THREE ESSAYS IN COMMODITY FUTURES MARKETS

BY

KISHORE JOSEPH

DISSERTATION

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Doctoral Committee:

Professor Philip Garcia, Chair and Director of Research
Professor Scott H. Irwin
Professor Paul E. Peterson
Assistant Professor Mindy Mallory
Professor Dwight Sanders (Southern Illinois University)
ABSTRACT

Three essays examining contemporary issues in diverse themes including commodity storage theory, livestock marketing and price discovery, and intraday announcement effects in electronic futures markets are presented.

In the first essay we investigate storage in the presence of backwardation and the existence of the Working curve for CBOT corn, soybeans, and wheat markets and the KCBT wheat market using 1990-2010 data. Two spread measures—the futures-spot and futures-futures—are matched with deliverable stocks on the first Friday of delivery. To account for grade and location aggregation issues, the futures-spot spreads are measured using the lowest spot bid and highest futures price. Storage in the presence of backwardation is pervasive both in terms of the percent of observations and the magnitude of the stockholdings. The Working curve emerges most clearly in KCBT wheat and soybeans. Convenience yield is also supported by the negligible holdings of delivery shipping certificates in backwardations.

The second essay examines the relationship between live cattle futures and negotiated boxed beef cutout prices. To account for temporal differences in information contained in boxed beef report release, Friday afternoon boxed beef prices are compared to both current day and one-day prior live cattle futures settlement prices. Extensive testing and innovation accounting based on VECM residuals indicate that the futures price leads boxed beef price as the dominant source of information in the fed cattle market. The futures price has a strong predictive influence on the boxed beef price and appears to assimilate fed cattle price information quicker than both current and one-day ahead boxed beef prices. Newly-developed price discovery metrics interpreted to allow for a maximum boxed beef effect in the pricing process still identify the dominance of the current futures price, and about equal weighting for the lagged one-day futures price.

The final essay contributes to the literature on intraday USDA announcement effects in electronic agricultural futures market by examining market reactions in CBOT electronic
soybean futures market using 15-second returns and trade volumes. Strongest market reactions to news occur in the first 10 to 15 minutes following report release regardless of the timing of the release. Marginally higher volatility in both magnitude and duration persist for trading-hour report releases compared to non-trading hour releases. Comparison of report effects using the normalized volatility measure which standardizes report day volatility by pre-/post-report day volatility indicates more pronounced market reactions during trading hour releases. The anticipated benefits of releasing reports during highly liquid market trading hours are not evident in the evolution of trade volume or return variance as more trades are required to incorporate information in the first few minutes following trading hour report release. Nonetheless, the results in general support earlier studies that indicate that soybean futures markets are quick and efficient in incorporating new information into prices.
To my parents, for their love and support.
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# TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION ............................................................................................. 1

CHAPTER 2: COMMODITY STORAGE UNDER BACKWARDATION: DOES THE WORKING CURVE STILL WORK? ................................................................. 12

CHAPTER 3: DOES THE BOXED BEEF PRICE INFORM THE LIVE CATTLE FUTURES PRICE? .................................................................................................. 43

CHAPTER 4: INTRADAY MARKET EFFECTS IN ELECTRONIC SOYBEAN FUTURES MARKET DURING NON-TRADING AND TRADING HOUR ANNOUNCEMENTS ....... 79

CHAPTER 5: CONCLUSIONS ........................................................................................... 116

APPENDIX A: .................................................................................................................... 119
CHAPTER 1
INTRODUCTION

This dissertation examines three contemporary issues in agricultural commodity markets. The first essay focuses on commodity grain storage, using precisely defined price and stock data to challenge the argument that the classic Working curve is an artifact of data aggregation and mismeasurement. The second essay examines the relative information content in live cattle futures and boxed beef prices in the post Mandatory Price Reporting (MPR) era to identify the price producers should focus on as an alternative to a thinly traded cash market price. The final essay offers pioneering work in soybean futures market microstructure and evaluates market reactions following selected United Stated Department of Agriculture (USDA) report releases during non-trading and trading hours.

The first essay “Commodity Storage under Backwardation: Does the Working Curve Still Work?” explores whether commodity inventories are being held when the expected returns to storage are negative. Storage under negative carrying charges or backwardation is controversial because it appears to contradict inter-temporal arbitrage conditions. Based on studies in Chicago wheat markets, Working (1933, 1948) developed the “Working curve” to describe the systematic relationship between storage and the difference between contemporaneous spot and future prices. The relationship identified by Working (1949) is positively sloped, displays storage under inverse carrying charges, and is consistent with convenience yield as a key component of the Supply of Storage Theory.

The existence of the Working curve and its convenience yield explanation have been challenged by Wright and Williams (1989), Benirschka and Binkley (1995), and Brennan, Williams, and Wright (1997). These authors argue that the Working curve is illusionary, an artifact of data aggregation and mismeasurement. Following these arguments the aggregation question has been investigated by several researchers including Frechette and Fackler (1999), Yoon and Brorsen (2002), Klumpp, Brorsen, and Anderson (2007), Franken, Garcia,
and Irwin (2009), and Carbónez, Nguyen, and Sercu (2012). These studies generally support the Working curve and the presence of convenience yield, but do not completely address the aggregation arguments raised by Wright and Williams (1989) or utilize data that cannot be easily generalized to other commodities and markets. Carter and Revoredo-Giha (2007) reassess the Working curve using Working’s original data. They argue that the literature has inadequately addressed the question of whether the Working curve is a “realistic stylized fact.” If the Working curve is valid, then explanations to clarify why stocks are held under backwardation are needed. If not valid, then convenience yield and its extensions used in modeling commodity markets are in question and other stylized facts must be used to reflect market behavior. My work is an extension of Carter and Revoredo-Giha’s (2007) research and is motivated by the notion that evidence developed with data on one market from the 1920s and 1930s may not be generalizable to current markets. Given backwardations in prices and the role that storage plays in commodity models (Williams and Wright 2005; Pirrong 2011), and the continued use of convenience yield in explaining price behavior in economic models, developing the existence of the Working curve in current markets warrants attention.

The existence of the Working curve and convenience yield is investigated with recent (1990-2010) spot and futures prices and stock data for Chicago Board of Trade (CBOT) corn, soybeans, and wheat and Kansas City Board of Trade (KCBT) wheat. The study is complemented with shipping certificate data that have been used as the delivery instrument for CBOT corn and soybean futures contracts since March 2000. A maximum futures and spot spread (the difference between the low spot bid and the high futures price of the day for the next-nearby contract) is used to reduce the likelihood that observed relationships are influenced by quality or locational differentials. Since the maximum futures and spot spread is a stringent measure to assess the Working curve, a futures only spread measure i.e., the difference between the nearby futures prices and the next-to-expire futures prices

1 Spot and cash prices are used interchangeably.
(Working 1948; Telser 1958; Thompson 1986; Yoon and Brorsen 2002) is also used. Weekly deliverable stock data on the first Friday of the delivery period are plotted against standardized one-month spreads. Finally, the findings are contrasted with the holding behavior for a pure financial instrument—the shipping certificate. The findings indicate that storage under backwardation is pervasive both in terms of the percent of observations that exhibited storage at a loss, and the magnitude of the stockholdings. Market agents tend not to hold shipping certificates (pure financial instruments lack convenience yield) in inverted markets while the convenience yield inherent in physical stocks facilitates continuous stock holding at the same delivery points.

The second essay “Does the Boxed Beef Prices Inform the Live Cattle Futures Price?” investigates the relative information content of live cattle futures prices and boxed beef cutout values. In recent decades the U.S. cattle industry has experienced added vertical integration and concentration, raising concerns about thin cash markets and the reliability of market information (Koontz and Ward 2011). The Livestock Mandatory Reporting Act (LMRA) was passed by the Congress in 1999 which implemented a mandatory system of price reporting for livestock and meat products to improve price transparency. However, concerns continue to increase as more negotiated cash price transactions are replaced by contracts, marketing agreements, alliances, formula-pricing arrangements, and packer-owned cattle. As packers and producers continue to choose non-negotiated cash methods to transfer cattle ownership, the market may be forced to look at alternate sources of information to perform its price discovery function.

While the fed cattle cash markets have been studied extensively since 2001, there has been less recent focus on the Chicago Mercantile Exchange (CME) live cattle futures contract and on negotiated boxed beef prices as tools for price discovery. Prior research identifies the close link between cash and futures prices with the futures price leading cash price movements (Oellermann and Farris 1985; Koontz, Garcia, and Hudson 1990; Yang, Bessler, and Leatham 2001). In a recent study Park, Jin, and Love (2011) argue that futures prices result from
market information and do not drive decisions made along the beef supply chain. According to the authors, causality during the 1988-2005 periods is from cash fed cattle price to the futures price. The live cattle futures quotes are readily available, easily accessible, and are based on broad based national trading making them valuable sources of information (Shroeder and Mintert 2000). Live cattle futures markets are also found to be efficient in incorporating new supply and demand information quickly into prices (Garcia et al. 1988; McKenzie and Holt 2002). Nonetheless, if packers continue to use non-negotiated cash methods to procure cattle, the underlying cash market may become thin and less representative of actual price levels, affecting the informational value of the live cattle futures contract.

