allowed us to determine if USDA projections move the futures price closer to or further from the final season harvest price, as measured by the monthly average of October futures prices. The *WASDE* report that provides a more accurate forecast can likely provide a more accurate futures price estimation as well. If USDA production forecasts move the futures price closer to the final harvest season price, market participants that rely on the futures price can make more prudent economic decisions.

Addressing the fourth issue,[9] we tested whether the accuracy of past forecasts affects the impact of current USDA announcements. Several authors (Macdonald, 1992; Hoffman et al., 2015) have evaluated the accuracy of the *WASDE* forecasts. To our knowledge, no one has tested if more accurate forecasts enhance the impact of any USDA-released information.

Finally, to address the fifth issue,[10] we evaluated the impact of USDA's monthly corn production forecast on the price level and daily price variability in a systematic fashion, from the planting month of May to the late harvest month of October.

[5]Which elements of the *WASDE* report drive market responses?

[6]The estimated impact of the zero-one variable is obtained from a separate model.

[7]How long does *WASDE*'s impact last?

[8]Do USDA forecasts benefit market participants?

[9]What is the relation between the accuracy of USDA forecasts and their impact on commodity prices?

[10]Does the market impact of the *WASDE* report change as a crop moves from planting to harvest?

Background: USDA's Projection of Corn Production

Several items suggest projections of crop production is a key variable in the *WASDE* report that drive responses in the corn futures market. First, the USDA's nationwide data-gathering network gives the department an advantage over the private sector and State government agencies in collecting corn production data (across the States where corn is grown and aggregating these data to construct a national forecast). Second, McKenzie (2008) showed corn traders would be willing to pay for early access to the August crop production reports. Third, USDA imposed stricter security controls on the *WASDE* reporting process starting in 1985, once the report included U.S. crop production numbers (Fortenbery and Sumner, 1993). This indicates USDA officials believe their projections of crop production can influence markets. Finally, Karali et al. (2019) and Adjemian and Arnade (2017) found the difference between prior forecasts of corn production and USDA projections influence future prices across various commodity markets.

USDA releases projections of annual U.S. corn production each month, beginning in May, through the harvest in September and October. After October, the projections tend to be repetitions of the final production estimate with only occasional revisions. Private firms offer similar forecasts based on their own surveys, satellite imagery reports, and information gleaned from experimental plots (Milonas, 1987). Yet USDA—with access to a nationwide network of statistical, extension, and research agencies, sophisticated information technologies, and data storage systems—may be in a unique position to provide a national view of potential crop outputs.

Production forecasts are released in the *WASDE* report, which includes estimates of a wide number of economic variables (such as prices, stocks, and trade). Multiple USDA agencies work together to obtain a consensus *WASDE* forecast. Initial production forecasts in May and June rely heavily on the *Prospective Plantings* report from USDA's National Agricultural Statistics Service (NASS) for its survey of crop producers on the number of acres they expect to plant for the year. A USDA report on actual planted acreage becomes available at the end of June**.** In July, yield forecasts are combined with the number of acres planted from the NASS *Acreage* report (USDA, NASS, various years). Starting in August, NASS releases its own production forecast, which is equivalent to the *WASDE* forecast released on the same day. Throughout this process, analysts constantly update their forecasts using NASS data, weather reports, forecasting models, and satellite imagery (Vogel and Bange, 1999).

For most of the United States, May is the key month for planting corn. As a result, the production forecast released in June is often like the forecast released in May. In July, weather data that shape yield expectations become available. In August and September, harvest begins in major corn-producing regions. By October—or even September—some definitive harvest numbers are available to USDA analysts.

For this paper, we used USDA's data set of current and past *WASDE* projections (USDA, Office of Chief Economist, 1998–2017) and Chicago corn futures for the December contract (CME Group, 1998–2017). Errors represent the percentage differences (in absolute value) between the USDA forecasts and the final production numbers reported in January (table 1).[11] Forecast errors in May are notably higher than in October—particularly in 2004 when the corn harvest was unusually large and in the drought year of 2012. Similar errors in May and June forecasts reveal that little additional information comes in between these 2 months. There is a slightly smaller error in the July forecast than the June forecast. For most years, August errors are somewhat smaller than those of preceding months. USDA crop forecast errors decrease considerably

[11]Crop production projections can only be based on the information available at the time. This often excludes the impact of unpredictable weather events. So differences between projections and actual harvest numbers should narrow as these events occur throughout the summer and early fall months.

in September and even more so in October for most years as well. There is little change in USDA production numbers from November through April. However, occasional revisions of the final harvest numbers are reported.

Table 1
U.S. Department of Agriculture (USDA) production forecast errors
Corn production forecast and actual production percentage difference of absolute value

	May	June	July	Aug	Sept	Oct
1992	8.08[1]	8.08	9.42	6.08	5.99	4.19
1993	23.49	30.70	20.71	14.15	11.17	7.05
1994	14.73	12.84	10.09	7.95	7.52	4.08
1995	14.26	7.14	5.58	10.14	6.22	2.27
1996	1.17	1.51	1.62	6.16	4.98	2.73
1997	4.88	5.13	3.64	0.89	0.98	0.51
1998	2.03	1.99	2.15	2.48	1.00	0.94
1999	0.98	0.97	1.18	0.25	1.64	0.74
2000	3.22	3.12	0.41	3.14	3.07	1.37
2001	0.31	0.31	0.53	2.92	3.22	1.21
2002	9.38	7.18	8.74	1.30	1.72	0.37
2003	2.17	2.12	0.08	2.08	3.24	0.69
2004	12.62	11.21	9.42	6.97	6.65	1.09
2005	0.43	0.43	2.24	6.18	3.57	1.58
2006	1.85	1.81	0.04	2.15	3.43	1.49
2007	5.68	5.37	2.49	0.87	1.07	1.14
2008	0.87	2.37	2.54	2.23	0.44	0.11
2009	6.87	7.63	4.88	1.24	0.26	0.75
2010	6.21	6.62	5.62	6.58	4.94	0.99
2011	8.85	7.23	9.42	4.91	1.52	1.00
2012	27.48	37.90	20.93	0.50	0.02	0.18
2013	1.07	0.12	0.28	1.61	1.04	NA[2]
2014	3.39	3.28	3.80	2.61	0.08	0.47
2015	0.17	0.17	0.90	0.24	0.50	0.72
2016	5.51	5.23	4.50	0.47	0.87	1.10
2017	3.64	3.52	2.21	2.91	2.70	2.04

[1]For example, in 1992, USDA's May forecast of U.S. corn production was off that year's corn estimate by 8.08 percent. The same forecast was issued in June 1992. Only in August did the forecast of that year's production become more accurate.

