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Article

Gone in Ten Minutes: Intraday Evidence of Announcement Effects in the Electronic Corn Futures Market

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Abstract *This article investigates the announcement effects of major USDA reports using intraday Chicago Board of Trade corn futures prices and trading volume from the electronic trading platform for July 2009 to May 2012. Focusing on intraday market reactions, we analyze the extent to which new information impacts and is rapidly reflected in prices. Results show that USDA reports contain substantial information for market participants. Strongest price reactions to the releases are found immediately after the market opens, and market reactions persist for approximately ten minutes. The electronic corn futures market quickly incorporates this new public information, and little evidence exists to support systematic under- or overreactions in prices. Other more subtle reactions occur in the last trading session before USDA announcements as traders adjust their market exposure in anticipation of the release.*

Key words: USDA reports, Informational value, Corn futures market, Intraday electronic trading, Market efficiency, Public information.

JEL codes: G14, Q11, Q13, D80.

That's not right. How can the price be going down? . . .
They're selling, Mortimer.
Why, that's ridiculous. Unless that crop report . . .
God help us.
– From the movie *Trading Places*, 1983

Researchers, as well as movie goers, are aware that USDA reports can have significant market effects. A large body of literature has analyzed the value and impact of public information in agricultural markets. Most studies on

USDA reports on corn and soybean markets, such as production and harvest forecasts (Sumner and Mueller 1989; Garcia et al. 1997; McKenzie 2008), crop progress and conditions (Lehecka 2014), and World Agricultural Supply and Demand Estimates (WASDE) reports (e.g., Isengildina-Massa et al. 2008a, 2008b; Adjemian 2012), find significant announcement effects.[1] This indicates that public information released by the USDA generates economic welfare benefits in these markets (Falk and Orazem 1985). Recently, Karali (2012) also provided insights into the spillover effects of USDA reports on the conditional return variances and covariances in related agricultural futures markets.

Despite these findings, the value of public agricultural information remains a subject of debate. It is challenged by the growth of private firms that provide information and analysis on agricultural markets (Egelkraut et al. 2003; Good and Irwin 2006; McKenzie 2008), leading some to argue that private information substitutes for public programs (Just 1983; Salin et al. 1998). Looming federal budget restrictions, particularly in recent years, have raised concerns about pressures on public information programs in agriculture.[2] Insignificant market impacts to the release of USDA reports have also been reported in some studies (e.g., Fortenbery and Sumner 1993). More recently, studies of wheat markets on WASDE reports (Marone 2008) and crop condition information (Bain and Fortenbery 2013) emphasize that market participants may be able to anticipate at least some of the information released.

During the last decade, uncertainty about future agricultural market conditions has increased dramatically. Agricultural prices have become volatile for a variety of well-documented reasons, including new demand due to biofuel mandates and heightened linkages to the energy complex, strong and continued increases in income in China and India, poor weather, low aggregate grain stocks, and the sharp and protracted changes in aggregate demand resulting from the financial crisis (Wright 2011, 2012). Further, commodity futures markets are experiencing large structural changes (Irwin and Sanders 2012). A shift to electronic trading, easier access to futures markets, and an emergence of new financial market participants (index funds, exchange-traded funds) have raised concerns about the quality of price discovery (Irwin and Sanders 2011). In this situation, public supply and demand information should be more valuable to market participants (Falk and Orazem 1985; Williams and Wright 1991).

In this environment, the release time of major USDA reports was changed to occur during the most active trading session at noon (EST) in January 2013. Recently, it has been reported that, because of USDA server capacities, not all market participants have immediate online access to USDA reports once they are officially released. Although this may have been a less significant issue when reports were of questionable value and were released in

[1] *Announcement effects have also been analyzed in cattle and hog markets in response to Hogs and Pigs, Cattle on Feed, and Cold Storage reports (e.g., Colling and Irwin 1990; Grunewald, McNulty, and Biere 1993; Isengildina et al. 2006) and to health and safety information in cattle and beef markets (McKenzie and Thomsen 2001; Tse and Hackard 2006).*

[2] *Most notably during the US federal government shutdown from October 1 to 17, 2013, the USDA's National Agricultural Statistics Service and World Agricultural Outlook Board cancelled and postponed selected USDA statistical reports because of the lapse in federal funding. This included, among others, cancellation of Crop Production and WASDE reports previously scheduled for release on October 11, 2013.*

advance of trading, it becomes a serious concern when public information is released during trading hours in electronic markets, which offer market participants the potential to rapidly change their positions.

Studies of agricultural futures markets demonstrate that market reactions to USDA reports can vary because of changing market conditions and US agricultural policy regimes (e.g., Garcia et al. 1997; Isengildina-Massa et al. 2008a; Adjemian 2012; Lehecka 2014). Further, studies suggest that the measurement of market impacts may be sensitive to the temporal frequency—market close-to-close compared with market close-to-open price changes—of price data used (Isengildina, Irwin, and Good 2006; Isengildina-Massa et al. 2008a; Adjemian 2012). Smaller and often insignificant market impacts emerge when using daily closing prices, suggesting that using nonrepresentative data can mask the value of information. In addition, more recent analysis of announcement effects is complicated by emergence of a viable computer/electronic market platform in 2006–2008.[3] Access to markets has increased, and trading hours have expanded to an almost around-the-clock basis (Kauffman 2013). Studies that analyze market reactions to announcements must be careful to match the release time with prices that reflect representative market responses.[4] Recent studies that cover the period after 2006 and rely only on daily changes of closing/settlement prices may not fully reveal the extent of market response (e.g., Marone 2008; Karali 2012; USDA 2013). By relying only on daily prices, they can only indirectly assess whether information is quickly incorporated into market prices, and they do not address the speed of adjustment during trading sessions. In contrast, an intraday analysis may improve the analysis of price discovery because the process of price adjustment within the trading session can directly be analyzed.

In this article, we conduct an intraday announcement effect analysis using futures prices and trading volumes on a minute-to-minute basis from the electronic trading platform. Intraday Chicago Board of Trade (CBOT) corn futures market reactions to the release of major USDA reports (WASDE, Crop Production, Grain Stocks, Prospective Planting, and Acreage reports) are analyzed for the period from July 2009 to May 2012. These reports are closely watched by market participants and are viewed as an important source of fundamental supply and demand conditions. Minute-to-minute return variability and volume levels on report release trading days are compared with and tested against pre- and post-report days. Price reactions are also tested for systematic under- or overreaction patterns. Over the period, most corn futures contracts were traded electronically and trading hours stayed unchanged. The reports were released at 8:30 a.m. (EST), after the end of the overnight electronic trading session and before the start of the floor/electronic day trading session.[5]

[3]*For example, monthly electronic trading volume in Chicago Board of Trade corn contract was only 1% of the total corn trading volume for the period 2000–2003. By 2009–2011, electronic corn trading accounted for 92% of the total monthly volume (Irwin and Sanders 2012).*

[4]*For futures markets with viable electronic trading such as corn, daily opening prices correspond to the opening prices of the electronic trading session in the evening on the previous calendar day (7:00 p.m.). See figure 1 for CBOT corn trading hours. Exact price reactions to the release of reports at 8:30 a.m. are reflected by changes in prices before (8:15 a.m.) and after (10:30 a.m.) the report release, which do not correspond to daily opening/closing price data.*

[5]*CBOT trading hours have subsequently changed, and as noted, USDA report release times changed in January 2013.*

Because of limited historical data availability, the literature in agricultural commodity futures markets on intraday trading, price, and volume (e.g., Tse and Hackard 2006; Eaves and Williams 2010; Kauffman 2013), as well as on electronic trading (e.g., Martinez et al. 2011; Shah and Brorsen 2011; Wang, Garcia, and Irwin 2014), is relatively scarce. This study contributes to the literature in several ways. First, it provides a new focus and discussion on the analysis of market reactions using intraday futures data in agricultural markets. Second, it demonstrates that USDA reports continue to provide important information to market participants as their value has not declined in recent years. Third, it examines market efficiency, information flows, and the quality of price discovery of electronic trading in agricultural markets. Finally, it demonstrates the speed with which new information is incorporated into electronically traded market prices.