The wholesale boxed beef cutout value, which reflects the price that packers receive for beef products, is an appealing alternate source of price discovery (Schroeder and Mintert 2000). Reported boxed beef cutout values represent a negotiated commitment from the packer to sell the product twenty-one calendar days ahead i.e., expected wholesale prices several days or even weeks ahead is incorporated into the boxed beef price. Boxed beef prices are reported by the USDA so that market participants can track meat prices on a daily and weekly basis and may use them in negotiations over cattle prices (Perry et al. 2005). Boxed beef prices have been extensively examined in U.S. fed cattle price transmission studies. The results are mixed, with studies indicating farm price causing wholesale prices (Boyd and Brorsen 1985; Shroeder and Hayenga 1987; Park, Jin, and Love 2011); others suggesting enhanced price transmission and information flow in both directions (Marsh and Brester 1989; Goodwin and Holt 1999); and one identifying wholesale and retail markets as the seat of price discovery (Hahn 1990). Schroeder and Mintert (2000) suggest that the difference between boxed beef wholesale prices and cash fed cattle prices may vary depending on processing margins, which generally include slaughter and processing costs less hide and offal values, making its use difficult for formula pricing. While several challenges exist, researchers have not ruled out the role of boxed beef prices as an important source of fed cattle information and in pricing cattle.
The dominance of futures price over cash price in fed cattle price discovery is well established. However, to date, the literature on the relationship between boxed beef and futures prices is limited by a lack of attention to the temporal aspects of boxed beef price reporting and by use of data not representative of the actual short-run (weekly frequency) pricing process in the market. We use the nearby CME live cattle futures price and average cutout value for the afternoon boxed beef report from 1/9/2004 to 9/27/2013. The nearby futures is the settlement price at 1:00 p.m., and the afternoon boxed beef value is an average of trades from 1:30 p.m. on the previous day to 1:30 p.m. of the current day. Consistent with the weekly fed cattle pricing process and to account for any temporal informational advantage in the futures price, the analysis is performed using Friday boxed beef prices, and both Friday and Thursday futures settlement prices. The futures settlement price also assimilates information from other contemporaneous alternative marketing arrangements (AMAs) released by USDA. Hence, assessing the lead-lag relationship between the boxed beef price, and Thursday and Friday futures settlement prices can help to establish which price producers should watch as an alternative to thinly-traded cash market prices. Data are examined using time series procedures including cointegration and error correction modeling, testing for time varying cointegration (Bierens and Martins 2010), innovation accounting, Granger causality tests using the Toda and Yamamoto (1995) procedure, and employing newly-developed price discovery metrics (Yan and Zivot 2010; Putnins 2013). We find that the boxed beef price does not meaningfully inform the live cattle futures price. Newly-developed price discovery metrics interpreted to allow for a maximum boxed beef effect in the pricing process still identify the dominance of the current futures price, and suggest equal weighting for the lagged one-day futures price.

The third essay “Intraday Market Effects in Electronic Soybean Futures Market during Non-Trading and Trading Hour Announcements” evaluates trade volumes and return variances in electronic soybean futures market following USDA report release during non-trading and trading hours. Beginning January 11, 2013 USDA began releasing several important
market reports including World Average Supply and Demand Estimates (WASDE), Acreage (AC), Crop Production (CP), Grain Stocks (GS), and Prospective Planting and Small Grains Summary (PPL) during trading hours at 11:00 a.m. While the change became effective in January 2013, the CBOT had already extended its electronic-only trading hours from May 21, 2012 allowing trade during the 7:30 a.m. USDA report release.

Following the change, concerns have emerged that trading hour report release leads to extended periods of volatility. Proponents of pre-opening report release argue that a period without trading when traders can submit and revise orders for possible later execution contributes to a more informative opening price, causing a quicker and efficient price adjustment to report release. Supporters of the change argue that releasing reports during the high volume, deeply-liquid trading hours dampens volatility, allowing shocks to be readily absorbed improving price discovery. Several studies in financial markets including Cao, Ghysels, and Hatheway (2000), Barclay and Hendershott (2003, 2008), and Moshiran, Nguyen, and Pham (2012) among others have attributed the efficiency of the pre-open period during news arrivals to the time available for market participants to evaluate the news. Intraday studies in CBOT corn futures markets by Kauffman (2013) and Lehecka, Wang, and Garcia (2014) indicate that market reactions to major USDA report releases are observed in the first 10 to 15 minutes following market open. Kauffman’s (2013) analysis with corn futures data post-May 2012 indicates that the release of the WASDE report during the trading sessions have heightened volatility and extended the price adjustments over 30 to 60 minutes. To date, no work has compared the differential impact of report release in agricultural commodity markets during trading and non-trading hours. While several microstructure studies have examined the impact of USDA report release in corn, none has discussed how the reports affect soybean intraday returns. Our paper offers pioneering work evaluating the release of USDA reports during non-trading and trading hours and quantifies its effects on volume, volatility, speed of price adjustment, trading intensity, and efficiency in CBOT electronic soybean futures market.
Report releases are categorized into two distinct periods, non-trading hour releases (June 2010-May 2012) and trading hour releases (June 2012-May 2014). The data consist of all WASDE, AC, CP, GS, and PPL reports for the period as well as prices and trade volumes for soybean nearby futures contracts obtained from CME Time and Sales data (Globex). Returns are computed as the difference in natural logarithms of the last price in each 15-second interval multiplied by 100. Volatility is measured using a specification similar to Entorf, Gross, and Steiner (2012), and Lehecka, Wang, and Garcia (2014). Average estimates of 15-second return variances and trade volumes are computed for report days, pre-/post-report days (five days before and five days after the report day), and compared using non-parametric procedures. We also measure normalized volatility by standardizing report day volatility by the corresponding pre-/post-report day volatilities. Trading intensity is measured as the number of contracts traded per transaction in each 15-second interval. The market effects are measured in a window 15 minutes before and 60 minutes after report release where most market reactions are expected. Finally, the market under- and overreactions following report release is answered by computing correlations among the first 15-second return after the report release, subsequent returns, and cumulative returns for 15 minutes. The findings indicate that trading hour report releases produce a relatively protracted response to market information, elevating volume and return variance briefly over 5 to 6 minutes compared to non-trading hour releases. The results in general indicate that soybean futures markets are quick and efficient in incorporating new information into prices.

The applied economic research presented in these contemporary agricultural commodity markets should provide valuable insights for academicians, industry, and policy makers. The findings of the first essay underline the relevance of the Working curve and its convenience yield explanation which challenges researchers to more carefully integrate processors along with speculators into their inventory models. The second essay identifies that live cattle futures prices reflect fundamental information on fed cattle much quicker than boxed beef prices, establishing the price market agents should watch as an alternative to thin cash mar-
ket price. The study also points to possible shortcomings in current boxed beef reporting which may be too thin to reflect or transmit price information quickly in the fed cattle market. The final essay provides the first assessment of the electronic soybean futures market microstructure. The strongest reaction to USDA reports occurs 10 to 15 minutes after news arrival regardless of the timing of release. The anticipated benefits of releasing reports during highly liquid market trading hours are not evident in the evolution of trade volume or return variance as more trades are required to incorporate information in the first few minutes following the report release. The market in general is found to be efficient in incorporating new information quickly into prices.
1.1 References


CHAPTER 2  
COMMODITY STORAGE UNDER BACKWARDATION: DOES THE WORKING CURVE STILL WORK?

2.1 Introduction

Storage is a key aspect for agricultural commodity markets in which output is seasonally produced and continuously used. The storage function is often closely aligned with the allocation role played by futures markets, enabling agents to decide when to store. If the difference between contemporaneous spot and futures is greater than the cost of storage (defined to include the physical warehousing costs and interest costs) the market signal is to store. However, inventories have been observed when the spread between the current spot and the next-to-expire futures contract price is negative. This apparent paradox—storage under negative carrying charges or backwardation—is controversial because it appears to contradict inter-temporal arbitrage conditions.¹

Kaldor (1939) offers an explanation, termed “convenience yield,” for the paradox. He argues that holders of physical commodities receive benefits that are not available from holding a futures contract. For instance, processors and merchandisers receive benefits from holding stocks to accomplish their operational activities. In closely related work, Eastham (1939) considers heterogeneous stockholders (processors and arbitrageurs) as opposed to assuming only one representative stockholder. According to Eastham (1939) processors may always carry inventory as working stocks whereas speculators carry stocks only if they can profit from the storage activity. While not mentioning convenience yield directly, it is clear that Eastham (1939) foresaw the development of convenience yield models in which firms hold inventory because it produces a flow of services.² Based on analysis of the Chicago wheat market, Working (1933, 1948) developed the “Working curve” to describe the systematic

¹ In the paper backwardation and negative carry are used interchangeably.
² Carter and Revoredo-Giha (2009) discuss Eastham’s model, its interaction with Working’s work, and different views on storage under backwardation.
relationship between storage and the difference between contemporaneous spot and future prices. The relationship is positively sloped and displays storage under inverse carrying charges (figure 2.1, panel A). Working (1949) used convenience yield as a key component of the Supply of Storage Theory to explain the Working curve.

Convenience yield can also be motivated as embedded option values arising from the physical storage of stocks. An optionality can arise when stock levels are low, generated by transaction costs (i.e., costs of communication, transport, and searching) associated with sourcing the commodity (Telser 1958) or by the possibility of stock outs (Routledge, Seppi and Spatt 2000). For instance, having grain in store allows processors and merchandisers to accomplish operational activities that require immediate access to grain. Another optionality arises when market agents arbitrage (buy or sell) spot and futures positions opportunistically before the end of a storage period (Heany 2002; Zulauf, Zhou, and Roberts 2006). In addition, a negative optionality may arise when stocks are large from the opportunity cost of filling binspace with competing commodities (Paul 1970), e.g., holding corn reduces merchandising opportunities in soybeans.