[2]No forecast was issued in November 2013 when the Federal Government was shut down.

Source: Calculated from USDA, *World Agriculture Supply and Demand Estimates* data; USDA, Economic Research Service, corn production forecasts; and Chicago Board of Trade data.

In 1992 and 1993, the *WASDE* projections—which represent USDA forecasts—were released at 3 p.m. eastern standard time (EST) on the day of release, after the Chicago Board of Trade (CBOT) closed for the day. Starting in 1994, *WASDE* projections were released at 8:30 a.m. EST in time for the opening of the futures markets. In January 2013, the release time of the *WASDE* projections was moved to noon EST, which is after the opening of the futures market but leaves time for the report to influence prices during the remainder of the day. In our model, we account for this 2013 change by moving *WASDE* variables back 1 (observation) day in the equation representing the opening futures price.

Specifying the Model

Following the example of Orazem and Falk (1989) and Karali et al. (2019), we tested if USDA's monthly release of the corn production forecast influences corn futures. To carry out our test, we specified a system of four futures price equations, each representing a different version of the daily futures price for corn. Each equation includes the USDA production forecast as an explanatory (right-hand-side, RHS) variable, as well as the lagged futures price. Using daily data from 1999 to early 2017, we estimated a distinct model, each representing a different month from May until November. Each monthly model consists of observations on the daily futures price and is specified as:

$$(1)\ Pf_{jit}=\beta_{oj}+\beta f_{ji}\ Pf_{jit-1}+\beta_{kji}*\sum_{k=1}^{n-1}Y_k+\tau_{ji}Vl_{it}+\sum_{r=0}^{3}\alpha_{jit-r}\ W_{it-r}+\sum_{r=0}^{3}\pi_{jit-r}WDM_{it-r}+\gamma_{ji}\ W_{ijt}u_{jik}+\epsilon_{jit}$$

where Pf_{jit} is the daily futures price j for month i and observation t. Observations represent daily data over n years. For example, observation 300 could represent the last daily reported futures price in May 2010 and observation 301, the second daily reported futures price in 2011.[12] The subscript j=1...4 denotes each of the four versions of the futures price, including the daily opening futures price, closing price, daily high price, and daily low price, respectively. Distinct equations are estimated for each version of the futures price. The subscript i=1...6 represents the months May thru October. A separate set of equations is estimated for each month of the year. Each month's model includes four futures price equations, including one for opening, one for closing, one for the daily high, and one for the daily low. Included as an explanatory variable is the one-day lag of the futures price Pf_{jit-1}.[13] Y_k equals one when the observations represent data from a particular year (k) and is zero otherwise. Vl_{it}, represents the volume of corn futures traded on the particular observation, representing a specific day in a particular year. W_{it-r}, is a *WASDE* content variable representing the difference between USDA's projection of corn production and its projection in the prior month. This difference is set equal to the production forecast difference on the day of the announcement and zero otherwise. WDM_{it-r} is a zero-one dummy variable[14] representing the timing of the *WASDE* announcement; otherwise, it is zero. ϵ_{jit} represents each equation's econometric error, which is assumed to be normally distributed.

Subscripts on the *WASDE* content and *WASDE* variable are used to indicate lags. In other words, *Wit-r*, represents lags—1, 2, or 3 days—of the aforementioned *WASDE* difference and timing variables, with *r=0…*3 indicating the number of days that have passed since the announcement day. Preliminary model results reveal that lags beyond 3 days were not statistically significant. The lagged futures price variable and release date lags permit the calculation of long-run elasticities.

The coefficient on the constant term is β_{oj}. βf_{ji} is the coefficient on the lag futures price; β_{kji} is the coefficient on yearly dummy variable; k; τ_{ji} is the coefficient on the volume variable; a_{jit-r} is the coefficient on *WASDE*'s crop output variable; π_{jit-r} and is the coefficient on the *WASDE* crop timing variable, both with daily lags representing r=0, ..3.

Also included in the model is the term $W_{itk} * u_{ik}$ which represents an interaction term between the USDA announcement variable and u_{ik}. The variable u_{ik} is a weighted average of the absolute value of the errors of past years' projections of USDA corn production, going back 3 years. To account for memory decay, last year's crop projection error was given a weight of 0.5, 2 years ago a weight of 0.3, and 3 years ago a weight of 0.2

[12]Each first monthly reported price is reserved for the lagged-dependent variable also occurring on observation 301.

[13]The first observation of each month is dropped from the model to ensure that lagged futures price does not represent a final price from the previous year.

[14]The zero-one dummy variable is equal to one on the day of the *WASDE* announcement; otherwise, it is zero.

when creating the forecast error u_{ik}.[15] Including this variable in our model makes it possible to test if there is a relationship between the accuracy of past USDA reports and the impact of current USDA forecasts on futures markets. The coefficient on the interaction variable for the *ith* month is $\gamma_{f,i}$ (i.e., i=1…6, May, June… October).

Equation 1 is used to estimate a system of four equations, each representing different versions of the futures price. Estimating distinct equations for the daily opening price, daily closing price, daily high price, and daily low price allows us to use one set of regressions to examine the impacts of the *WASDE* forecast on both prices and daily price variability. That is, differences between the forecast's impact on the daily high price and its impact on the daily low price will provide some insights on the forecast's influence on price variability within the trading day.

What Equation 1 Means

In equation 1, the USDA production variable (W) is set equal to zero each day of the month, except the day of the announcement—and for 3 days following the announcement when we test for lagged impacts—when the variable is replaced by *WASDE's* crop projection. The USDA timing variable is set equal to zero each day of the month and set equal to one the day and the 4 following days that represent lagged impacts of the announcement. The projected number is represented by the difference between the current projection and the USDA's projection in the previous month.[16] For the first forecast month in May, this difference between projections is represented by the difference in the May projection and the previous crop year's final output, as reported in April. If the monthly difference variable is significant, it would reveal the content of USDA's projection of crop output has an impact on commodity prices. However, in some months, spillover effects from variables possibly related to the difference in *WASDE's* projected crop outputs—such as stocks—could influence USDA's estimated-impact coefficients.