Announcement Effects and Market Efficiency

Studies on the informational value of news announcements are based on the assumption that if prices react to the release (the event) in an efficient market, then the information is valuable to market participants (Campbell, Lo, and MacKinlay 1997). New supply and demand information changes market participants' perceptions and expectations, which will be reflected in market prices. Because the direction in which the expectations change is not known a priori, movements in market prices can either be positive or negative. Although an average of market price movements is perhaps zero, the variability of price returns around the release of new important announcements should be greater than the "normal" variability on days without announcements (e.g., Sumner and Mueller 1989; Isengildina-Massa et al. 2008a; Lehecka 2014). In this context, USDA reports are valuable to the market if the variability of price returns around the release of reports is significantly greater than the variability on days without report releases (Falk and Orazem 1985).

This concept of informational value must be interpreted with care. Although price movements around the release of reports (reflected by greater variability of price returns) indicate that news announcements have value, this does not represent an explicit measure of the value of publicly generated reports—that is, whether the value of news announcements justifies the costs cannot be addressed by the analysis (Bain and Fortenbery 2013). Further, other reports (e.g., backward-looking studies) are widely read and have value even if they do not cause market reactions. These reports may not change market participants' supply and demand expectations, and thus have no immediate influence on futures market prices, but they can still be highly informative to decision makers, providing general information about changes in industry and the market.

Analyses of announcement effects assume that markets are less than strong-form efficient (e.g., Isengildina-Massa et al. 2008a; Lehecka 2014). In strong-form efficient markets (Fama 1970), futures prices reflect all information, public and private. Markets are able to fully anticipate not only market information contained in news announcements but also all private ("insider") information possessed by market participants. In this case, the variability of price returns around releases would be the same as on days without releases. Studies commonly reject that markets, including agricultural futures markets, are strong-form efficient (e.g., Fama 1991;

Zulauf and Irwin 1998). Further, Grossman and Stiglitz (1980) demonstrate theoretically that markets cannot be fully strong-form efficient. Acquiring information is costly, and market participants who use resources to obtain it need to be compensated. However, if all information is fully anticipated, the information will have no market value, which will eliminate the incentive to collect and analyze it and will lead to the collapse of the market. Thus, announcement effect studies assume that agricultural futures markets are less than strong-form efficient and releases can affect prices.

Under semi-strong-form efficiency, prices will adjust to new publicly available information rapidly and in an unbiased manner (Fama 1970). Because USDA reports considered are released before the start of the floor/electronic trading day session (July 2009 to May 2012), price adjustments should occur immediately as the day trading session opens and be revealed as heightened volatility. Normalizing price volatility for the trading sessions on report release days by volatility for "normal" trading sessions provides a measure of "excess" volatility, revealing the magnitude of the market adjustment to the new information. In a semi-strong-form efficient market, excess volatility will follow an L-shaped pattern, with an immediate price reaction reflected by greater volatility when trading begins followed by normal volatility corresponding to trading sessions without report releases.

However, a market may be less than (semi-strong-form) efficient, and not all new information may be reflected in prices immediately. Given position limits and financial and liquidity constraints of market participants,[6] as well as price limits,[7] a market may underreact to new information. In contrast, panic selling or buying, fads, feedback trading, or herding behavior (e.g., Tse and Hackard 2006; Boyd et al. 2013) can lead a market to overreact.[8] In both cases, the excess volatility measure would be slightly less steeply L-shaped, decreasing for a period of time after the market opens. Market participants may also place too much (too little) emphasis on the most recent information, which under bounded rationality (Kahneman 2003) could lead to either response pattern.[9] In the context of the corn futures market, if the market is not fully efficient and tends to underreact (overreact) to a release, then the price changes or returns in the first minute after the market opens will understate (overstate) the subsequent impact, and they will reverse direction in the subsequent minutes as the market converges to a new equilibrium level later in the trading session. Underreaction

[6] *By discouraging aggregate speculative interest, position limits and futures margins may decrease liquidity and restrict informational efficiency (e.g., Pliska and Shalen 1991; Pirrong 2011; Gwilym and Ebrahim 2013). In this context, the speed of adjustment to new information is slower in less-liquid stock markets (e.g., Chorida and Swaminathan 2000; Lasfer, Melnik, and Thomas 2003).*

[7] *Although price limits may constrain prices from reacting efficiently, and potentially cause underreaction, they are intended to reduce effects of herding behavior and prevent overreaction (e.g., Ma, Dare, and Donaldson 1990; Kim and Rhee 1997; Chen 1998; Park 2000).*

[8] *Although there is a body of literature on over- and underreaction in stock market prices (e.g., DeBondt and Thaler 1985, 1987; Hong and Stein 1999; Lasfer, Melknik, and Thomas 2003), these patterns have been less well investigated in announcement studies in agricultural futures markets (Colling and Irwin 1990; Grunewald, McNulty, and Biere 1993; Isengildina-Massa et al. 2008a, 2008b).*

[9] *The rationality of market participants is bounded by traders' cognitive inability to process information in the time available to make market decisions. They also may overweigh recent information and underweigh prior information when revising supply and demand expectations. Further, when market participants receive a sequence of good (bad) information, they may become too optimistic (pessimistic) about future market conditions (e.g., Tversky and Kahneman 1974; DeBondt and Thaler 1985; Ma, Dare, and Donaldson 1990). In addition, they may be slow in changing their market perceptions in the face of new and contrary information (e.g., Edwards 1968; Barberis, Scleifer, and Vishny 1998).*

(overreaction) can be reflected in a statistically significant positive (negative) correlation between the returns (i.e., price change) in the first minute and returns in subsequent minutes of the trading sessions on report release days (e.g., Isengildina-Massa et al. 2008a).[10]

To assess reactions to USDA reports on the electronically traded corn futures market, an announcement effect analysis similar to Sumner and Mueller (1989), Isengildina-Massa et al. (2008a), and Lehecka (2014) is performed, but with intraday data. Minute-to-minute return variability and volume levels on report release trading days are compared with those for the same time of day on pre- and post-report days. In contrast with most announcement studies that focus only on price reactions, we also analyze reactions in trading volume. Reactions in trading volumes to the announcement of public information are generally less well studied and understood in agricultural futures markets (e.g., Mann and Dowen 1996; Eaves and Williams 2010). Because greater trading volumes tend to be associated with greater return variability (Bessembinder and Seguin 1993), we expect similar announcement effects. If USDA reports contain valuable information for corn market participants, then price movements and volume levels on days of report releases will be larger than on other days, and we anticipate that the intraday patterns should be close to an L-shaped pattern. If less than L-shaped patterns exist, then the question of whether it is because of systematic under- or overreaction is addressed.