The existence of the Working curve and its convenience yield explanation have been challenged by Wright and Williams (1989), Benirschka and Binkley (1995), and Brennan, Williams, and Wright (1997). They argue that the Working curve is illusionary, an artifact of data aggregation and mismeasurement. Specifically, stocks are generally aggregated across locations and grades for reporting purposes and this may not accurately reflect market conditions. Once stocks and prices are measured at the appropriate location and grade, evidence of stocks being held in backwardations should disappear. Working’s Supply of Storage relationship becomes more like an “L” rotated clockwise (figure 2.1, panel B).

Carter and Revoredo-Giha (2007) take a different perspective by reassessing the Working curve using the original data. They argue that the literature has inadequately addressed the question of whether the Working curve is a “realistic stylized fact.” If the Working curve is valid, then explanations to clarify why stocks are held under backwardation are needed. If
not valid, then convenience yield and its extensions used in modeling commodity markets are in question and other stylized facts must be used to reflect market behavior. Using Working’s 1921-1932 data, they examine stocks only for Chicago to minimize potential spatial aggregation problems. The use of a single location reduces the emphasis on the longer-term stock/price endogenous relationship that motivated Working’s research, but permits a clearer reassessment of whether firms hold stocks at an apparent loss. In addition, they are careful to avoid errors due to aggregating different wheat grades. They find that wheat stocks were carried under backwardation in a single location, supporting the Working curve and casting doubt on aggregation arguments. However, a question emerges: Can evidence developed with data on one market from the 1920s and 1930s be generalized to current markets? Given backwardations in prices and the role that storage plays in commodity models (Williams and Wright 2005; Pirrong 2012) and the continued use of convenience yield in explaining price behavior in economic models, developing the existence of the Working curve in current markets warrants attention.

This paper investigates the existence of the Working curve and convenience yield with recent spot and futures prices and stock data for Chicago Board of Trade (CBOT) corn, soybeans, and wheat and Kansas City Board of Trade (KCBT) wheat. Weekly stocks at delivery locations are available for 1990-2010, which provide an extensive data set for assessing storage under backwardation. In addition, data on shipping certificates (delivery instruments) are available for CBOT corn and soybean starting in March 2000. Shipping certificates are pure financial instruments lacking convenience yield and their holding patterns can be compared to deliverable stocks for corn and soybeans to provide insights into the convenience yield explanation of the Working curve. Carter and Revoredo-Giha (2007) focus on price spreads towards the end of the crop year, i.e., September-July wheat spreads calculated each Friday during the month of July. In contrast, our study examines all price spreads to explicitly establish the relationship between the spread magnitude and stock holding behavior.

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Storage under an expected loss can also occur if risk-averse processing firms hold inventory to avoid price uncertainty of a commodity they will acquire later (Carter, Rausser, and Smith 2011).
throughout the crop year. We also contribute to existing literature by examining the proportion of stocks held in backwardation relative to the average stocks in the delivery period. This evidence may help clarify what amounts to “substantial” stock holding for a particular market under negative carry.

Previous researchers (e.g., Working 1948; Gray and Peck 1981) have used a conventional measure of the spread, futures less spot to study the temporal price structure of commodities. Following Carter and Revoredo-Giha (2007), a maximum futures and spot spread (the difference between the low spot bid and the high futures price of the day for the next-nearby contract) is used to reduce the likelihood that observed relationships are influenced by quality or locational differentials. The maximum spread can make backwardations less likely to be observed, but it provides a more stringent benchmark for assessing the Working curve. As an alternative, a futures only spread measure i.e., the difference between the nearby futures prices and the next-to-expire futures prices (Working 1948; Telser 1958; Thompson 1986; Yoon and Brorsen 2002) is used as a robustness check. Weekly deliverable stocks on the first Friday of the delivery period are plotted against standardized one-month spreads. Finally, the findings are contrasted with the holding behavior for a pure financial instrument–shipping certificates–that have been used as the delivery instrument for CBOT corn and soybean futures contracts since March 2000.

2.2 Literature Review

The aggregation argument has been investigated by several researchers. Frechette and Fackler (1999) examine the corn market and find that backwardations are influenced more by the aggregate level of stocks than their location, contradicting the claim that location of stocks explains backwardation. Yoon and Brorsen (2002) compare nearby futures price spreads with the contemporaneous costs-of-carry and find more frequent instances of backwardation.

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4 Spot and cash prices are used interchangeably.
5 In academia the spread is often measured as the next-nearby futures price less the current spot price and we follow this convention. In contrast, the grain industry commonly calculates the spread as the difference between the current spot and the next to expire futures contract price.
towards the end of the crop year when commodities are scarce. They argue the decision to store during backwardations by processors and livestock producers is consistent with the theory of price of storage. However, for farmers with relatively low convenience yield they attribute the decision to store during backwardations to behavioral concepts such as anchoring, overconfidence, and regret.

Klumpp, Brorsen, and Anderson (2007) take a different approach and compare differences in storage returns between disaggregate (elevator) and aggregate (USDA) data for wheat markets at three elevator locations in Oklahoma. Finding little difference in returns, they contend that their results do not support the conclusion that storage at a loss is due to data aggregation. Franken, Garcia, and Irwin (2009), examine the spatial aggregation argument for the storage-at-loss paradox using weekly regional and elevator level prices for corn and soybeans in Illinois. Their findings suggest limited aggregation effects and identify backwardations inconsistent with spatial aggregation explanations for storage at a loss.

Two recent analyses have examined indirectly the existence of convenience yield in agricultural commodities. Sorenson (2002) uses a Kalman filter framework to estimate implied net convenience yield in corn, soybeans, and wheat futures spreads. Subsequently, he identifies a negative relationship between convenience yield and stocks. While the convexity of the convenience yield-stock relationship was difficult to identify in corn and wheat, the Working curve pattern clearly emerged in soybeans. More recently, Carbonez, Nguyen, and Sercu (2012) indirectly model convenience yield in corn, soybean, and wheat using a cost-adjusted basis measure employing concurrent spot and futures prices. They find a negative relationship between their measure of convenience yield and deliverable stocks using a framework that accounts for the time to maturity and harvest effects. While both studies generally support the existence of the Working curve, the findings do not directly address aggregation concerns raised by Wright and Williams (1989) and others, and may be complicated by econometric issues. Sorenson’s analysis does not consider aggregation questions as he uses an average futures price spread and aggregate U.S. quarterly stocks. Carbonez, Nguyen,
and Sercu (2012) use more detailed inventory data, but their spot prices are an aggregate or an average of reported prices in a somewhat heterogeneous region of Illinois. Further, both studies do not consider potential endogeneity that may exist in statistical analysis between their indirect convenience yield measure and the levels of stocks.

2.3 Data and Empirical Procedures

Our objective is similar to Working’s (1933, 1948) studies and Carter and Revoredo-Giha’s (2007) more recent study. The methods used are direct and include simple tests on inventory (certified stock data from delivery locations on the first Friday following the first day of delivery for the contract) matched against the price of storage (spreads calculated relative to the next nearby futures contract) and recording positive storage at substantial magnitudes during negative carry. To develop a sense of how “substantial” stock holdings are during backwardations, the average inventory for each backwardated spread (e.g., December-March) at a location is expressed as a percent of the average inventory at the same location and spread.

The traditional method to calculate the spread is to measure the difference between contemporary spot and futures prices. However, commodities certified for delivery can be of different grades which are deliverable at a premium or discount to the par grade. In addition, spot prices from the delivery territory can vary even within small distances causing average prices used in previous studies to be less representative of actual trades. To address these issues, we follow a conservative approach similar to Carter and Revoredo-Giha (2007) by calculating the largest possible spread of the day. For any given nearby contract, this maximum spread is calculated as the high futures price of the day (adjusted by location-specific discount/premiums) for the next-to-expire futures contract minus the lowest spot bid for the par deliverable grade at the deliverable location. This ensures that when the maximum futures-spot spread for the par deliverable grade is negative, the spread for all bids

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6 See Irwin et al. (2011) for a review of the delivery process for U.S. grain futures markets.

7 The deliverable stocks used are mostly par deliverable grade or higher and deliverable for a premium.
for the deliverable grade at that location on the given date are also negative. For example, consider a futures contract for delivery two months from now priced at 700 cents/bu. with current spot prices (low bids of the day with all premiums/discounts applied) for deliverable grades at 710 cents/bu. for no. 2 soft red winter wheat (par deliverable grade) and 715 cents/bu for no. 1 hard red winter wheat. The use of the lowest bid for the par deliverable grade ensures that the -10 cents/bu. spread (700 cents minus 710 cents) is a ceiling spread and other combinations of futures and spot prices for all grades on that day are more negative.

The conventional method to calculate the spread (the difference between current spot and next nearby futures price) assumes convergence of cash and futures prices for the contract in the delivery period. Recent studies on CBOT corn, soybean, and wheat futures markets (Irwin et al. 2011; Garcia, Irwin, and Smith 2014), indicate that spot and futures prices did not converge as expected during parts of analyzed period, with the spot being below futures prices. These episodes of non-convergence can lead to a wider, positive, futures-spot spread making it less likely that we observe backwardations and the Working curve. As a result, the spread between the nearby and the next-nearby futures contract on the first Friday of the delivery period that corresponds to the weekly stock data is also examined. The term spread as measured from the futures-futures measure provides a downward estimate of the expected returns from storage when the storage rates in the contract specification are less than the market price of storage (Garcia, Irwin, and Smith 2014). However, these downward estimates are more likely to occur when stocks are large and should not affect the price of storage during backwardations when stocks are in short supply.