It may be useful to evaluate what equation 1 means. The dependent variable is the daily futures price in a respective month for the December futures contract price. In May, the dependent variable equals the 5-month-ahead forecast for October's corn harvest price.[17] On the right-hand side of the equation is a lagged futures price, representing the previous day's futures price. The projection of corn production represents the difference between the current USDA projection and its projection in the previous month. This variable equals zero except on the days of USDA's announcement. Ultimately, equation 1 implies that changes in the futures price are a function of several exogenous factors. Some of these changes include changes in USDA's projection of corn production and USDA's release date, which effectively serve as a proxy for all other variables contained in the USDA's *WASDE* report.

USDA's *WASDE* report is released on a particular day each month that varies based on the respective month. Between monthly *WASDE* reports, new information—perhaps even new crop projections—is made available from other sources in the private markets. The lagged futures price in equation 1 represents this updated information. If the futures market deems private projections of crop output relevant, it will influence or be absorbed in each day's futures price. If markets are efficient, the lagged futures price is the market's prediction

[15]Several other weighting schemes were experimented with. More in-depth investigation of ways to weight past errors from past *WASDE* output projections lies outside the scope of this paper.

[16]We estimated two sets of price equations, one with the USDA production forecast and one with the difference between USDA's current forecast and the previous month's forecast.

[17]USDA defines the harvest price as the average value of the December contract in the month of October. However, we also experimented with using the delivery price of the December contract as the harvest price and the average price in the last week of November—when most participants rollover to a new futures contract—as the harvest price. The results were not dramatically different across the three different harvest price definitions. In the end, we stuck with using USDA's definition of the harvest price.

of the subsequent days' futures price (Fama, 1970). Thus, contained within equation 1 is the efficient market forecast for the corn futures price.

If the coefficient on the lagged futures price is 1 and the coefficients on the other variables 0, the market is efficient. Under these circumstances, the market would have anticipated any new information contained in the *WASDE* report. However, if the *WASDE* coefficients are not 0, and/or the coefficient on the lag futures price does not equal 1, then it reveals that markets act as if USDA has information that other sources do not have. That is, equation 1 contains two sources of updated information, the lagged futures price and the monthly *WASDE* report. If both are statistically significant, then USDA can be viewed as producing a subset of new information on the day of the *WASDE* release.

Observations where the production forecast difference variable equals zero represent observations where no new information from USDA is available to the public. Yet even this may have an influence if the market's own expectations evolved since the last *WASDE* report was released. Our specification highlights two possible channels that could affect the futures price, even when no new USDA information is available.

Finally, the estimated coefficient on the lagged futures price can demonstrate how long the impact of USDA's announcement remains embodied in the futures price. This lag effect is restricted by a geometric decay. To add more flexibility in measuring the impact lags of the USDA announcement variable, daily lags of each *WASDE* variable are included in the model.[18]

[18]To handle moving the *WASDE* release to noon EST, we set the *WASDE* impact and lag variable back by one observation. The estimated coefficients on the high and low variable—on average—reveal whether the impact occurred before or after 12:30 p.m. EST.

Affordances of Our Approach

Most impact analyses of USDA forecasts use a dummy variable to represent the date of the *WASDE* report's release as an explanatory variable. Since forecasts of numerous variables are contained within this report, a dummy variable cannot identify which forecasted item influences market prices. Our specification includes both a dummy variable indicating the date of release and a variable representing the content of USDA's projection of each annual season's corn production. In other words, it represents the difference from the projection in the previous month. If this content variable is significant in a model that includes a dummy variable representing the release date, then we know the content of the projection of corn production is a key feature that influences futures prices.[19]

Impact and Duration

Our specification is designed to test market memory in several ways. First, we included a lagged-dependent variable. The estimated coefficient of this variable reveals how long the impact of USDA's announcement remains embodied in corn's futures price. However, this variable alone restricts the lag impacts to follow a geometric decay. Second, to allow for less restrictive lag, we also included lags of the USDA announcement variable as explanatory variables, which allows our model to have more flexibility in determining the true relationship. Third, we estimated separate equations for the daily opening, daily closing, daily high, and daily low futures prices. This allowed us to obtain evidence of whether the impact of USDA's forecast announcement declines within the trading day on which the *WASDE* report is released.

Impact Versus No Impact: Possible Market Benefits

The closer the release of the *WASDE* report moves the futures price to the final price, the greater the benefit to market participants who rely on the futures price to make decisions. After estimating monthly futures price equations, we removed USDA's impact on corn futures by setting the coefficients of the USDA variables to zero. This creates a data series representing what the futures price would be in the absence of a *WASDE* report's projection of corn production. We measured the difference between this hypothetical futures price and October's harvest price. We then compared the abilities of observed futures prices and the alternate price series—stripped of *WASDE*'s impacts—to forecast our harvest price. The difference between these two forecasts revealed the degree that USDA's crop forecast can improve or worsen the ability of the futures price to predict each season's harvest price.

In carrying out this analysis, we compared the futures price forecast accuracy with a hypothetical futures price that prevails in the absence of the *WASDE* report's production forecast. This comparison revealed the extent that the USDA forecast moved each month's futures contract prices toward (or away from) the October harvest price. Specifically, we represent each month's futures price (May through October) only over the days following the *WASDE* announcement. For example, suppose a USDA forecast was released on May 12. We compared the actual futures price (with a USDA forecast) and its fitted value (in the absence of a USDA forecast) from May 12 through the end of May. A similar procedure was applied to each month's futures price from June to October. Next, we measured how far these two versions of May's futures price are from the harvest price. We then measured how far the June price is from the harvest price, how far the July price is from the harvest price, and so on until we reach October.

[19]There often is a mistaken belief that the ever-changing production forecast would be collinear with a constant dummy variable.

Impact and Accuracy

To analyze the impact of projection accuracy on futures prices, we created a weighted, 3-year sum of the *WASDE* report's past forecasting errors to test if the forecasts' market influence can be influenced by previous forecasting errors. We created a distinct error variable for each month. For example, we took the absolute value of the difference between USDA's May production forecast and that year's actual production level. Then, for observations representing the year 2008 in May, we created a weighted, 3-year sum of the absolute value of USDA's forecasting error for 2007 (with a weight of 0.5), 2006 (with a weight of 0.3), and 2005 (with a weight of 0.2).[20] The interaction of the weighted forecasting error and USDA's current production forecast served as an explanatory variable in our May model. We applied a similar procedure to each of the months. If this interaction term was significant, it would suggest the accuracy of past USDA forecasts influences the current forecasts' impact on future prices.