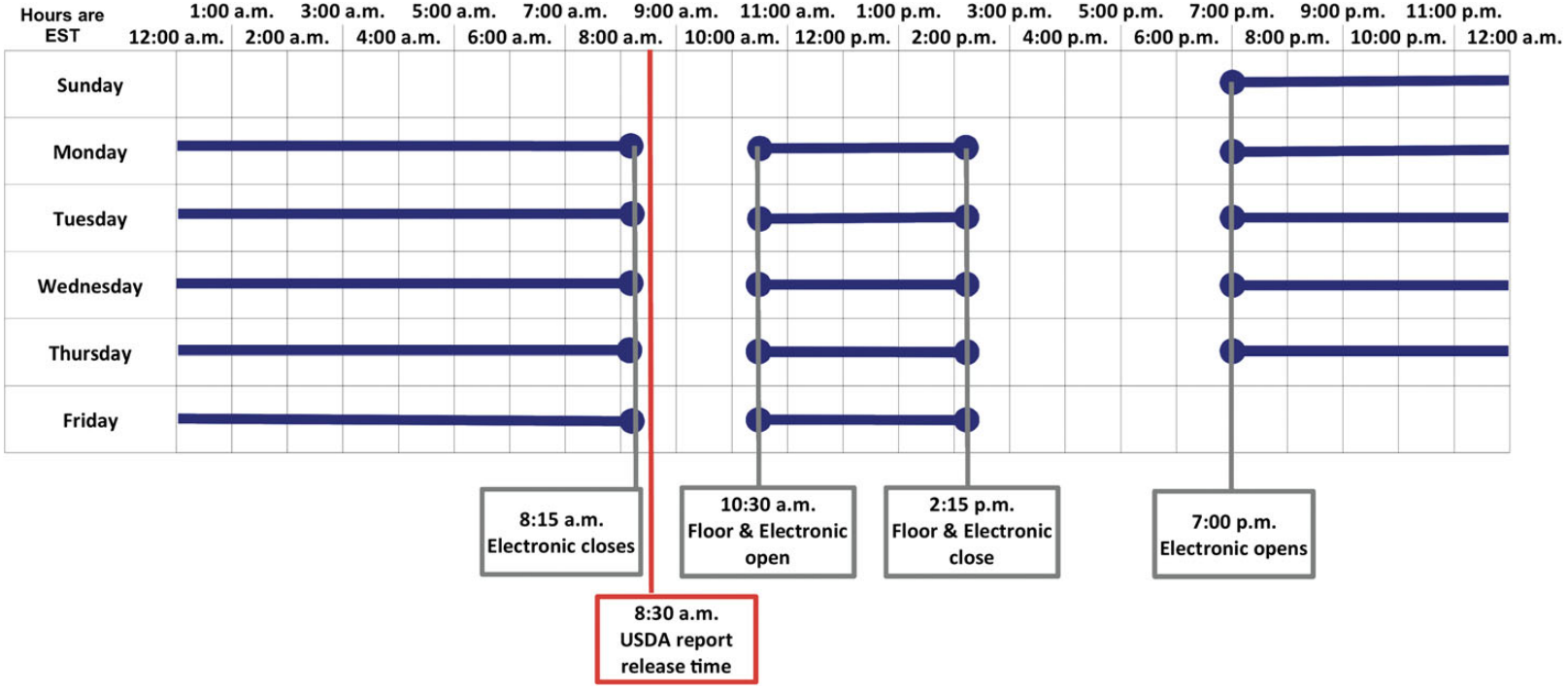
USDA Reports and Intraday Corn Futures Data

Among the reports released by the USDA, we focus on major reports that contain corn supply and demand information. Reports analyzed include the National Agricultural Statistics Service publications on Crop Production (monthly), Grain Stocks (quarterly), Prospective Planting (yearly at the end of March), Acreage (yearly at the end of June), and WASDE releases (monthly) issued by the World Agricultural Outlook Board. Over the period of observation, these reports were released at 8:30 a.m. (EST) before the start of the day trading session at 10:30 a.m. (EST) (figure 1). Crop Production reports include crop production data for the United States, including acreage, area harvested, and yield. Grain Stocks reports contain stocks of grains by states and United States and by position (on-farm or off-farm storage). Prospective Plantings and Acreage reports contain the expected plantings as of March 1 and acreage by planted and/or harvested areas, respectively, for several crops, including corn. WASDE reports provide current USDA forecasts of US and world supply and demand balances of major grains. The data analyzed (the events) include the release of all these reports for the period July 1, 2009, to May 18, 2012. In that period, thirty-five WASDE, thirty-five Crop Production, eleven Grain Stocks, three Prospective Planting, and two Acreage reports were released.

Intraday futures data for nearest-to-maturity (nearby) corn contracts from electronic trading are collected from the September 2009 contract to the July

[10] *Evidence of under- and overreaction does not necessarily imply profitable trading opportunities exist. Even if the magnitude of under- and overreaction is economically significant, market participants—unless better informed—would need to know not only the direction of market reactions in advance but also whether under- or overreaction will occur (to profit from futures or options strategies), which would require not only the knowledge of the very information that is to be released and causes the price reaction but also how prices will specifically react to the information. (Remember Mortimer.)*

Figure 1 CBOT corn trading hours and the report release time of major USDA reports (WASDE, Crop Production, Grain Stocks, Prospective Planting, and Acreage reports) during the period July 1, 2009, to May 18, 2012



2012 contract and include last prices and volume traded per minute. Nearby contracts for storable commodities such as corn should reflect the price impact of both old and new crop information (Working 1948). Because USDA reports analyzed include both old crop and new crop information, it is reasonable to argue that the best measure of announcement effects can be derived from nearby contracts for each release (e.g., Isengildina-Massa et al. 2008a; Karali 2012). Further, nearby contracts tend to be the most heavily traded and liquid contracts, which should allow for an accurate measure of market response. We select nearby corn contracts by rolling over to the next expiration once a contract reaches its delivery month. The nearby CBOT corn futures contracts used for each report released in the particular month is presented in table 1. Because reports are often released on the same day, there are forty-three days with USDA report releases in the sample. To assess whether the analysis is robust to the use of other contract expirations, market reactions are additionally tested using nearby contracts rolled before first notice day and with only corn new-crop (December) contracts.