Our study uses 1990-2010 data for CBOT corn, soybean, and wheat futures prices, KCBT wheat futures prices, with daily spot bids at various delivery locations. Futures prices are from barchart.com. The lowest spot bids at Chicago, Toledo/Maumee, Illinois River North of Peoria, and Kansas City are from the USDA Agricultural Marketing Service (USDA-AMS) archives. The Hutchinson delivery location was added for KCBT wheat in 1996 and spot
prices reported in *Wichita Eagle* are used from 1996-2007. USDA-AMS lowest spot prices are available from 2008 forward. These spot bids are at the point of delivery and are mostly U.S. no. 2 yellow corn, U.S. no. 2 soft red winter wheat for CBOT wheat, and U.S. no. 2 hard red winter wheat for KCBT wheat. For soybeans, the spot prices are for U.S. no. 1 yellow soybean and we adjust the spread by adding CBOT determined premiums to the high futures price for the deferred futures contract, which reflects U.S. no. 2 yellow soybeans.\(^8\) Since data include 1, 2, or 3 month spreads, corresponding to the temporal structure of futures contracts, calculated spreads are standardized by the number of months between the nearby and next-to-expire futures.

Both the CBOT and KCBT collect weekly stock data from firms regular for delivery. Stocks are classified as deliverable grades, non-deliverable grades/ungraded and CCC (Commodity Credit Corporation) inventories. The stocks are from delivery regions specified by the exchanges where firms regular for delivery have storage facilities and/or shipping stations. Following Wright and Williams (1989), we use deliverable stocks which meet exchange quality requirements for futures delivery and correspond most closely to the actual market prices. The stock data, compiled from CBOT and KCBT weekly reports, provide a unique opportunity for testing storage under backwardation.\(^9\)

Shifting commercial activity over time, e.g., increased flows to port destinations, have forced the CBOT to close some traditional delivery locations and set up new delivery locations closer to the commercial grain flow (Irwin et al. 2011). Previous research (Working 1948, 1949; Gray and Peck 1981; Carter and Revoredo-Giha 2007; Carbonez, Nguyen, and Sercu 2012) has often used Chicago as the location to study backwardations. Commercial flows of grain through Chicago have been reduced sharply in recent decades, marking the decline of Chicago as a terminal grain market. Nonetheless, Chicago continues to be a par delivery location for CBOT corn, soybean, and wheat for the 1990-2010 period.

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\(^8\) All futures-spot spreads are adjusted for grade and delivery location premiums/discounts.

\(^9\) Analysis using total stocks including CCC and non-deliverable inventory resulted in similar findings.
and is included. In March 2000, the CBOT undertook major changes in the delivery system by closing the Toledo/Maumee delivery location and opening new delivery points for corn and soybean contracts. The new locations are along the Illinois River north of Peoria (Lockport-Seneca, Ottawa-Chillicothe, and Creve Coeur-Pekin); locations that had become major trans-shipment points. The cheapest-to-deliver location for corn and soybeans in the 1990s tended to be Toledo/Maumee with Northern Illinois River regions becoming the cheapest-to-deliver for corn post-2000.\footnote{Relatively large deliverable stocks for soybeans are found at Chicago compared to the river delivery locations for the post-2000 period. The USDA-AMS low spot bids are more or less comparable at both these locations. Nonetheless, we combine Toledo and Northern Illinois River delivery regions similar to corn.} To reflect inventory from cheapest-to-deliver locations with significant commercial grain flows, stocks from Toledo/Maumee delivery regions and Northern Illinois River delivery regions are concatenated and reported as a single delivery point—Toledo/Maumee-Northern Illinois (TOL/MA-NI). The Toledo/Maumee delivery location has tended to be the cheapest-to-deliver location for CBOT 1990-2010 wheat contracts and is used for CBOT wheat. For KCBT wheat, we use the Kansas City location which has been an important par delivery point since the development of the contract. In addition, we also examine stocks at Hutchinson which has been the cheapest-to-deliver location for KCBT for the major part of the analysis post 1996. Hence, KCBT stocks are examined at Kansas City, a market that has not been subject to changes in location and delivery requirements and at Hutchinson reflecting the more active delivery location with substantial flow of grain.\footnote{The results for other delivery locations excluding the river delivery points for CBOT wheat and KCBT wheat are available upon request.}

### 2.4 Results on the Working Curve

Tables 2.1-2.4 provide a summary of the number of spreads, number and percent of spreads with negative carry, stocks held under backwardation, and the percent of stocks held during backwardations relative to overall average stocks for that period. The results are reported for the futures-spot (F-S) price spread (i.e., high next-to-expire futures price less the low spot bid) and the futures-futures (F-F) price spread (i.e., next-to-expire futures contract
price less the expiring futures contract price) by commodity, location, and contract. Finally, stocks and corresponding spreads based on the F-S and F-F measures are plotted by commodity and location (figures 2.2-2.5). As identified, the F-S measure is a maximum (and conservative) spread, which may require large market inversions to identify the shape of the Working curve. The F-S spreads post-2004 belong to a period of persistent non-convergence with the cash settling below the futures and those stocks may not fit into the structure of the Working curve as directly as in the F-F measure. To facilitate better assessment of the shape of the Working curve for this more stringent benchmark, we mark stocks for corn, soybeans, and wheat post-2004 using hollow triangles.

2.4.1 Corn

For both spread measures in table 2.1, the highest proportion of backwardations for corn occur late in the crop year in July, which is a reflection of the differences between old and new crop prices (Yoon and Brorsen 2002). The particularly large number of backwardations in the July-September spreads (35% at Toledo/Maumee-Northern Illinois and 20% at Chicago for the F-S spread, 40% for the F-F spread) facilitate the assessment of positive stock holding behavior in inverted markets. There are no observations with zero stocks when the spreads are matched against inventory. The percentage of total observations exhibiting positive storage under backwardation are comparable for the F-S spread at Toledo/Maumee-Northern Illinois (14.7%) and the F-F measure (18.6%), and is small for Chicago (8.8%).

The magnitude of the average stocks carried under backwardation late in the crop year is large in Toledo/Maumee-Northern Illinois and is non-trivial in Chicago relative to the average stocks that are held at those locations. For example, the average stocks in July for the inverted July-September spreads is 4 million bu. for the F-S spread in Toledo/Maumee-Northern Illinois and 4.1 million bu. for the F-F spread. Irrespective of the spread measure, close to 93% of the average stock holdings (4.3 million bu.) is held under backwardation in this location. At Chicago which is not a major delivery location for corn, substantial deliverable stocks (i.e., close to 1.5 million bu. or approximately 40.6% of overall average)
are held in July when the July-September F-S spreads are inverted. The conservative nature
of the maximum F-S spreads at both delivery regions (figure 2.2, Toledo/Maumee-Northern
Illinois region (panel A), Chicago (panel B)), make it somewhat difficult to identify the
Working curve. However, the F-F spreads in figure 2.2 (Toledo/Maumee-Northern Illinois
region (panel C), Chicago region (panel D)) provide strong evidence in support of the Work-
ing curve.\footnote{The 1996 July-September corn spread is one of the most extreme old crop/new crop inversions in
recent memory at -64.25 cents/bu./mo. for the F-F spread, -59.5 cents/bu./mo. at Chicago, and -58.5
cents/bu./mo. at Toledo/Maumee-Northern Illinois. Calculations in table 2.1 include this spread, but figure
2.2 does not as it distorts the shape.}

\subsection*{2.4.2 Soybeans}

The new crop for soybeans is the November contract. The transition from old to new crop
is evident from the higher frequencies of negative carry in the spreads late in the crop year,
i.e. the July-August, August-September, and September-November spreads for both spread
measures (table 2.2). The July-August spreads in particular exhibit a higher frequency of
backwardations (20\% of the F-S spreads at Toledo/Maumee-Northern Illinois, 25\% of F-S
spreads at Chicago, and 60\% of the F-F spreads) among all spreads. There are no observa-
tions with zero stocks when the soybean spreads are matched against inventory. For the F-S
spread, 9.1\% at Toledo/Maumee-Northern Illinois and 9.8\% at Chicago exhibited positive
stock holding under backwardation, while for the F-F spread 30.8\% have a similar pattern.
In general, backwardations are more prevalent in soybeans (30.8\%) than in corn (18.6\%) for
the F-F spread.

The magnitude of average soybean stocks held under backwardation is rather high for
both spread measures in Toledo/Maumee-Northern Illinois and Chicago. The stock hold-
ings for the backwardated July-August spreads using the F-S spread measure is above 1
million bu. at both delivery locations, which amounts to 43\% of the overall average at
Toledo/Maumee-Northern Illinois and 30.3\% of the overall average at Chicago. For the
July-August F-F spreads, the average stock holdings during backwardation is 1.8 million
bu. in Toledo/Maumee-Northern Illinois which is 76.6% of the average stocks held at that location for that spread horizon. Large stock holdings for soybeans exist despite the high levels of the negative carry in soybeans. The shape of the Working curve is also evident at both the Toledo/Maumee-Northern Illinois and Chicago locations regardless of the spread measure used. Plots for soybean (figure 2.3) at Toledo/Maumee-Northern Illinois (panel A, panel C), and Chicago (panel B, panel D) provide strong evidence of stockholdings under backwardation in support of the Working curve.