Impacts, Month By Month

Most USDA impact studies estimated separate models for each month to account for the dissimilar time variables for each month's forecast. For instance, May's futures price forecast is a 5-month forecast, whereas September's futures price forecast is a 1-month-ahead forecast. Incorporating all months into a single model could incorrectly amalgamate different dependent variables into one data series. We started by estimating a model using 19 years of daily data for the month of May, accounting for all years since the production forecast was first released. To confirm any differenced variable in the model did not differ across 2 separate years, we began each year with the second observation in May. Subsequently, we estimated models for the remaining months from June to October. We did not estimate models for November or December because USDA customarily does not change production forecasts for these months.[21]

Impacts and Price Variability, What We Do Different

Several preceding studies have evaluated the impact of USDA forecasts on implied futures volatility (McNew and Espinosa, 1994; Isengildina-Massa et al., 2008; Adjemian et al., 2013). Implied volatility is embodied within options contracts (Beckers, 1981; Christensen and Prabhala, 1998). Implied volatility measures the anticipated price variability, as well as the responses to unanticipated information (Fackler and King, 1990). Yet Christensen and Prabhala (1998) showed that implied volatility is often a poor predictor of realized price variability in futures markets.

Our four equation specification allows us to measure *WASDE* futures market impacts and test how *WASDE* impacts the daily price spread—or the difference from each day's high price and each day's low price. Previous studies either tested the impact on future prices or some measure of variability of future prices but never both in one study. Our study is unique because it tests both aspects within one model. As an alternative to testing impacts on implied volatility, we evaluated the impacts of the *WASDE* reports on the spread between the daily high futures price and the daily low futures price, which is a measure related to daily price variability.

To test these aspects, we first took actual futures prices with *WASDE* impacts and our hypothetical futures price stripped of *WASDE* impacts—as described in the preceding "*Impact and Duration*" section. For each series, we took the difference between the high and low price for the price series with *WASDE* impacts and

[20]No formal criteria were used to determine weights, only that older forecast errors were weighted less. Varying weights did not appreciably change the estimated coefficients of the model.

[21]On a few occasions, there is a revised production estimate in the spring.

also for the alternate price series, which was stripped of *WASDE* impacts. We then calculated the ratio of these two differences. In table 5, we reported the measured spread ratio of these two positive differences and represented these ratios as percentages. The numerator of this ratio is the spread between the daily high and low price that has had the USDA impact removed. The denominator represents the same high-low spread of a price series that accounts for the USDA impact. For example, the number of 85.7 for June shows that without *WASDE*'s impact (on day 1), the spread between the high and low price would be 14.3 percent lower. In contrast, the August number of 117.6 shows the spread would be 17.6 percent higher without *WASDE's* impact.

The spread ratio can reveal whether the USDA announcement has increased or decreased the daily spread between the daily low and daily high prices. A ratio greater than 100 suggests that without a USDA forecast, the daily price spread would be higher.

Estimation and Results

Estimation

We used the specification in equation 1 to estimate a system of equations representing daily prices: opening, closing, high, and low. We estimated the system of equations using seemingly unrelated equations (SUR) with data from 1999 to 2017.[22] We estimated the system over 2 categorical periods: 1999–2013, when USDA forecasts were released at 8:30 a.m. EST, and 2013–17, when USDA released its forecast at noon EST. We estimated separate systems for each month from May to October. The trading volume variable may be related to other RHS variables in the model, creating multicollinearity, which would distort regression statistics. To account for possible multicollinearity among the USDA forecast variables and trading volume variables, we regressed the daily trading volume on other RHS variables, including the USDA forecast variable. The error of this regression represented the impact that trading volume variables—free of any USDA influence—may have on the futures price. This ensures the RHS USDA forecast variable is not collinear with any variable. The error of the regression also allows the USDA forecast variable to account for both a direct effect on futures market prices for corn and an indirect effect arising from any influence that USDA's announcement has on trading volumes.

There were approximately 420 observations in each monthly model. With a 4-equation system and 24 exogenous variables, this combination of observations, equations, and variables creates approximately 1,584 degrees of freedom[23] for each monthly model we estimated. System R2's for every estimated monthly model above show the *WASDE* variables—such as volume variables and interaction variables—were statistically significant and belong in the model estimating the *WASDE* impact on corn futures (table 2).

To test if the release of the *WASDE* report's production forecast has an impact on corn futures, we restricted the coefficients on the *WASDE* output projection variables to be zero. We then used a likelihood ratio test (Greene, 2002) to determine the significance of this "no impact" restriction. When USDA's production forecast was represented by the difference from the previous announcement, the resulting *Chi* squared (χ^2) distributed test statistic was significant at the 0.01-confidence level for every month (except September) for both the model estimated over the entire period and the model estimated for the period 1999–2017 (table 2). Thus, we are 99 percent confident that USDA's release of a new production forecast influences corn futures prices for 5 months of the year.[24] For the model covering the 2013–17 subperiod—when USDA *WASDE* reports were released at noon—USDA's forecast variable was only significant in June and October.

Tests using USDA's forecasted levels of output as an explanatory variable were not reported. This variable came out significant in about a third of the conducted tests. The contrast between found test results—or the level of forecasted production versus the difference in forecasted production—implies new information in USDA forecasts influences corn futures markets.

[22]Prior to estimating each monthly model, we applied unit root tests to corn futures data. Applying the most general version of the augmented Dickey-Fuller test (Greene 2002) using the opening price for each month, we rejected the null hypothesis that future prices for corn were nonstationary (had unit roots) at the 0.01 confidence level for the May, July, August, and October models. We rejected unit roots at the 0.05 confidence level for the September model. The test result for the June model was right on the boundary at the .1 confidence level. From this, it was clear each model could be estimated, with level data, without distorting estimated coefficients or test statistics.

[23]Degrees of freedom can be defined as the number of independent pieces that went into estimating our model.

[24]All lags of the USDA forecast were jointly tested. For most months, the USDA announcement was significant up to 3 days (equal to three lags) after the announcement.