Summary statistics for CBOT corn minute-to-minute returns and volumes are given in table 2. The returns used for the statistics include all minute-to-minute returns over the sample period, July 1, 2009, to May 18, 2012, from the nearby futures contracts in which at least one transaction took place in the particular minute. Returns are computed as

$$r_{m,d} = \ln\left(\frac{p_{m,d}}{p_{m-1,d}}\right) \times 100, \tag{1}$$

with $p_{m,d}$ being the last price per minute of the nearby corn futures contract for minute $m = 1, ..., 1440$, which is the number of minutes in 24 hours covering both evening and day trading sessions, and trading day $d = 1, ..., D$. Note that the return of the first minute after the market opens is based on the last price of the previous trading session—that is, the first return in the day trading session (10:30 a.m.) is based on the last price of the trading session in the morning (8:15 a.m.). Similarly, the first return in the evening trading session (7:00 p.m.) is based on the last price of the day trading session (2:15 p.m.). The estimated mean of the returns is very small and insignificantly different from zero. In contrast, the mean of the absolute returns is significantly different from zero, reflecting the variability in price movements. Skewness and kurtosis statistics for returns and volumes indicate that distributions are skewed and have fatter tails than a normal distribution, which is confirmed by Jarque-Bera tests that strongly reject normality in all cases. For daily commodity futures returns, non-normality is a well-established distributional characteristic because they appear to be skewed and leptokurtotic (e.g., Yang and Brorsen 1994). Less is well known about intraday distributions, but our non-normality findings lead us to confirm our results with tests that do not rely on normality.

Figure 2 shows intraday corn futures return volatility and volume patterns from July 1, 2009, to May 18, 2012. As a measure of return volatility that is more robust to outliers, the average absolute deviation is used, and is defined as

$$AAD_m = \frac{1}{D}\sum_{d=1}^{D} |r_{m,d} - median_m|, \tag{2}$$

Table 1 Futures Contracts Used for USDA Report Releases, July 1, 2009, to May 18, 2012

Report release date	Reports	Corn futures contract
2009-07-10	WASDE, CP	September 2009
2009-08-12	WASDE, CP	September 2009
2009-09-11	WASDE, CP	December 2009
2009-09-30	Grain Stocks	December 2009
2009-10-09	WASDE, CP	December 2009
2009-11-10	WASDE, CP	December 2009
2009-12-10	WASDE, CP	March 2010
2010-01-12	WASDE, CP, Grain Stocks	March 2010
2010-02-09	WASDE, CP	March 2010
2010-03-10	WASDE, CP	May 2010
2010-03-31	Grain Stocks, Prospective Planting	May 2010
2010-04-09	WASDE, CP	May 2010
2010-05-11	WASDE, CP	July 2010
2010-06-10	WASDE, CP	July 2010
2010-06-30	Grain Stocks, Acreage	July 2010
2010-07-09	WASDE, CP	September 2010
2010-08-12	WASDE, CP	September 2010
2010-09-10	WASDE, CP	December 2010
2010-09-30	Grain Stocks	December 2010
2010-10-08	WASDE, CP	December 2010
2010-11-09	WASDE, CP	December 2010
2010-12-10	WASDE, CP	March 2011
2011-01-12	WASDE, CP, Grain Stocks	March 2011
2011-02-09	WASDE, CP	March 2011
2011-03-10	WASDE, CP	May 2011
2011-03-31	Grain Stocks, Prospective Planting	May 2011
2011-04-08	WASDE, CP	May 2011
2011-05-11	WASDE, CP	July 2011
2011-06-09	WASDE, CP	July 2011
2011-06-30	Grain Stocks, Acreage	July 2011
2011-07-12	WASDE, CP	September 2011
2011-08-11	WASDE, CP	September 2011
2011-09-12	WASDE, CP	December 2011
2011-09-30	Grain Stocks	December 2011
2011-10-12	WASDE, CP	December 2011
2011-11-09	WASDE, CP	December 2011
2011-12-09	WASDE, CP	March 2012
2012-01-12	WASDE, CP, Grain Stocks	March 2012
2012-02-09	WASDE, CP	March 2012
2012-03-09	WASDE, CP	May 2012
2012-03-30	Grain Stocks, Prospective Planting	May 2012
2012-04-10	WASDE, CP	May 2012
2012-05-10	WASDE, CP	July 2012

Notes: All contracts refer to CBOT futures contracts. CP = Crop Production report; WASDE = World Agricultural Supply and Demand Estimates.

where $median_m$is the median of $r_{m,d}$ in the minute m. The patterns for return volatility and average volumes in figure 2 reveal a generally consistent pattern—a reverse-J-shape and more of a U-shape, respectively. Return volatility and volumes are at the highest point at the open of the market, fall quite rapidly to lower levels in the trading session, and then rise toward the

Table 2 Summary Statistics for Corn Intraday Minute-to-Minute Returns and Volumes, July 1, 2009, to May 18, 2012

	Returns		Volumes
	r	$\|r\|$	v
Mean	0.00	0.05**	121.33**
Media	0.00	0.04	14
Minimum	−10.89	0.00	1
Maximim	6.20	10.89	17880
Variance	0.01	0.01	114662.5
Skewness	−3.08**	21.43**	9.64**
Kurtosis	935.66**	1966.70**	182.04**
Jarque-Bera	$17.39\ 10^{9}$**	$77.11\ 10^{9}$**	$648.12\ 10^{6}$**

Notes: Returns r are computed as the difference in the natural logarithm of prices multiplied by 100. Number of observations is 479,710. Tests on the skewness and kurtosis are D'Agostino and Anscombe-Glynn tests for normal samples, respectively. Nearby CBOT futures contracts are used.
**Signficant at the 5% level.*
***Significant at the 1% level.*

close of the market.[11] These intraday patterns are well documented for return variability and volumes for financial futures markets (e.g., Lockwood and Linn 1990; McInish and Wood 1990; Goodhart and O'Hara 1997) and, to a lesser degree, for agricultural commodity futures (e.g., Eaves and Williams 2010; Martinez et al. 2011).[12] It is also worth noting that the majority of futures contract transactions in the sample period occur during the day trading session (approximately 90%).

The analysis of announcement effects may be complicated by limit moves (e.g., Colling and Irwin 1990; Isengildina-Massa et al. 2008a; Lehecka 2014).[13] Price limits in futures markets restrict daily futures price movements and may bias estimates of announcement effects. For the forty-three report release days in the analysis, corn futures were subject to limit moves six times in the first minute when the market opened after a report is released (10:30 a.m.) and eight times when the day trading session closed at the price limit (2:15 p.m.).