2.4.3 Wheat (CBOT)

Coinciding with the U.S. soft red winter wheat harvest in mid-May through mid-July, the March-May and May-July spreads for CBOT wheat exhibit the most consistent backwar-
dations. In contrast to corn and soybeans, the July-September spreads for CBOT wheat indicate only limited evidence of backwardation for both spread measures. Backwardations in the December-March spreads are rarely observed in the conservative F-S spreads at both locations, whereas they are more prominent (25%) for the F-F spread measure. Deliverable stocks for CBOT wheat remain positive for all the dates when spreads are matched with inventory. In table 2.3, 28.6% of the March-May F-F spreads and 19% of the May-July F-F spreads exhibited positive storage under negative carry. Similar patterns of storage are also visible at Chicago for the March-May and May-July F-S backwardated spreads. In Toledo/Maumee and Chicago, the percentage of total observations showing storage under backwardation are 3.9% and 6.9% for the F-S spread, and 16.7% for the F-F spread. This difference in the number of backwardations appears to emerge from the persistent failure to converge (with the spot price below the futures) in the CBOT market.

Average stock size at Toledo/Maumee in March when F-S March-May spreads are in-
verted is 2.5 million bu. and close to 14% of average stocks held at that location during the

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13 Soybean prices on 3/7/2008 dropped from news that China reportedly flooded its domestic markets with soybean oil to control rising prices. Since the March-May F-F spread for soybeans measured on 3/7/2008 at 33.88 cents/bu./mo. is considerably higher than other observed spreads during the period, we use the spread from the previous day (3/6/2008). For consistency, the March-May spread for the F-S measure is also calculated on 3/6/2008.
March-May spread horizon. Stocks in Chicago during backwardations are negligible when compared to the average stocks size held at Chicago. Nearly 8.8 million bu. of deliverable wheat is carried in March at Toledo/Maumee during the inverted March-May F-F spread which amounts to almost 50.3% of average stocks held at that location for that spread. We find only one incidence of backwardation among the July-September spreads using the F-F measure for CBOT wheat with an average 2.3 million bu. (17.7% of overall average) stored in Toledo/Maumee. Substantial quantities of wheat are also held early in the crop season in Toledo/Maumee when the December-March spreads are inverted, with average stock sizes of 5.7 million bu. (28.8% of overall average) for the F-S spread and 8.5 million bu. (43.3% of overall average) for the F-F spread. For CBOT wheat, evidence of stocks being held under backwardation is observed in figure 2.4, for Toledo/Maumee (panel A, panel C) and Chicago (panel B, panel D) regions. In both markets, strong support of the Working curve emerges in the F-F spreads.

2.4.4 Wheat (KCBT)

Hard red winter wheat is the largest wheat crop in U.S., planted in the fall and harvested in the following summer. Table 2.4, panel A presents spreads and stocks for the full period (1990-2010) at Kansas City, and panel B compares the stocks at Hutchinson and Kansas City for a shorter period post July 1996. Similar to CBOT wheat, the March-May and May-July spreads for KCBT wheat show higher incidence of backwardations reflecting the shift from old to new crop. In contrast to CBOT wheat, the July-September, September-December, and December-March spreads for KCBT wheat also indicate higher incidence of backwardations for both spread measures. Deliverable stocks for KCBT wheat are non-zero for all dates. Data prior to July 1996 include frequent backwardated observations for the Kansas City location, indicating the importance of using the extended period (panel A). Regardless of the spread measure, nearly 38% of the observations exhibit positive storage under backwardation at Kansas City in panel A. The frequency of backwardations at Hutchinson is less compared to Kansas City in panel B particularly for spreads later in the crop year. This
difference arises despite adjusting the Hutchinson spreads by KCBT specified location differentials. Nevertheless, 14% of the F-S spreads at both locations and 26% of the F-F spreads exhibit positive storage at a negative carry. Similar to corn and soybeans, backwardations are not concentrated in the old/crop new crop spreads.

In panel A, nearly half of all March-May, May-July, and December-March spreads are backwardated with average storage in excess of 4 million bu. for both spread measures, reaching an average 11 million bu. for the inverted F-S spreads. The stock holdings during backwardations are also substantial when compared to the average stocks held at Kansas City and is consistent across all spread horizons and spread measures. For example, the average stock holdings in March during inverted March-May spreads is 9.4 million bu. for the F-S spread, and 7.8 million bu. for the F-F spread, both amounting to nearly 70% of the average stock holdings at Kansas City. Comparison of stocks at Hutchinson and Kansas City in panel B indicates substantial stocks being held during the backwardated March-May, May-July, and December-March spreads relative to the average holdings at those locations. Kansas City stocks are measured against F-F spreads for the full period in panel A and Hutchinson stocks are used in panel B as it is the most active delivery location for the major part of the analysis post 1996. Irrespective of stocks used, the F-F spreads in both panels exhibit clear evidence of substantial stock holding during backwardation. The evidence for positive stockholding under backwardation, and the Working curve appears to be overwhelming for Kansas City spreads for the full period in figure 2.5 (panel A, panel B). Clearly, backwardations are observed more frequently in KCBT wheat than in CBOT. Kansas City is predominantly a milling center, whereas Chicago and Toledo/Maumee are traditional trans-shipment points (Gray and Peck 1981). This is further supported by the Working curve emerging more clearly for the shorter period in the F-S spreads at Kansas City (panel D) relative to Hutchinson (panel C) which is also a trans-shipment point. Consequently, higher convenience yield may accrue at Kansas City where commodities are more likely stored for milling and processing operations. Strongest support of the Working curve
emerges in the F-F spreads at both locations (panel E, panel F).

2.5 Shipping Certificates

Prior to March 2000 for corn and soybeans and July 2008 for CBOT wheat, the delivery instrument for CBOT contracts was a warehouse receipt (Irwin et al. 2011). The delivery instrument for KCBT has always been a warehouse receipt. A warehouse receipt conveys title to the grain held under storage in a designated warehouse facility which is same as the deliverable grain physically held at the warehouse facility. In contrast, the shipping certificate is a “Call on Demand” instrument that does not require the regular (elevator) to hold grain at the warehouse facility, but have it readily available when called upon in an exchange-specific time. In short, shipping certificates are pure financial instruments that break the link between the delivery instrument and the physical grain stocks.

The longs who receive shipping certificates from the shorts during the delivery process are not required to cancel the certificates for shipment. The firm holding a shipping certificate has several alternatives, including: 1) hold the certificate and pay the exchanged-determined storage charge; 2) sell the certificate to another market participant at a negotiated price; 3) sell a futures contract and re-tender the certificate by making an intention to deliver; and 4) cancel out the certificate by demanding load out (Irwin et al. 2011). Shipping certificates will remain outstanding if the price spread between the current and next-to-expire futures contract exceeds the cost of owning the delivery instrument (Irwin et al. 2011). Under normal market conditions, shipping certificates are traded in a secondary market and commonly sell for not less than the nearby futures price (Aulerich, Fishe, and Harris 2011). In backwardation, it is not clear why speculative market agents would hold a tradable financial instrument incurring storage and opportunity costs if it can be purchased at a lower price in the near future. Since shipping certificates contain no immediate convenience yield gains, it is not expected that they will be held during backwardations, and the relationship between shipping certificates and the spreads should yield an “L” shaped curve rotated clockwise (figure 2.1, panel B) as opposed to a convex Working curve pattern for physical stocks con-
sistent with convenience yield.

Total corn and soybean deliverable stocks are plotted against the futures-futures (F-F) spreads, and the stocks of pure financial instruments-shipping certificates (figure 2.6).\footnote{Wheat is excluded because shipping certificates were only introduced in July 2008.} The total outstanding shipping certificates for CBOT corn and soybeans are obtained from the Delivery Certificates under Registration (DCUR) report by the Registrar at the CBOT. The data period spans from the March 2000 delivery through May 2010 delivery for corn, and January 2000 delivery through May 2010 delivery for soybeans. Since data for shipping certificates by location (delivery zone) are sparse and could not be matched consistently with deliverable stocks, we use outstanding shipping certificates for corn and soybeans issued from all delivery locations, and available stock data from all active delivery locations beginning in 2000.\footnote{A few observations were not used due to lack of shipping certificate data.} We use the futures-futures backwardations as our measure of price of storage which is independent of price, grade, and location considerations and more consistent with the nature of the certificate data, and focus on the differential behavior between stock and shipping certificate holdings.

The general patterns in the two corn and soybeans curves support the differential structure consistent with the convenience yield explanation. While backwardations are limited for corn (panel A), they are more frequent in soybeans (panel B). As expected, when the spreads reflect a more positive carry, the number of outstanding shipping certificates held increases for both CBOT corn and soybeans. The increased number of shipping certificates as the spread approached 5 cents/bu./mo. (the futures capped storage rate) reflects the period in the sample when the market price of storage exceeded the capped rate making it attractive to hold shipping certificates (Garcia, Irwin, Smith 2014). For the two backwardated observations in corn (panel A), the magnitude of deliverable stocks is much higher than that implied by the number of shipping certificates, revealing evidence in support of convenience yield inherent in physical stock holdings. For soybeans (panel B), the number...
of shipping certificates being held is minimal compared to the total deliverable stocks and in many instances close to zero when the spreads are in negative carry. As a less stringent test of convenience yield, we plotted the differences between shipping certificates and stocks for each corn and soybean spread, and failed to find an observation for which shipping certificates exceeded stocks in the presence of backwardation.\footnote{The only exception is shipping certificates exceeding deliverable stocks on 7/7/2000 at -0.25 cents/bu./mo. This observation coincides with the July 2000 contract when the new delivery instrument was first introduced. These figures are available upon request.}

Despite this evidence, some certificates were held during backwardations for both corn and soybeans. The exact reasons for this occurrence are not clear, but may be related to variations in the “strategic games” played at delivery documented by Peck and Williams (1991), and facilitated by the financial dimension of certificates. In the presence of backwardation, differences in expectations along with difficulties in selling (or cancelling out) certificates at a price that wouldn’t result in a substantial loss may have led certificate holders to maintain their positions. For instance, the largest number of shipping certificates (1131 certificates) held for soybeans in backwardation occurred after large price increases and just before the financial market crash in 2008. Attracted and buoyed by recent price rises, certificate holders may have temporally resisted cancelling positions at a loss by selling at lower next-nearby futures prices or at negotiated prices that also likely reflected a decline in value. While the explanation is plausible, further research in the shipping certificate market during backwardations may clarify these occurrences.