Table 2
Testing select exogenous variables

			Whole period		Before 2012		After 2011	
Month	Variable[1]	Degrees of freedom (Df)	χ^2(.)[2]	Sig[3]	χ^2(.)	Sig	χ^2(.)	Sig
May	USDA	20	38.0	0.01	53.4	0.01	6.1	NS
June	USDA	20	72.0	0.01	104.0	0.01	32.0	0.05
July	USDA	20	214.0	0.01	156.0	0.01	17.0	NS
Aug	USDA	20	40.0	0.01	61.0	0.01	21.6	NS
Sept	USDA	20	20.1	NS	20.5	NS	10.2	NS
Oct	USDA	20	43.1	0.01	67.6	0.01	44.0	0.01
		Df	χ^2(.)	Sig	χ^2(.)	Sig	χ^2(.)	Sig
May	Inter	4	10.7	0.05	8.4	0.10	3	NS
June	Inter	4	32.0	0.01	13.6	0.01	10	0.05
July	Inter	4	26.0	0.01	25	0.01	12	0.05
Aug	Inter	4	33.1	0.01	31.2	0.01	8.4	0.10
Sept	Inter	4	3.9	NS	0.6	NS	0.4	NS
Oct	Inter	4	1.5	NS	4.0	NS	20	0.01
		Df	χ^2(.)	Sig	χ^2(.)	Sig	χ^2(.)	Sig
May	Vlm	4	20.2	0.01	12.0	0.01	32.0	0.01
June	Vlm	4	6.6	NS	7.0	NS	6.6	NS
July	Vlm	4	16.6	0.01	22.0	0.01	16.0	0.01
Aug	Vlm	4	18.1	0.01	8.2	0.10	2.0	NS
Sept	Vlm	4	7.8	0.10	11.7	0.05	14.8	0.01
Oct	Vlm	4	7.0	NS	10.2	0.05	6.2	NS

[1]U.S. Department of Agriculture (USDA) is the production forecast variable, Vlm is the right-hand-side trading volume, and inter is the interaction term between the USDA forecast and a weighted average of the USDA (production) forecast error over the past 3 years.

[2]χ2 is a Chi sq. statistic for the log likelihood ratio test. A system of four futures price equations and the coefficients on selected variables were set equal to zero. For example, the likelihood ratio test uses the difference between the restricted and unrestricted system of equations to determine if the joint impact of all USDA production variables forecast any variables that improved the performance of the estimated system of equations (see Green, 2002).

[3]0.01, (0.05) significant at the 0.01 (.05) confidence level or 99 percent (95) percent confidence that variable is significant. NS stands for "not significant".

Source: Calculated from USDA, *World Agriculture Supply and Demand Estimates* data; USDA, Economic Research Service, corn production forecasts; and Chicago Board of Trade data.

Testing Content and Timing

To answer our first question,[25] we tested whether a model using USDA forecast differences is distinct from the more common approach of using a zero-one variable—also known as a time variable—to represent the USDA announcement (see "Impact Date Versus Content"). We estimated a model specified with both a zero-one variable—including three lags—and a forecast difference variable—also including three lags. Although both variables are zero on the date of the report's release, the time variable is always one or zero. The forecast difference variable can be any value—either positive or negative—when it does not equal zero. We tested each representation of USDA's forecast announcement by dropping tested variables in every equation. A log likelihood ratio test of the zero-one variable was not statistically significant in May and June. In July and August, the zero-one variable was significant at the 0.01 level—or the 99 percent confidence level. Additionally, in September and October, the zero-one variable was only significant at the 0.1 level—or 90 percent confident. When both USDA variables were included in the zero-one and forecast differences models, log likelihood ratio tests found forecast differences were significant at the 0.01 level—or 99 percent confidence—for every month of the growing harvest season. Interestingly, including the zero-one variable generated statistically insignificant changes to the coefficients of the forecast difference variables. These broader specification tests suggest the *WASDE* report's corn production forecast is a crucial variable in influencing the corn futures market. However, for some months, there are other USDA forecasts that influence futures markets.

These specification tests demonstrate how USDA's crop output projection variables apply to each monthly model. Since the *WASDE* variable was consistently significant, we focused on the model that includes the differences between USDA's projection of crop output.

Measuring the Impact of the USDA Announcement Variable and its Duration

One notable result is that an increase in the *WASDE* report's corn production forecast has a downward impact on the price of corn futures. Among all our results—within the three sets of 6-monthly models with four equations per month—corn futures fall as the production forecast rises. However, there are a few instances—particularly in the month of June—when a higher production forecast does not lead to a decline in the futures price.

Long-run elasticities estimate the cumulative effect of the *WASDE* report's corn production forecasts on futures prices (table 3). Cumulative impacts are based on coefficients on the day of the release and three lags, which answers the second question.[26] Three sets of monthly elasticities are reported for three periods: 1999–2017, 1999–2012, and 2013–17.[27] Elasticities represent the futures price response to percentage changes between the difference of each month's forecast and the previous month's forecast.[28] Table 3 illustrates how the impacts of corn production forecasts vary by month. Most elasticities fall within the 2–4 percent range or from -0.02 to -0.04**.** Over the whole period, the elasticities in September and October were considerably larger than in earlier months. For example, in October, the elasticity on the opening price was -0.134, and in September, the elasticity on the high price was -.061. This makes sense given that USDA's forecasts are more accurate in the September and October harvest months. Notably, prior to 2013, the impact of May's corn production forecast is larger than over the subsequent months. May's corn production forecast is the first one

[25]Which elements of the *WASDE* report drive market responses?

[26]How long does *WASDE*'s impact last?

[27]Long-run elasticities represent the sum of the USDA variable at impact and three lags and account for each day's diminishing effect through the lagged dependent variable.

[28]An elasticity of 4 percent means that a 10-percent increase in the monthly difference of USDA's corn production forecasts lowers the price of corn by four-tenths of 1 percent.

to be issued during the year. Markets receive the first information about the potential size of that year's crop from May's forecast, which might have a more powerful effect on futures prices than subsequent forecasts.