Intraday Announcement Effect Analysis

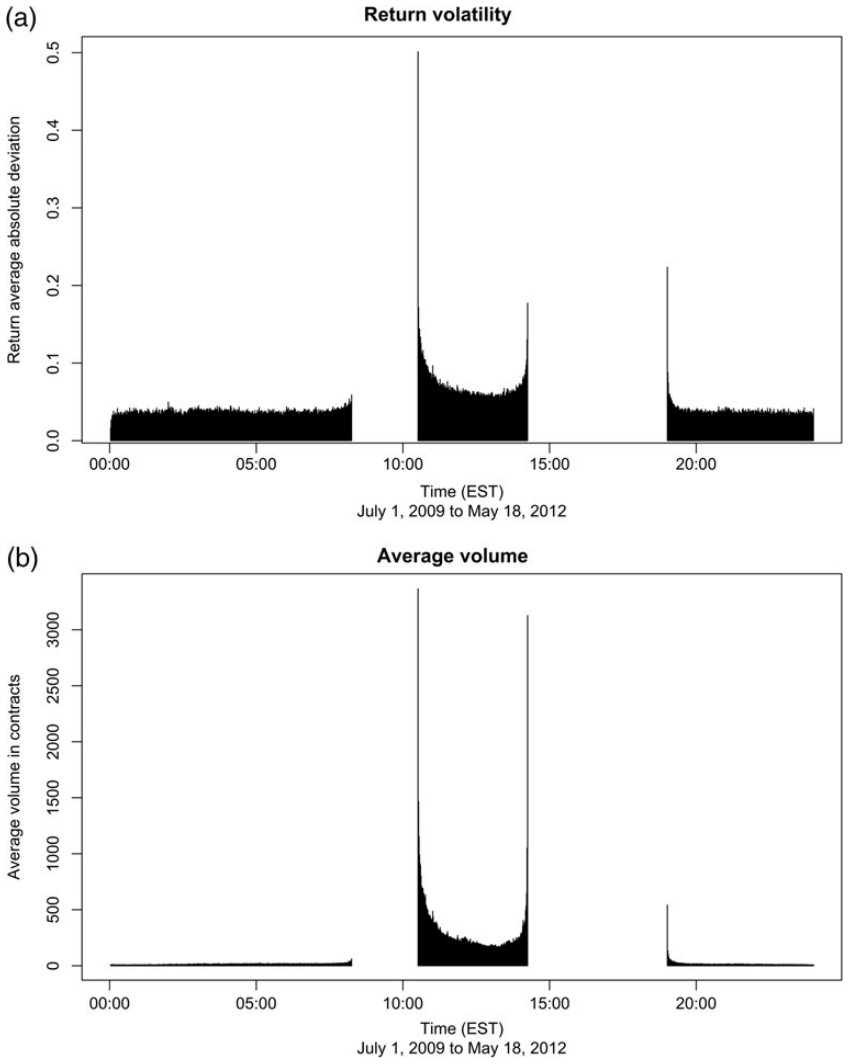
In the intraday announcement analysis, statistical tests are used to detect differences in minute-to-minute return variability and volume on report

[11] *The shape of intraday volatility and volume patterns also holds when other measurements (e.g., variance/standard deviation, median absolute deviation, average/median differences between high and low prices for return volatility, and median for volumes) are used.*

[12] *Although an L-shaped pattern of volatility may be explained by trading breaks (e.g., Brock and Kleidon 1992; Cyree and Winters 2001), the "empirical regularity" of reverse-J-shaped or U-shaped intraday volume or volatility patterns lacks rigorous theoretical explanation. Eaves and Williams (2010) argue that these intraday patterns are explained by public information and cross-correlations with related commodity markets. Their results from markets at the Tokyo Grain Exchange (TGE) suggest that, after controlling for public information and cross-correlations, intraday volume and volatility patterns of TGE agricultural futures are weak, in particular for volatility. Because trading at the TGE is a sequence of periodic auctions, which differs from the CBOT, effects of public information can be controlled in their analysis of intraday patterns.*

[13] *The daily price limit for CBOT corn contracts was 30¢/bu. (expandable to 45¢/bu. and 70¢/bu.) from March 28, 2008, to August 22, 2011, and 40¢/bu. (expandable to 60¢/bu.) since that time.*

Figure 2 Intraday CBOT corn futures return volatility and volume patterns, July 1, 2009, to May 18, 2012



release and pre- and post-report release days. If USDA reports contain valuable information for market participants and the market is efficient, then price movements and traded volumes once the market opens on days after report releases will be larger than other days, the intraday pattern will be close to L-shaped, and systematic under- or overreaction will not exist.

For each release date from July 1, 2009, to May 18, 2012, corn intraday futures data per minute for nearest-to-maturity CBOT contracts are collected for five trading days before the release date, the day of release, and five trading days after the release, or a total of eleven trading days.[14] Minute-to-minute returns for these specific days and minutes are computed as

$$r_{t,m,i} = \ln\left(\frac{p_{t,m,i}}{p_{t,m-1,i}}\right) \times 100, \tag{3}$$

[14]*This also includes Sundays because weekly trading starts on Sunday afternoon. See figure 1.*

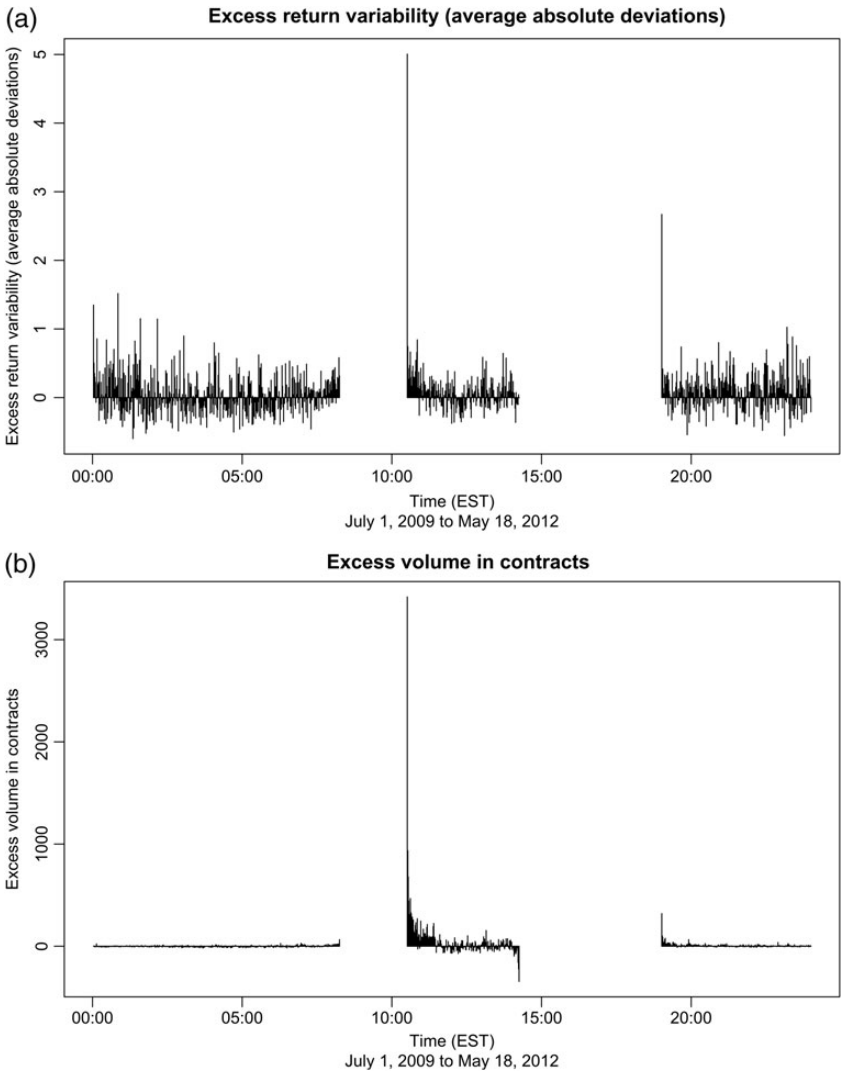
with $p_{t,m,i}$ being the last price per minute of the nearby corn futures contract for trading day $t = -5, \ldots, 0, \ldots, +5$ for minute $m = 1, \ldots, 1440$ and event day $i = 1, \ldots, 43$, and ln is the natural logarithm. That is, for every minute m, forty-three data of returns on report release days ($t = 0$) are compared with 430 pre- and post-report days ($t \neq 0$). The same approach is followed to compare volumes. If there are no trades in the minute of interest for report release or pre-/post-report days, then observations are treated as missing values and are not included in the calculations.[15]