\subsection{2.6 Conclusions}

This paper investigates the existence of the Working curve and convenience yield with recent spot and futures prices and stock data for Chicago Board of Trade (CBOT) corn, soybeans, and wheat and Kansas City Board of Trade (KCBT) wheat. The analysis is performed using traditional futures-spot and futures-futures price spreads, and deliverable stocks. Storage under backwardation is pervasive both in terms of the percent of observations that exhibited storage at a loss, and the magnitude of the stockholdings. The futures-futures spreads often
provide the strongest evidence of storage under backwardation, except for KCBT wheat at Kansas City location and CBOT soybean market where substantial evidence is provided by both measures. In all cases, stocks decline monotonically as the spread falls, but remain positive as the spread falls below zero. Our backwardation measures do not account for storage and interest costs, and hence the incidence of storage-at-a-loss (spreads with magnitude lower than the full cost-of-carry) is likely much higher.

While we observe the Working curve in the futures-futures plots, the maximum conservative futures-spot plots makes the identification of the exact shape of the Working curve somewhat difficult. The most convincing evidence for the existence of convenience yield is revealed in the magnitude of stockholdings under backwardation in Kansas City, where wheat is likely stored for milling and processing, and in the plot for shipping certificates and deliverable stocks for soybeans with large processors in the vicinity. Kansas City, Chicago, and Toledo/Maumee have the most heterogeneous end-users, while Hutchinson and locations along the Illinois waterway are probably less likely to hold grain for long-term storage purposes. Nevertheless, we find evidence in support of the Working curve at all locations. There is a positive relationship between spreads and (a wide range of) inventories suggesting that even terminal locations hold some stocks for storage as well as convenience. We demonstrate that market agents tend not to hold shipping certificates (pure financial instruments lacking convenience yield) in inverted markets while the convenience yield inherent to physical stocks facilitates continuous stock holding at the same delivery points. The results support Working’s (1933, 1948) original analysis and Carter and Revoredo-Giha’s (2007) more recent re-assessment. In simplest terms our results show that the working curve does indeed still work in modern grain markets. Convenience yield is the most likely explanation for the observed phenomenon of holding stocks during backwardations at an apparent loss. Stocks are held for reasons other than speculation, and the spatial aggregation argument alone is inadequate to explain storage-at-a-loss.

What are the implications of the results in periods of low stocks and high price volatility?
The response of prices to supply and demand shocks when stocks are low is well established (Deaton and Laroque 1992, Ng and Pirrong 1994). The fact that commodities are increasingly being put to diverse uses, for instance, the increased use of corn due to the ethanol mandate, puts extra pressure on stocks making precise modeling of storage dynamics even more crucial (Carter, Rausser, and Smith 2012). Identifying the Working curve as a stylized fact in agricultural commodity markets points to the need for integrating models in the tradition of commodity storage model proposed by Gustafson (1958) and those that belong to the supply of storage convention of Working (1933, 1948). Following Eastham (1939) and Carter and Revoredo-Giha (2009), it may be useful to model the interaction of heterogeneous market agents (processors and arbitragers) separately to represent commodity price behavior more accurately. In short, the relevance of the Working curve and convenience yields challenges us to more carefully integrate heterogeneous agents into our inventory models.
2.7 References


## 2.8 Tables and Figures

### Table 2.1. Seasonal Backwardations and Stock Holding in the Corn Market, 1990-2010

<table>
<thead>
<tr>
<th>Spread measure</th>
<th>Months</th>
<th>No. Obs.</th>
<th>Sp&lt;0 &amp; I&gt;0</th>
<th>% Sp&lt;0 &amp; I&gt;0</th>
<th>(1) I. Sp&lt;0 &amp; I&gt;0</th>
<th>(2) I.</th>
<th>(1) as a % of (2)</th>
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<tbody>
<tr>
<td>F-S</td>
<td>Dec-Mar</td>
<td>20</td>
<td>1</td>
<td>5</td>
<td>9,244</td>
<td>8,337</td>
<td>110.9</td>
</tr>
<tr>
<td>TOL/MA-NI</td>
<td>Mar-May</td>
<td>21</td>
<td>1</td>
<td>4.8</td>
<td>22,496</td>
<td>8,561</td>
<td>262.8</td>
</tr>
<tr>
<td>May-Jul</td>
<td>21</td>
<td>2</td>
<td>9.5</td>
<td>6,593</td>
<td>6,968</td>
<td>94.6</td>
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<tr>
<td>Jul-Sep</td>
<td>20</td>
<td>7</td>
<td>35</td>
<td>4,014</td>
<td>4,291</td>
<td>93.6</td>
<td></td>
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<tr>
<td>Sep-Dec</td>
<td>19</td>
<td>4</td>
<td>20</td>
<td>1,630</td>
<td>2,370</td>
<td>68.8</td>
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<tr>
<td>All</td>
<td>102</td>
<td>15</td>
<td>14.7</td>
<td>5,303</td>
<td>6,138</td>
<td>86.4</td>
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</table>

| F-S            | Mar-May   | 21       | 2          | 9.5          | 13,488           | 8,561 | 157.6            |
| May-Jul        | 21        | 2        | 9.5        | 2,804        | 4,811            | 58.3  |
| Jul-Sep        | 20        | 4        | 20         | 1,497        | 3,689            | 40.6  |
| Sep-Dec        | 20        | 2        | 10         | 240          | 1,926            | 12.5  |
| All            | 102       | 9        | 8.8        | 1,886        | 4,565            | 41.3  |

| F-F            | Dec-Mar   | 20       | 1          | 5            | 9,244            | 8,337 | 110.9            |
| May-Jul        | 21        | 2        | 9.5        | 13,488       | 8,561            | 157.6 |
| Jul-Sep        | 20        | 8        | 40         | 4,142        | 4,291            | 96.5  |
| Sep-Dec        | 20        | 5        | 25         | 2,326        | 2,370            | 98.2  |
| All            | 102       | 19       | 18.6       | 5,185        | 6,138            | 84.5  |

Notes: Sp is a term to denote spread measures which include futures-spot (F-S) and futures-futures (F-F) spreads. The F-S TOL/MA-NI spread is for Toledo/Maumee for the March 1990-December 1999 contracts, and Northern Illinois River for the March 2000-May 2010 contracts. The CH is Chicago delivery for March 1990-May 2010 contracts. I is the deliverable corn inventory (1,000 bu.). (1) is the average inventory under backwardation at a location for the identified spread, and (2) is the average inventory in the sample at a location for the identified spread. TOL/MA-NI inventories are used for the F-F spread since it is the most active delivery location. All is the average calculated at a location for all spreads.
Table 2.2. Seasonal Backwardations and Stock Holding in the Soybean Market, 1990-2010

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<th>Months</th>
<th>No. Obs.</th>
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<th>% Sp&lt;0 &amp; I&gt;0</th>
<th>(1) I. Sp&lt;0 &amp; I&gt;0</th>
<th>(2) I. (1) as a % of (2)</th>
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<td>0</td>
<td>–</td>
<td>–</td>
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<td>TOL/MA-NI Jan-Mar</td>
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<td>4.8</td>
<td>1,010</td>
<td>3,895</td>
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<td>4.8</td>
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<tr>
<td></td>
<td>F-S Nov-Jan</td>
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<td>0</td>
<td>0</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>CH Jan-Mar</td>
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<td>0</td>
<td>–</td>
<td>–</td>
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<tr>
<td></td>
<td>Mar-May</td>
<td>21</td>
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<tr>
<td></td>
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Notes: Sp is a term to denote spread measures which include futures-spot (F-S) and futures-futures (F-F) spreads. F-S TOL/MA-NI spreads is for Toledo/Maumee for the January 1990-November 1999 contracts, and Northern Illinois River for January 2000-May 2010 contracts. The CH is Chicago delivery for January 1990-May 2010 contracts. I is the deliverable soybean inventory (1,000 bu.). (1) is the average inventory under backwardation at a location for the identified spread, and (2) is the average inventory in the sample at a location for the identified spread. TOL/MA-NI inventories are used for the F-F spread since it is the most active delivery location. All is the average calculated at a location for all spreads.
Table 2.3. Seasonal Backwardations and Stock Holding in the CBOT Wheat Market, 1990-2010

<table>
<thead>
<tr>
<th>Spread measure</th>
<th>Months</th>
<th>No. Obs.</th>
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Notes: Sp is a term to denote spread measures which include futures-spot (F-S) and futures-futures (F-F) spreads. The F-S TOL/MA spread is for Toledo/Maumee for the March 1990-May 2010 contracts. The CH is Chicago delivery for March 1990-May 2010 contracts. I is the deliverable CBOT wheat inventory (1,000 bu.). (1) is the average inventory under backwardation at a location for the identified spread, and (2) is the average inventory in the sample at a location for the identified spread. TOL/MA inventories are used for the F-F spread since it is the most active delivery location. All is the average calculated at a location for all spreads.
Table 2.4. Seasonal Backwardations and Stock Holding in the KCBT Wheat Market, 1990-2010