One anomaly in the estimated elasticities concerns the June forecast. Prior to 2013, June's impact on three out of four representations of the futures price was abnormal; higher production forecasts increased the corn futures price. After 2012, June's impact had a large downward impact on three of the four corn futures prices. Most often, there is little new information concerning the corn crop between May and June. For example, before 2013, there were only 5 years in our sample when the June forecast was different from the May forecast. From 2012 onward, 2013 was the only year June's forecast was dissimilar from May's forecast. Therefore, the impact response for June is contingent on a few forecasts and could be dominated by one unique event.

The impact of USDA's corn production forecasts on different representations of the futures price varies considerably.[29] For example, in the months before August 2013,[30] the closing price elasticity equaled -0.073, and the opening price elasticity equaled -0.179. This suggests some of the continued impacts dissipate during the trading day. Additionally, the daily low price for the corn futures price impacted the price of the corn futures more so than the daily high price did. However, in September, USDA's *WASDE* forecast influenced the daily closing price almost twice as much as the forecast influences the daily opening futures price. Consequently, the *WASDE* forecast influences the daily high price more so than the daily low price in September. Overall, the results indicate USDA's production forecasts have a significant yet small impact on futures prices. Moreover, forecast impacts remain embodied within corn futures prices for several days and—at times—for several weeks before the impact of the forecasts dissipates. Notably, futures markets respond somewhat differently after 2012 since the USDA changed the time that *WASDE* reports were released from 8:30 a.m. to noon EST.

Overall, the *WASDE* impact elasticities are small yet statistically significant. One reason for this is that some of the changes in the USDA forecast may have been accounted for by the lagged futures price variable, which represents all relevant information the market received after the previous *WASDE* report. The key point is, even when accounting for private sector updating, USDA reports have an impact large enough to indicate UDSA reports contain information that the private sector does not have.

Does USDA's Impact Make Future Prices a Better Predictor of the Harvest Price?

Table 4 provides answers for our third question.[31] The first column of table 4 reports the absolute value of the difference between each month's average futures price and the harvest season price. Averages only were taken over the remaining days of each month after the release of the *WASDE* report. Each monthly measure was then averaged across all years. Differences are reported in percentage terms. The second column of table 4 reports the same percentage differences when the impact of the corn production forecast on the futures price is removed.

A comparison of these differences, reported in the third column, shows to what extent the release of USDA's forecast improves the ability of the futures market to predict the October harvest price (table 4). For example, over an approximately 2-week period following the release of the *WASDE* report, the May futures price—on average—was 22.62 percent further from the October harvest price (table 4). The September price was 8.9 percent off the October harvest price (table 4).

[29]A likelihood ratio test of the equation strongly rejected the restriction that impact coefficients were equal across equations (opening, close, high, and low).

[30]Prior to 2013, the opening price was the first price to be exposed to USDA's forecast.

[31]Do USDA forecasts benefit market participants?

The second column of table 4 indicates a hypothetical price that represents what each month's forecast of the December price would have been had there been no USDA production forecast. In May, without USDA's forecast, the average futures price at closing would have been 23.63 percent off the harvest price instead of being 22.62 percent off. On average, the forecast's impact on the futures price moved May corn futures 1.01 percent closer to the harvest price.

The difference between the actual and hypothetical forecast accuracy at closing is 1.01 percent in May, 4.08 percent in June, 0.02 percent in July, 1.11 percent in August, and 3.56 percent in September (table 4). Interestingly, even though the June forecast often contains little new information beyond May, it has a bigger impact in moving prices in the direction of October's harvest prices. Overall, table 4 indicates the USDA corn production forecast improves the ability of the futures market for corn to serve as a forecasting tool and benefits market participants relying on futures prices to make decisions.

Testing If Accuracy Influences Impact

To answer our fourth question,[32] we tested if the errors from past USDA forecasts influence the impact of a current USDA forecast on corn futures. Prior to 2013, the interaction term—consisting of errors from previous USDA forecasts and the current USDA announcement—indicated that May, June, July, and August models were significant at the 0.01 confidence level (table 2). However, the interaction term was not indicated as significant in the September and October models. The September and October models' statistical insignificance was due to USDA's September and October corn production forecasts often containing harvest information. Additionally, forecast errors were notably smaller for these two months. After 2012, the interaction term was significant at the 0.05 level in June and July, the 0.10 level in August, and the 0.01 level in October.

The significance of the error interaction variable suggests past forecast accuracy influences the impact that the *WASDE* report's production forecasts have on corn futures prices. However, the impact magnitude of the error interaction term on future prices was small. Elasticities reported in table 3 have incorporated the error effect on *WASDE* impact when past errors were considered. Notably—when calculating these elasticities—we found the larger the May and September forecast errors were, the more the impact of the May and October reports increased. In May, the impact of past errors was mixed. However, in August—a month when some key data from USDA becomes available to the public—large projection errors from the past projections generated significant reductions in *WASDE* report impact, which effectively reduced the *WASDE*'s opening elasticity from -0.045 to -0.019. It appears markets can tolerate errors early on in May, and the markets are less tolerant of projection errors later in August.

USDA's Impacts on Daily Price Variability

Our variability measure refers to the spread of futures prices within a trading day—also known as the spread ratio (table 5). The spread ratio represents the ratio of the absolute value of the difference between the daily high and daily low futures price. The numerator of this ratio is the spread between the hypothetical daily high and hypothetical daily low price, with the impact of the USDA projection of corn production removed from the calculations. The denominator of the measure is the same high-low spread of a price series, which includes the USDA projection's impact in the denominator spread. A ratio greater than 100 means that, without USDA's *WASDE* forecast, the daily spread between high and low prices would be higher (table 5).

The first column in table 5 represents the spread ratio on the day of the projection's release, the second averages the spread ratio over the day of release and the following day, the third averaged over the day of the

[32]What is the relation between the accuracy of USDA forecasts and their impact on commodity prices?

release and the following 3 days, and the final column over 7 days after the release date. The top-third rows of table 5 report the spread ratio averaged across all years of the sample. The middle-third rows represent the spread ratio averaged over the years in the sample prior to 2013.

According to the findings in table 5, prior to 2013, USDA releasing its corn production projection increased the spread between the daily high and low price in the months of May, June, and July. Without reliable potential yield data, market participants may skeptically perceive new information. Conversely, the August and September forecasts decrease the high-low spread, resulting in a spread ratio greater than 100. Moreover, 7 out of 8 spread ratios in the months of August and September exceed 100 (table 5). By day 4, after the USDA projection release, the ratio is substantively higher than 100 (table 5). For example, in September, the 4-day average spread ratio of 111.6 means that the spread would be 11.6 percent wider in the absence of the USDA forecast. From 1999 to 2013, USDA's October forecasts reduced the daily high-low spread measure of 188.9, indicating the USDA impacts reduced the spread by 88.9 percent for the first 2 days following the forecasts. Additionally, after 8 days, the spread ratio was 124.2, indicating the release of USDA's *WASDE* report—on average—reduced the spread between the daily high and low price by 24 percent.