As an initial visual analysis, we graphically analyze excess minute-to-minute return variability (average absolute deviation) and volume levels. Recall excess means price volatility and volume on the report release days exceeding the normal volatility and volume on days without report releases for every minute. In the excess return volatility measure, every minute m denotes the average absolute deviation of all returns on the report release days ($t = 0$) divided by the average absolute deviation of pre- and post-report days ($t \neq 0$). The number one is then subtracted from this measure to highlight the percentage difference from the base one that reflects equality between report release and pre-/post-report days. In the excess volume measure, for every minute the average number of contracts on pre- and post-report days is subtracted from the average number of contracts on the release days.

Figure 3 shows these patterns for the calendar day. If the information included in USDA reports is valuable for corn market participants and the market is working effectively, then excess volatility and volume patterns will be L-shaped, with an immediate increase in volatility and volumes as the market opens followed by zero excess. Visually, there are a number of interesting patterns in return volatilities and volumes. For return volatility depicted in figure 3a, there is not only a spike in excess volatility when the market opens after a report is released but also in the first minute of the following trading session in the evening, with volatility being fivefold and almost threefold the volatility on days without report releases, respectively. The pattern during the day trading session appears generally to be slightly less than L-shaped. Although the largest increase in excess volatility is in the first minute as the market opens, consistently positive excess volatility continues for almost half an hour. For volume depicted in figure 3b, during the day trading session, the excess volumes pattern as well is less than L-shaped, with consistently positive excess volume for almost an hour after the market opens. In the first minute after the market opens and a report is released, more than three thousand contracts are traded in excess compared with days without report releases (about twice as many). In the second and third minute after the market opens, more than five hundred contracts also are traded in excess to normal trading. Informatively, a pattern emerges revealing negative excess volumes in the minutes before the trading session closes. Moreover, there appear to be slightly higher volumes before the

[15] *Using a wider event window for pre-/post-report days leads to an overlap with previous/subsequent report release days in several cases. Day trading sessions after report releases are heavily traded in every minute. For instance, within the first fifteen trading minutes after reports are released, there is only one minute without a trade. Treating minutes with no trades as missing is a conservative approach relative to the hypothesis of announcement effects to the release of information. Robustness checks of changing values to zero even in minutes without trades yield even stronger support for announcement effects after report release. These alternative results are available from the authors on request.*

Figure 3 Announcement effects in CBOT corn futures return variability and volumes to World Agricultural Supply and Demand Estimates, Crop Production, Grain Stocks, Prospective Planting, and Acreage reports, July 1, 2009, to May 18, 2012



morning trading closes before reports are released and after the evening trading session opens.

The intraday announcement patterns from the release of USDA reports are statistically tested. Because of to the non-normality of minute-to-minute returns and volumes, nonparametric tests that do not rely on the assumption of normality are used to control and confirm the results of parametric tests. The null hypothesis that minute-to-minute return variability for report days and pre-/post-report days is equal is tested by two-tailed F tests on the variance and Kruskal-Wallis χ^2 tests applied on absolute returns. To test that minute-to-minute volumes are equal on report days and pre-/post-report days, t tests and Wilcoxon tests are used.

Table 3 provides the test results. Because they reflect the most pronounced excess variation, minutes before and after the trading breaks in the

Table 3 Intraday Announcement Effect Test Results for Corn Futures Return Volatility and Volume Reactions to the Release of USDA Reports, July 1, 2009, to May 18, 2012

Time is EST	Returns					Volumes				
	Report AAD	Pre-/post-report AAD	Difference	*F* statistic	χ^2 statistic	Report mean	Pre-/post-report mean	Difference	*t* statistic	W statistic
Electronic trading closes a.m.										
08:11	0.06	0.05	0.01	1.19	2.65	55.63	34.77	20.85	2.45*	4,334.0**
08:12	0.06	0.05	0.01	1.00	2.99	51.84	37.11	14.73	1.82	4,897.5**
08:13	0.06	0.05	0.01	1.56*	1.26	65.36	44.38	20.98	2.21*	4,583.0**
08:14	0.08	0.05	0.03	2.30**	5.70*	71.74	48.20	23.55	2.53*	3,640.0**
08:15	0.08	0.06	0.02	1.78*	1.54	127.57	62.29	65.28	4.04**	3,775.5**
Floor and electronic trading opens a.m.										
10:30	2.36	0.39	1.97	39.95**	57.46**	6935.95	3,517.65	3,418.31	4.81**	4,357.0**
10:31	0.29	0.17	0.12	3.41**	4.89*	2496.47	1,560.84	935.62	3.29**	5,449.0**
10:32	0.21	0.15	0.06	2.77**	0.59	1915.60	1,237.69	677.92	3.17*	5,468.0**
10:33	0.18	0.15	0.04	1.99**	0.01	1515.09	1,072.32	442.77	2.86*	5,373.5**
10:34	0.16	0.13	0.03	1.38	2.93	1278.47	1,004.69	273.77	1.90	6,101.0
10:35	0.19	0.13	0.06	2.02**	7.55*	1268.49	957.95	310.54	1.96	6,404.0
10:36	0.20	0.12	0.08	2.94**	7.50*	1307.23	839.82	467.41	2.71*	6,096.0
10:37	0.14	0.11	0.03	1.92**	0.57	1078.63	749.25	329.38	2.25*	6,049.0
10:38	0.13	0.11	0.02	1.43	0.22	1057.65	739.82	317.83	2.28*	6,122.5
10:39	0.11	0.11	0.01	1.13	0.04	909.12	691.21	217.91	1.85	6,365.0
10:40	0.16	0.11	0.04	1.60*	5.24*	1036.28	751.35	284.93	2.24*	5,929.0*
10:41	0.16	0.11	0.05	2.23*	1.44	825.37	703.09	122.28	1.28	6,501.5
10:42	0.12	0.10	0.02	1.35	0.44	975.40	718.63	256.77	2.28*	5,568.0*
10:43	0.13	0.10	0.03	1.69*	0.74	853.93	704.42	149.51	1.26	6,719.0
10:44	0.13	0.10	0.03	1.56*	1.30	808.40	676.68	131.72	1.39	6,162.5