<table>
<thead>
<tr>
<th>Panel</th>
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Notes: Sp is a term to denote spread measures which include futures-spot (F-S) and futures-futures (F-F) spreads. Panel A represents spreads and stocks for March 1990-May 2010 contracts. Panel B represents spreads and stocks for July 1996-May 2010 contracts. The F-S KC spread is for Kansas City and F-S H spread is for Hutchinson. (1) is the average inventory under backwardation at a location for the identified spread, and (2) is the average inventory in the sample at a location for the identified spread. KC inventories are used for the F-F spread in panel A as it is available for the extended period. Hutchinson stocks are used for the F-F spread in panel B since it is generally the most active delivery location post-1996. All is the average calculated at a location for all spreads.
Figure 2.1. Supply of Storage

Panel A. The Working curve

Panel B. Alternative supply of storage relationship
Figure 2.2. Corn Price Spreads and Deliverable Stocks, 1990-2010

Panel A. TOL/MA–NI (F–S)
Panel B. Chicago (F–S)
Panel C. TOL/MA–NI (F–F)
Panel D. Chicago (F–F)

Notes: F-S denotes futures-spot spread and F-F denotes futures-futures spread. TOL/MA-NI stands for Toldeo/Maumee-Northern Illinois. For the F-S spreads, stocks post-2004 are marked as hollow triangles.
Figure 2.3. Soybean Price Spreads and Deliverable Stocks, 1990-2010

Panel A. TOL/MA–NI (F–S)

Panel B. Chicago (F–S)

Panel C. TOL/MA–NI (F–F)

Panel D. Chicago (F–F)

Notes: F-S denotes futures-spot spread, and F-F denotes futures-futures spread. TOL/MA-NI stands for Toledo/Maumee-Northern Illinois. For the F-S spreads stocks post-2004 are marked as hollow triangles.
Figure 2.4. Wheat Price Spreads and Deliverable Stocks (CBOT), 1990-2010

Panel A. TOL/MA (F−S)

Panel B. Chicago (F−S)

Panel C. TOL/MA (F−F)

Panel D. Chicago (F−F)

Notes: F-S denotes futures-spot spread, and F-F denotes futures-futures spread. TOL/MA stands for Toledo/Maumee. For the F-S spreads stocks post-2004 are marked as hollow triangles.
Figure 2.5. Wheat Price Spreads and Deliverable Stocks (KCBT), 1990-2010

Panel A. Kansas City (F−S)
Panel B. Kansas City (F−F)
Panel C. Hutchinson (F−S)
Panel D. Kansas City (F−S)
Panel E. Hutchinson (F−F)
Panel F. Kansas City (F−F)

Notes: F-S spread denotes futures-spot and F-F spread denotes futures-futures spread. Panel A and B are for 1990-2010. Panel C, D, E, and F are for 1996-2010. For the F-S spreads, stocks post-2004 are marked as hollow triangles.
Figure 2.6. Supply of Storage for Deliverable Stocks and Shipping Certificates, 2000-2010

Panel A. Corn

Panel B. Soybeans

Notes: Data for shipping certificates and deliverable stocks are from March 2000 to May 2010 for corn, and from January 2000 to May 2010 for soybeans.
CHAPTER 3

DOES THE BOXED BEEF PRICE INFORM THE LIVE CATTLE FUTURES PRICE?

3.1 Introduction

In recent decades the U.S. cattle industry has experienced added vertical integration and concentration, raising concerns about thin cash markets and the reliability of market information. These structural trends have heightened the debate on economic and policy issues related to price discovery in the cattle markets (Koontz and Ward 2011). Effective price discovery is critical as it facilitates pricing, quantity and quality of a commodity at a specified time and place. Recently, there have been concerns that the decline in the volume of negotiated fed cattle cash market transactions could reduce the representativeness of these prices, lead to market manipulation and other distortions, and lower the quality of the pricing process in the marketing chain. In this context, we evaluate the Chicago Mercantile Exchange (CME) live cattle futures price and boxed beef cutout as alternate sources of price discovery in the fed cattle market.

The Livestock Mandatory Reporting Act (LMRA) was passed by the Congress in 1999 to improve price transparency in livestock markets. The Act directed the United States Department of Agriculture-Agricultural Marketing Service (USDA-AMS) to implement a mandatory system of price reporting for livestock and meat products. Mandatory Price Reporting (MPR) requires beef packers with an annual slaughter of over 125,000 head to report volume and terms of trade for every cattle purchase and boxed beef sale twice daily to USDA-AMS (Grunewald, Schroeder, and Ward 2004).¹ Research in general suggests that there have been improvements in the amount and quality of information available since the implementation of the LMRA in April 2001 (e.g., Perry et al. 2005; Ward 2006; Boyer and

¹ The price reporting act expired in September 2005 and was not renewed until October 2006 (Becker 2006). After five years, the legislation was renewed again in late 2010 and extended to September 2015 (PUBLIC LAW 111–239–SEPT. 27, 2010).
Brorsen 2013). However, MPR has also raised concerns about the increased availability of fed cattle information facilitating coordination among beef packers (Wachenheim and Devuyyst 2001; Azzam 2003; Njoroge 2003; Njoroje et al. 2007; Cai, Stiegert, and Koontz 2011a, 2011b).

Recently Lee, Ward, and Brorsen (2012) report causality and cointegration between the negotiated fed cattle cash and other alternative marketing arrangement (AMA) prices have not been affected by the thinly traded cash market. However, concerns continue to increase as more negotiated cash price transactions are replaced by contracts, marketing agreements, alliances, formula-pricing arrangements, and packer-owned cattle. In 2005 cash market transactions in which buyers and sellers negotiated the price and other terms of the transaction accounted for 55.8% of reported packer procurement, and formula pricing 31.9%. By 2013, these negotiated transactions had declined to 24.1% of reported packer procurement and formula priced cattle volume had increased to 61.8%. The threat to price transparency exists as packers and producers continue to choose non-negotiated cash methods to transfer cattle ownership. The market may be forced to look at new alternate sources to perform its price discovery function.

While the fed cattle cash markets have been studied extensively since 2001, there has been less recent focus on the CME live cattle futures contract and on negotiated boxed beef prices as tools for price discovery. Early research identifies the close link between cash and futures prices with the futures price leading cash price movements (Oellermann and Farris 1985; Koontz, Garcia, and Hudson 1990; Yang, Bessler, and Leatham 2001). In a recent study Park, Jin, and Love (2011) argue that futures prices result from market information and do not drive decisions made along the beef supply chain. According to the authors, causality during the 1988-2005 periods is from cash fed cattle price to the futures price. Using more recent 2001-2010 data, Lee, Ward, and Brorsen (2012) report that negotiated cash prices led

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2 The percentages reported are for five-area averages and closely represent the national averages (USDA-AMS).
all AMA prices except forward contracts which are closely tied to futures prices (Koontz, Garcia, and Hudson 1990). Ji and Chung (2012) also report bidirectional causality between forward contract prices and cash fed cattle prices during the 2004-2011 periods identifying the close interaction between prices.

Live cattle futures quotes are readily available, easily accessible, and are based on broad based national trading making them valuable sources of information (Shroeder and Mintert 2000). Live cattle futures markets are also found to be efficient in incorporating new supply and demand information quickly into prices (Garcia et al. 1988; McKenzie and Holt 2002). A derivative market is a market in which prices are determined by observation from other markets (Hasbrouck 1995). If packers continue to use non-negotiated cash methods to procure cattle, the underlying cash market may become thin and less representative of actual price levels, affecting the informational value of the live cattle futures contract.

The wholesale boxed beef cutout value, which reflects the price that packers receive for beef products, is an appealing alternate source of price discovery (Schroeder and Mintert 2000). Boxed beef price is closer to retail sources and represents a broad based average composed entirely of negotiated trades, making it a viable alternative for pricing cattle. Reported boxed beef cutout values represent a negotiated commitment from the packer to sell the product twenty-one calendar days ahead i.e., the expected wholesale prices several days or even weeks ahead. Boxed beef prices are reported by the USDA so that market participants can track meat prices on a daily and weekly basis and use them in negotiations over cattle prices (Perry et al. 2005). Producers and retailers look at price levels in boxed beef cutout values that may provide bargaining power in negotiated trades. Packers monitor these reports for a negotiating leverage with producers and retailers; use them in determining quality grade discounts and premiums; and consider them a benchmark for gauging their performance in the industry. In fact, the cutout values are important to all segments of the industry (USDA-AMS). As a result, boxed beef prices provide a solid indication of change in prices that will prevail in the cattle market. Further, as seen later, par quality grade
specified boxed beef prices, which reflect the primary value of the animal, when adjusted for differences in animal live weight closely reflect CME live cattle futures prices, providing another indication of their potential usefulness in price discovery.

Boxed beef prices have been extensively examined in U.S. fed cattle price transmission studies. The results are mixed, with several studies indicating farm price causing wholesale beef prices (Boyd and Brorsen 1985; Shroeder and Hayenga 1987; Park, Jin, and Love 2011); others suggesting enhanced price transmission and information flow in both directions (Marsh and Brester 1989; Goodwin and Holt 1999); and one identifying wholesale and retail markets as the seat of price discovery (Hahn 1990). However, little recent attention has been given to relationship between futures prices and boxed beef prices, another potentially important source of market information. Both futures prices and boxed beef cutout values are reported in all major daily and weekly cattle reports reflecting the importance of these prices to the marketplace. Early studies by Ward (1981) identify that wholesale carcass price and nearby live cattle futures price are important variables in explaining significant proportion of the variation in transaction prices for fed cattle. Ward et al. (1997) suggests that the move towards a value based cattle pricing system would shift the center of price discovery to the wholesale level. In contrast, Schroeder and Mintert (2000) suggest that the difference between boxed beef wholesale prices and cash fed cattle prices may vary depending on processing margins, which generally include slaughter and processing costs less hide and offal values, making its use difficult for pricing. While several challenges exist, researchers have not ruled out the role of boxed beef prices as an important source of fed cattle information and in pricing cattle.