The spread ratios after 2012 represented in table 5 indicate a different pattern than the pre-2013 high-low spread ration findings. USDA's corn production forecasts created a similar reduction in the high-low spread in August and had an even stronger impact in September, resulting in spread ratios well over 100. In October, USDA's impact initially increased the spread. However, the 4-day and 8-day averages' impact on the high-low spread was neutral. USDA information neither creates nor reduces uncertainty. This finding may represent the impact of internet accessibly circulating corn data and crop projections. By October, markets may have absorbed information about the actual harvest from other public sources other than the USDA *WASDE* projections.

Table 3

U.S. Department of Agriculture (USDA) impact of futures price

Long-run elasticities[1,2]					
Whole period					
	Open[3]	Close	High	Low	Days to delivery
May	-0.020	-0.014	-0.008	-0.017	152
June	-0.015	-0108	-0.083	-0.054	132
July	0.003	-0.001	0.014	-0.015	11
August	-0.045	0.000	-0.027	-0.017	89
September	-0.032	-0.055	-0.061	-0.056	67
October	-0.134	-0.194	-0.318	-0.209	46
Before 2013					
	Open	Close	High	Low	Days to delivery
May	-0.053	-0.040	-0.036	-0.055	152
June	0.380	0.016	0.048	0.340	132
July	-0.012	-0.004	0.051	-0.091	11
August	-0.179	-0.073	-0.084	-0.156	89
September	-0.065	-0.110	-0.117	-0.106	67
October	-0.056	-0.100	-0.121	-0.099	46
After 2012					
	Open	Close	High	Low	Days to delivery
May	-0.010	-0.008	-0.002	0.005	152
June	-0.014	-0.118	-0.012	-0.503	132
July	-0.102	-0.107	-0.069	-0.122	11
August	0.031	0.042	0.044	-0.003	89
September	-0.012	0.187	-0.034	-0.015	67
October	-1.345	-1.019	-2.159	2.255	46

[1]For example, in May, on average over all years, if the change in the USDA forecast rose by 100 percent (or doubled) from the previous forecast, forecast prices would decline 2 percent.

[2]We used repeated substitution into the lag-dependent variable, up to the final day to delivery, to generate the long-run elasticity. For every month but September and October, this was equivalent to standard long-run elasticity, represented by the impact elasticity over one minus the coefficient of the lagged-dependent variable.

[3]Open is the opening price; closing, daily high price, and daily low price are self-explanatory.

Source: Calculated from USDA, *World Agriculture Supply and Demand Estimates* data; USDA, Economic Research Service, corn production forecasts; and Chicago Board of Trade data.

Table 4

Percent difference in corn futures and October harvest price

December futures contract

	With USDA	Without USDA	Gain in accuracy
May	22.62[1]	23.63[2]	1.01[3]
June[4]	17.33	21.51	4.18
July	12.84	12.82	-0.02
August	12.00	13.11	1.11
September	8.90	12.46	3.56

[1]May corn futures, on average, are 22.62 percent different than the October harvest price in the period following the U.S. Department of Agriculture (USDA) announcement.

[2]Without a USDA announcement, May corn futures, at opening, would have been 23.63 percent different than the October harvest price when averaged over the same period.

[3]The impact of the USDA announcement, on average, led the May futures price to be 1.01 percent closer to the October harvest price.

[4]Monthly average: from the day of the USDA announcement day until the end of the month. Each month's forecast error has been averaged over all years from 1992 to 2017.

Source: Calculated from USDA, *World Agriculture Supply and Demand Estimates* data; USDA, Economic Research Service, corn production forecasts; and Chicago Board of Trade data.

Table 5

Ratio of price spreads

Without U.S. Department of Agriculture (USDA) impact relative to with USDA impact[1]

1992–2017	Number of days since WASDE announcement			
	Day 0[2]	Day 2	Day 4	Day 8
May	99.8	103.8	100.3	98.1
June	85.7	100.1	88.5	97.7
July	78.4	93.1	94.1	98.5
August	117.6	109.1	105.6	102.6
September	100.7	110.0	113.0	107.4
October	126.8	176.7	138.0	120.6
Before 2013				
May	80.7	94.8	96.5	98.5
June	84.4	101.4	88.7	97.8
July	72.0	91.0	92.4	97.9
August	117.0[3]	108.8	106.6	102.9
September	99.4	101.4	111.6	107.4
October	131.6	188.9	143.5	124.2
After 2012				
May	149.7	127.2	110.2	97.0
June	92.2	98.8	87.0	97.6
July	100.2	102.2	101.0	100.6
August	119.1	110.1	103.0	101.5
September	105.5	143.4	120.2	107.2
October	89.2	90.9	100.4	100.2

[1]Spread ratio: The numerator is the absolute value of the difference between the daily high and daily low price when the impact of USDA's forecast on futures prices has been removed. The denominator is the same measure when USDA's impact on futures prices is accounted.

[2]Day 0 represents the spread ratio the day of the announcement; day 2 represents the spread ratio averaged over the announcement day and following day; day 4 is averaged over announcement day and 3 days after the announcement; and day 8 is averaged over announcement day and 7 days after the announcement.

[3]For example, the ratio of 117.6—August on day 0—means the spread between the daily high and daily low price would be 17.6 percent higher without USDA's announcement. In contrast, a ratio of 85.7 means that the USDA announcement increases the spread by 14.3 percent.

Source: Calculated from USDA, Economic Research Service (ERS) calculations using USDA, *World Agricultural Supply and Demand Estimates* data; USDA, Economic Research Service, corn production forecasts; and Chicago Board of Trade data.