Floor and electronic trading closes p.m.										
02:11	0.09	0.10	−0.01	0.76	0.04	530.64	547.46	−16.82	−0.25	7,221.5
02:12	0.09	0.10	−0.01	1.05	1.37	566.07	569.21	−3.13	−0.04	7,203.5
02:13	0.10	0.11	−0.01	0.73	0.49	577.12	735.14	−158.02	−2.11	8,465.5
02:14	0.14	0.14	0.01	1.22	0.09	994.07	1,215.55	−221.48	−1.71	8,519.0
02:15	0.17	0.17	−0.00	1.12	0.17	3129.33	3,474.01	−344.68	−1.05	8,184.0
Electronic trading opens p.m.										
07:00	0.62	0.17	0.45	25.81**	7.71**	875.60	555.48	320.12	1.37	4,963.5
07:01	0.09	0.09	0.01	0.90	0.87	239.48	138.42	101.06	1.55	4,321.5
07:02	0.11	0.08	0.03	1.86*	2.08	191.52	103.48	88.03	1.24	4,789.5
07:03	0.06	0.06	0.01	1.54	0.33	123.03	79.79	43.24	1.41	4,645.0
07:04	0.06	0.06	0.00	1.16	0.16	100.20	65.60	34.60	1.30	4,872.5

Notes: F and χ^2 statistics denote test statistics for two-tailed F tests on the variance and Kruskal-Wallis χ^2 tests on absolute returns to test that return variability on report days and pre-/post-report days is equal. t statistics and W statistics denote test statistics for t tests and Wilcoxon tests to test that volumes are equal on report days and pre-/post-report days. Returns are computed as the difference in the natural logarithm of prices multiplied by 100. Forty-three USDA report releases are included in the sample. Nearby CBOT futures contracts are used. AAD = average absolute deviation.

**Significant at the 5% level.*

***Significant at the 1% level.*

morning and in the afternoon are the focus of the statistical investigation. Specifically, five minutes before the trading closes in the morning, fifteen minutes after the day trading begins, five minutes before day trading closes in the afternoon, and five minutes after trading opens in the evening are tested. The findings indicate that USDA reports provide substantial information to the corn market, as market participants' changed expectations about supply and demand conditions are reflected in much greater movements in prices on release days. Specifically, the return variance for the first minute of the day trading session is forty times as much on days when a report is released as on days without a report release.[16] Note that these returns directly reflect the change in prices from trading before (8:15 a.m.) and after the report release (10:30 a.m.). Daily close and open prices (from electronic or floor trading sessions) used in previous studies, however, may not fully reflect and correspond to the change in prices between the releases of reports.[17] Further, in the minutes after day trading opens, significant and consistent results for the parametric and nonparametric tests reveal excess return volatility and volume for at least ten minutes. This indicates that the market needs several minutes to fully adjust to new information included in reports. At the end of the day trading session, however, no significant excess volatility and volume patterns are detectable.

In the minutes before trading closes in the morning session, significant and consistent excess volume levels and, to a lesser degree, return volatility are also encountered.[18] Market participants are more actively trading in the last minutes before the report release. The greater volatility and volume levels may reflect last-minute changes in expectations as traders become more focused on the release and/or steps to manage their exposure to the release of new information. The finding affirms the expected importance of the informational release regardless of the magnitude of price reactions.

After trading opens in the evening, significant and consistent results are also observed for excess return volatility in the first minute, but not for volume. This may be because of price limits.[19] Market reactions to the release of

[16] *As a comparison, Isengildina-Massa et al. (2008a) find that WASDE reports (1985–2006) cause daily close-to-open return variance on report release days to be 3.7 times greater than pre-/post-report day variance for corn futures.*

[17] *In general these results are consistent with analyses using daily closing/settlement prices; excess volatility exists on announcement days. However, results of studies using only daily closing prices may confound the information effect related to releases with price changes that emerge from information that enters the market within trading sessions. Although using daily opening and closing prices was appropriate before the emergence of viable overnight electronic trading, close-to-open returns cannot measure price changes related to report releases at 8:30 a.m. when previous closing prices are measured at 2:15 p.m. and subsequent opening prices at 7:00 p.m. In addition, intraday analysis provides a far richer picture of how a market reacts during the arrival of public information and permits us to identify immediate and resulting price effects.*

[18] *This is consistent with findings of studies in the finance literature that analyze intraday data and also include the time before announcements in their event window. Increased price volatility, trading activity, and widened bid-ask spreads in the minutes before major macroeconomic announcements have been reported in stock, interest rate, and foreign exchange markets (e.g., Ederington and Lee 1995; Fleming and Remolona 1999; Frino and Hill 2001; Taylor 2010).*

[19] *Although the release of other reports in the afternoon, such as Crop Progress, Feed Outlook, Cattle on Feed, or Hogs and Pigs, could influence the findings, closer examination of the other releases during the period suggest this is not the case. Only two afternoon reports (a Crop Progress report on September 12, 2011, and a Hogs and Pigs report on March 30, 2012) emerged on days when WASDE, Crop Production, Grain Stocks, Prospective Planting, or Acreage reports were released. Excluding these two days from the analysis does not substantially affect results, and considerable excess return volatility is still detectable in the first minute after trading opens in the evening.*

important new information may be limited by the daily price limit. In this context, the price cannot reach the new "equilibrium level" within the day trading session, which will lead to further reactions in the evening trading session when a new price limit is in effect, which is based on the settlement price of the previous day trading session. Excluding the eight days when the day trading session closed at the price limit resolves the excess return volatility and volume pattern in the first minute of the evening trading session (7:00 p.m.) and also the negative excess volume levels at the end of the day trading session.[20] This suggests that these patterns of reactions are explained by price limits and trading continues to react once trading is permitted.

Thus, these results significantly and consistently indicate that patterns of intraday market reactions in return volatility and volumes are less than L-shaped and the market needs about ten minutes to fully reflect the new information contained in USDA reports. This implies that the market may be slightly less than semi-strong-form efficient because not all available information is immediately reflected in prices. As identified earlier, these patterns of decreasing excess volatility and volumes over a period of time after the markets opens may be due to systematic under- or overreaction. Underreaction (overreaction) should be reflected in statistically significant positive (negative) correlations between the return in the first minute after the market opens and returns in subsequent minutes. To test for under- and overreactions in minute-to-minute returns, Pearson's correlation and Spearman's rank correlation, which does not rely on normality, are used. Correlations are calculated between the first return and cumulative subsequent returns, as well as between minute-to-minute returns after the market opens.

Results for patterns of under- and overreactions on report release days are provided in table 4. Fifteen minutes after the day trading begins and five minutes after trading opens in the evening are examined. Overall, correlations tend not to be significant between the first minute-to-minute return and cumulative subsequent returns or between every minute-to-minute return. However, correlations between minute-to-minute returns are significant for the third and fourth minute after the market opens for day and evening trading, respectively. Prices appear to be oscillating within the first minutes after the market opens and new information is released until the price reaches a new equilibrium level. These results generally imply that patterns of decreasing excess volatility in the first trading minutes after USDA reports are released are not systematically explained by under- and overreactions and prices oscillate during this time.