Comparing Study's Findings to Other Studies

Impact on Price Levels

Orazem and Falk's (1989) estimated elasticity of soybean futures' reaction to USDA August production forecasts was -0.08. Orazem and Falk's finding was similar to our estimation for July's daily low price and August's daily closing and daily high price for corn futures before 2013. Our September and October elasticities were slightly higher. Using data from 1965 to 1989, Fortenbery and Sumner (1993) found the price reaction to the *WASDE* report release was significant. However, zeroing in on monthly data from December through July over the period 1985–99, Fortenbery and Sumner (1993) did not find evidence of a significant price reaction to the USDA forecast release. The authors argued that by 1985, market participants might have become sufficiently aware to anticipate USDA's forecast, thus implying markets had become efficient in the Fama (1970) sense. Yet, our 1992–2017 data indicate there is hardly any change in USDA's corn production forecasts from November through April. This lack of variation over these months may explain why Fortenbery and Sumner's post-1985 findings differed from our price response estimates.

Adjemian (2012) tested USDA's impact on the difference between the closing futures price the day before the *WASDE* report's release and the opening price the day afterward. Although Adjemian calls this a variance measure, it is actually a measure of the report's impact on futures prices. Like Adjemian, we found USDA forecasts impact futures markets. In his empirical analysis, Adjemian used a dummy variable to indicate the *WASDE* report's release date and did not distinguish between new and old information. When using a dummy variable to represent the release date, we found the forecasts occasionally influenced the futures price. However, when we represented the forecasts by the difference between the current month's forecast and the previous month's forecast, we found a consistent and significant impact on futures prices. Similarly, Karali et al. (2019) found corn futures react to the difference between USDA's production forecast and the latest private sector forecast, particularly in October and November. Adjemian and Arnade (2017) previously studied the market effects of this difference and found it impacted several foreign markets as well. Similarly, Adjemian and Arnade consistently found a strong market reaction to this difference in October.

Using high frequency (or "tic") data, which produced thousands of observations each trading day, Lehecka et al. (2014) found evidence of the USDA's production forecast impact on future prices immediately dissipates. However, in our study, we found—in some cases—a 3-day lag of the announcement variable was significant. Estimated coefficients of the lagged dependent variable in our futures equations revealed the impact of the forecast's release affected the futures price for up to a week. This finding is similar to the lagged response found by Yin et al. (2019). By using a lagged dependent variable, we found USDA's corn production forecast continued with a small but discernable impact for 10 to 14 days after the forecast's release.

Impact on Daily Variability

We found the corn projection's release significantly reduces the difference between the daily high price and daily low price in the early harvest months of August and September. Our September and October results align with McNew and Espinosa's (1994) findings. McNew and Espinosa (1994)—focused on September and October—found implied volatility declined up to 4 days after the release date. Our results are also consistent with Isengildina-Massa et al. (2008), who found frequent drops in implied volatility for September and October. Notably, our results align with studies that used a very different measure of variability, yet our results also indicate the forecasts released in September and October reduce market uncertainty as well as the variability of futures prices.

Conclusion

Many studies have found the futures market responds to USDA's release of agricultural forecasts into the public domain, as published in the monthly *WASDE* report. However, USDA's ability to provide the market with unique information is arguable as alternative information sources have become available on the internet. Using data from 1998 to 2017, we evaluated the impact of USDA's corn production projection release on the price of corn futures. Corn production takes place in multiple States across the country, and USDA analysts have unique access to information from every corn producing State in the United States.

Overall, we found USDA's projection of corn production influences the futures price of corn. We found, in general, the larger the change in the projected corn harvest, the more the futures price falls. However, the impact was small. Long-run impact elasticities tend to be in the range of -0.02 to -0.04. These long-run elasticities mean it would require a 100-percent increase in the production forecast's change to reduce the futures price by 2 to 4 percent. We also found projections released in August, September, and October reduce the daily variability of corn futures prices—or a measure of market uncertainty—while the forecasts issued in May, June, and July had a less defined impact on daily variability.

Our study expands the literature in several ways. First, we tested whether USDA's projection of corn production can influence four distinct versions of the daily futures price: at opening, at closing, the high price, and the low price. We found significant differences regarding impacts on each version of the futures price. Second, we tested whether the level of the projection or the difference between the current USDA projection and the previous projection has a greater impact on corn futures. We found forecast differences consistently influence the futures price but that forecast levels only occasionally influence the futures price. Thus, futures markets do indeed respond to new USDA information. Additionally, we found that a model, including a zero-one variable to represent the date when USDA releases its forecast, generates similar results to a model that also includes differences in USDA's corn production projections. This result indicates the content of USDA's projections of corn production can influence the price of corn futures.

Third, we tested whether the accuracy of past USDA corn production projections influences the impact that current USDA projections have on futures markets. Test results revealed that for most months the accuracy of these forecasts enhances the forecasts' impact in August. Therefore, the smaller past *WASDE* corn projection errors are, the more (future prices) react to current *WASDE* crop projections for this key month. However, these forecast errors from the May report increased the impact of the May report on corn futures prices. This may be because markets expect the May projections to be less accurate than reports later in the season because May is a key planting month. Other monthly report errors have a mixed impact on corn futures. This may be because USDA's corn production projections do not contain systematic errors; years of overly high projections are often followed by overly low ones.

Fourth, we compared the price of corn futures after the release of the forecast to the price that corn futures could hypothetically be without releasing USDA crop projections. We found the monthly release of USDA's forecast moved the futures price closer to the harvest season price of corn, thereby improving the futures price as a forecasting tool and aiding market participants who rely on futures prices for making decisions. Using lags, we found the impact of the USDA forecast remains embodied in the futures prices for approximately 10 to 14 days.

Although we address various issues regarding USDA corn production projections, several issues remain to be addressed. One issue is the relationship between USDA's ability to influence the market price over time and the integration of the internet as an informational tool into agriculture and market projections. Second, it could be beneficial to examine the interaction between past USDA forecast errors and the impacts of

current USDA forecasts. For instance, testing various methods of measuring past errors could be insightful by determining whether positive forecast errors have different effects than negative forecast errors. Third, similar studies could include other key crops like soybeans or wheat to test the impact of other key variables in the *WASDE* report, such as stocks. Finally, future studies could consider the impact of the release of USDA information outside of the *WASDE* report, such as the *Prospective Plantings* report issued in March by USDA's National Agricultural Statistical Service (NASS). The findings of this study can aid policymakers to better understand the role that USDA plays in influencing the corn futures, and it allows market participants to better understand how USDA forecasts influence prices in the futures market. This, in turn, may influence how traders view USDA forecasts.

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