Additionally, to test for underreactions due to price limits, the lower panel of table 4 reports correlations of returns between the last price in the morning trading session before reports are released (8:15 a.m.) and the last price of the subsequent day trading session (2:15 p.m.) and between the last price of the day trading session (2:15 p.m.) and the price of the first minute in the following trading session in the evening (7:00 p.m.). If underreactions due to price limits exist, then this correlation should be positive because prices are limited until the day trading session closes and continue to react in the same direction once trading opens in the evening and a new price limit is in effect. Indeed, the correlation is significantly and consistently

[20]*Removing the limit-move observations does not affect the significant results presented in the text for the periods ten minutes after trading opens and the minutes before trading closes in the morning session. To conserve space, these results are not reported, but are available from the authors on request.*

Table 4 Intraday Under-/Overreaction Test Results for Corn Futures Return Reactions to the Release of USDA Reports, July 1, 2009, to May 18, 2012

	Pearson's correlation		Spearman's correlation	
Time is EST	**Cumulative**	**Per minute**	**Cumulative**	**Per minute**
Floor and electronic trading opens a.m.				
10:31	0.25	0.25	0.02	0.02
10:32	−0.06	−0.31*	−0.06	0.16
10:33	−0.01	−0.37*	−0.07	−0.31*
10:34	−0.11	−0.07	−0.15	0.11
10:35	−0.05	0.13	−0.13	0.18
10:36	−0.10	0.21	−0.17	0.24
10:37	−0.12	−0.20	−0.19	−0.21
10:38	−0.11	−0.03	−0.15	0.05
10:39	−0.13	0.05	−0.15	0.01
10:40	−0.07	0.26	−0.10	0.28
10:41	−0.13	0.31	−0.18	0.26
10:42	−0.08	0.07	−0.10	0.14
10:43	−0.05	−0.04	−0.09	−0.03
10:44	−0.05	0.33	−0.11	0.27
10:45	−0.02	0.14	−0.05	0.07
Electronic trading opens p.m.				
7:01	−0.05	−0.05	−0.04	−0.04
7:02	−0.17	−0.32	0.02	−0.30
7:03	−0.12	0.38*	0.10	0.13
7:04	−0.02	−0.60**	0.13	−0.40*
7:05	−0.14	0.29	−0.07	0.19
Correlations of returns between prices at 08:15 a.m - 02:15 p.m and 02:15 p.m - 07:00 p.m.	0.61**		0.51**	

Notes: Pearson's correlation and Spearman's rank correlation coefficients are calculated between the returns in the first minute (10:30 a.m. and 7:00 p.m.) and the cumulative returns of the subsequent minutes, as well as between returns per minute, respectively, for report day and evening trading sessions. The lower panel reports correlations of returns between the last price in the morning trading session before reports are released (8:15 a.m.) and the last price of the subsequent day trading session (2:15 p.m.) and between the last price of the day trading session (2:15 p.m.) and the price of the first minute in the following trading session in the evening (7:00 p.m.). Returns are computed as the difference in the natural logarithm of prices. Forty-three USDA report releases are included in the sample. Nearby CBOT futures contracts are used.
**Significant at the 5% level.*
***Significant at the 1% level.*

positive. Excluding the eight days when the day trading session closed at the price limit yields insignificant correlations, which suggests that price limits lead to underreaction during the day trading session.

Results may be sensitive to used futures expirations or biased by a small number of events with very strong reactions in price movements and volume traded. To examine whether findings are robust to different futures expiration months, the analysis was also conducted using nearby contracts rolling before first notice day and using only corn new-crop (December) contracts. Although the magnitude of excess variability and volume patterns slightly decreases with more deferred futures expirations, alternate test results lead to generally unchanged findings. Consistent with results found by Adjemian (2012) for WASDE reports, we find significant

announcement effects to emerge at different delivery horizons. Excluding report releases with the three largest reactions in (absolute) returns and volumes (in the first trading minute at 10:30 a.m. after reports are released), respectively, also fails to change findings.[21]

Conclusions

This article analyzes the effect of new public information using intraday futures prices and volumes for the electronically traded corn futures market. Intraday CBOT corn futures market reactions to the release of major USDA reports (WASDE, Crop Production, Grain Stocks, Prospective Planting, and Acreage reports) for the period July 2009 to May 2012 are empirically examined. If USDA reports contain valuable information for market participants, then price movements and traded volumes on report release days will exceed those market responses on other days. If the market is less than semi-strong-form efficient and not all new information is immediately reflected after the release, then intraday market reactions will exhibit patterns of decreasing excess volatility after the market opens with possible under- or overreactions.

Although our analysis does not allow us to differentiate between the effects of individual reports, the findings reveal that major USDA reports (WASDE, Crop Production, Grain Stocks, Prospective Planting, and Acreage reports) as a whole have substantial informational value for corn market participants. Results show that return variability and volume levels for corn in the first minute of the trading session after major USDA reports are released are significantly greater on report release days than in the same minute on pre-/post-report days. Measured as return variance, the variability in the first trading minute on report release days is forty times as much as on days without USDA reports, and volume in excess of nonreport days is more than three thousand contracts.

Although the strongest price reaction occurs immediately after the opening, market reactions persist for approximately ten minutes, which suggests that the market needs time to fully reflect the new information. Importantly, the decreasing patterns of excess volatility and volume after the opening are not due to systematic under- or overreactions. Rather, prices appear to oscillate in the first minutes after the opening before reaching a new equilibrium level. These patterns may simply reflect position limits and financial and liquidity constraints faced by market participants or the limits imposed by bounded rationality. Other more subtle reactions, which point to the impact of expected USDA information, occur in the last trading session before the announcement as traders appear to adjust their positions to manage market exposure. Additionally, results identify the constraining effect of price limits on market reactions, as prices in subsequent trading sessions respond to information when limits are reached in earlier trading. Previous studies that have relied only on daily close and open price data may not have captured the magnitude of these announcement effects and only indirectly provided assessment of the speed and manner in which new USDA information is reflected in market prices. Our findings

[21] *To conserve space, these results are available from the authors on request.*

demonstrate a high degree of the quality in price discovery and rapid transmission of information flows in the electronically traded futures market.

It should be clear that, although research indicates that private forecasts of supply and demand conditions have improved (Egelkraut et al. 2003; Good and Irwin 2006; McKenzie 2008), measured as a group, USDA reports, including WASDE, Crop Production, Grain Stocks, Prospective Planting, and Acreage reports, provide a highly important source of market information. In particular during recent periods characterized by increased uncertainty about future market conditions and low aggregate stock levels (Falk and Orazem 1985; Williams and Wright 1991), public supply and demand information appears to be essential to market participants. Hence, our findings strongly indicate that the informational value of these reports has not declined in recent years and report releases are still closely followed and anticipated by market participants.

Mumsie wants to have a party for us right after New Year's. . . . Is that good for you?

Oh, heck. Can't do it. . . . It's the day the crop reports come out. . . . It's the busiest time of year in the office, sugarpuff.
– From the movie *Trading Places*, 1983

Our findings, which shed light on the importance of analyzed USDA announcements and the speed with which the information is incorporated into market prices, provide insights into the current market issue of changed report release times during the day trading session. *Trading Places* aside, the USDA emphasizes the secure preparation of reports in order that contents are not leaked before official releases. In a world of instant information and rapid electronic trading, it may be necessary to ensure all market participants have immediate access to the reports that our research has demonstrated have such high, but short-lived, informational content.

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