The dominance of futures price over cash price in fed cattle price discovery is well established. However, to date, the literature on the relationship between boxed beef and futures prices is limited by a lack of attention to the temporal aspects of boxed beef price reporting and by use of data not representative of the actual short-run (weekly frequency) pricing process in the market. We use the nearby CME live cattle futures price and average cutout
value for the afternoon boxed beef report from 1/9/2004 to 9/27/2013. The nearby futures price is the settlement price at 1:00 p.m., and the afternoon boxed beef value is an average of trades from 1:30 p.m. on the previous day to 1:30 p.m. of the current day. Consistent with the weekly fed cattle pricing process and to account for any informational advantage in the futures price because of the definition of the boxed beef value, the analysis is performed using Friday boxed beef prices, and both Friday and Thursday futures settlement prices. The futures settlement price also assimilates information from trades in other contemporaneous AMA cattle reports released by USDA. Hence, assessing the relationship between the boxed beef price and Thursday and Friday futures settlement price should establish which price producers should watch as an alternative to a thinly traded cash market price. A weekly interval is used because from a practical stand point, the buyers and sellers of fed cattle operate in a weekly market and the bid and ask prices are conducted in a window within a week where almost all transactions takes place (Cai, Stiegert, and Koontz 2011b). Ending Friday prices are selected because they represent the information that most producers have available to them going into the following week cash markets. Data are examined using time series procedures including cointegration and error correction modeling, testing for time varying cointegration (Bierens and Martins 2010), innovation accounting, Granger causality tests using the Toda and Yamamoto (1995) procedure, and employing newly-developed price discovery metrics (Yan and Zivot 2010; Putnins 2013).

3.2 Data

The data are from multiple sources. We use both Friday and Thursday futures settlement prices for the nearby CME live cattle futures contract from the Commodity Research Bu-

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3 A consistent daily price series for boxed beef cutouts are available from DATAMART beginning 1/5/2004, extending to the September 2013 government shutdown.
4 Time in Central Standard Time (CST).
5 The MPR mandates that packers submit the details on purchases of cattle that are scheduled for delivery fifteen-plus days from the date they are purchased or priced on a daily basis as either forward contract or a formula marketing agreement purchase type (Perry et al. 2005). These reports are generally released in the morning and afternoon such that all trade information from 9:30 a.m. previous day to current day 1:30 p.m. is public by 3:00 p.m. current day.
The boxed beef cutout (BBC) represents the estimated value of a beef carcass based on the sale prices received from packers for the individual beef items obtained from the carcass. The BBC formulation matches industry practices for calculating cutouts. During fabrication, carcasses are first broken into primal units and further fabricated into sub-primal styles. A processor’s overall cutout is based on the value and volume of sub-primal styles being produced (USDA-AMS). The boxed beef cutouts are released twice a day. The morning report (LM_XB402) is released at 11:00 a.m. and the afternoon report (LM_XB403) is released at 3:00 p.m. The price reported in the morning is a two-day average of all trades reported from 1:30 p.m. the previous day until 9:30 a.m. on current business day. The afternoon report is cumulative including market activity reported in the morning plus all additional transactions between 9:30 am and 1:30 p.m. Trades are reported electronically by meat packers with slaughter sizes more than 125,000 heads. Since the LMRA protects the confidentiality of packers, not all sales and prices reported by the packers are used in the published boxed

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6 See CME Rulebook, Chapter 101 Live Cattle Futures, for a detailed description of daily settlement procedures.

7 See document “USDA DAILY BOXED BEEF REPORT” at USDA-AMS website for more detailed description of the boxed beef report and calculation of cutout values.

8 “A two-day weighted average price for each beef item is computed by combining current reported prices in the individual item section of the report with the prices from the previous day. These item prices and average of industry cutting yields are used to calculate sub-primal style values which are then combined into primal values. These primal values are factored against their yield from the carcass and the resultant values are combined into the final carcass cutout values” (USDA-AMS). See footnote 7 for detailed explanation of steps involved in calculating cutout values.
beef cutout reports.\textsuperscript{9}

The daily average cutout value from the National Daily Boxed Beef Cutout and Boxed Beef Cuts-Negotiated Sales report (LM\_XB403), with the Choice: 600-900 lbs. prices weighted 55% and the Select: 600-900 lbs. prices weighted 45% are used to match the par quality grade specification for the CME live cattle futures contract. To more closely reflect the futures par delivery specification, which is on live animal basis, we adjust the actual boxed beef cutout value by the expected average hot yield of 63\% (CME Rulebook, Chapter 101 Live Cattle Futures) and use this adjusted value as our boxed beef price. Boxed beef cutout values are downloaded from USDA Livestock Market News Service historical data website (DATAMART) for Livestock Mandatory Price Report (LMPR). When prices are not available on Fridays, the missing value is replaced with the closest reported weekday price for both series going backward in time. We are careful to match prices from the same day. All price series are expressed in cents/lbs., and are converted into their natural logarithms consistent with procedures used in previous research.

\textbf{3.3 Empirical Procedures}

Multiple time series procedures are used to assess the relative information content of the live cattle futures price and boxed beef price. Mostly, we rely on the cointegration properties of the data to provide a rich characterization of the bivariate price relationship. We begin by testing for cointegration using the Johansen’s (Johansen and Juselius 1990; Johansen 1992) procedure and then assess the stability in the price relationship using a time varying cointegration procedure proposed by Bierens and Martins (2010). Standard weak exogeneity tests are performed on the cointegrated series followed by innovation accounting using forecast error variance decompositions and impulse response functions to identify the dynamic interaction of the two price series. Next, the Toda and Yamamoto (1995) test is performed to assess Granger causality in prices. Finally, newly developed price discovery metrics that

\textsuperscript{9} For a price from a firm to be included, the 3/70/20 guideline specifies that 60 days prior to a report at least three entities have to provide data at least half the time, no single entity can provide more than 70\% of the data, and no single entity can be the sole source for a report more than 20\% of the time.
rely on cointegration properties of the data are employed to identify the market providing the most relevant and timely information on fed cattle price.

3.3.1 Cointegration Analysis

In the presence of non-stationary series, the interaction between the futures price and the boxed beef price is examined by exploiting the cointegration relationship between them. A description of the Johansen’s test for cointegration in the matrix form is given below. We start with the general $P^{th}$ order VAR model as follows

\begin{equation}
\Delta Y_t = D + \Pi Y_{t-1} + \sum_{j=1}^{p-1} \Gamma_j \Delta Y_{t-j} + \epsilon_t \quad (t = 1, \ldots, T),
\end{equation}

where $Y_t$ is an $(n \times 1)$ vector to be tested for cointegration, and $\Delta Y_t = Y_t - Y_{t-1} ; D$ is the deterministic term and may take different forms such as a vector of zeros or non-zero constants; $\Pi$ and $\Gamma$ are matrices of coefficients, $\Pi = \alpha \beta'$; and $p$ is chosen so that $\epsilon_t$ is a multivariate normal white noise process with mean zero and finite covariance matrix ($\epsilon_t \sim iid(0, \Sigma)$).

We begin by testing whether the vector $Y_t$ is trend stationary rather than a multivariate unit root with drift process. Under the trend stationary hypothesis the matrix $\alpha \beta'$ has full rank ($k$). One of Johansen’s cointegration tests, the trace test, has this alternative hypothesis (Johansen and Juselius 1990; Johansen 1992). Since the Johansen’s test is sensitive to the number of lags the Schwarz Bayesian Information Criterion (SBIC) is used to select the number of lags. The long-run pattern of price transmission is examined by testing the number of cointegration relations ($r$), using Trace tests and $\lambda$-max tests (Johansen and Juselius 1990; Johansen 1991). The cointegrating relationships explain the long-run equilibrium in prices, facilitated by the transmission of information. The rank of $\Pi$ determines the number of cointegrating vectors, tested as follows

\begin{equation}
H(r) : \Pi = \alpha \beta'.
\end{equation}

If prices are found to be cointegrated, a vector error correction model (VECM) imposing the cointegrating relationship is estimated to examine how prices adjust interactively under the constraint of the identified long-run equilibrium price relationships. The short-run dy-
dynamic pattern of price transmission can be observed from both, $\alpha$ and $\Gamma_j$, where $\alpha$ parameter defines the short-run adjustments to the long-run relationship, and parameters $(\Gamma_j, ... \Gamma_{p-1})$ defines the short-run adjustment to changes in the process. Weak exogeneity tests for each price series $Y_t$ (Johansen and Juselius 1990; Johansen 1992) are also performed as they allow us to identify the market that dominates in price discovery in the long run. This hypothesis is framed as

$$B'\alpha = 0.$$  

The null hypothesis is that each price does not respond to disturbances in the long-run relationship i.e., the $i^{th}$ row of the II matrix is zero (Johansen and Juselius 1990, 1992; Johansen 1991).

In conventional cointegration analysis, cointegration vectors are assumed to be time invariant. However the long-run relationship between prices may change due to structural breaks, and a time-invariant formulation of the cointegrating vector may no longer be appropriate (Hansen, 1992). A time-varying cointegration test based on Bierens and Martins (2010) is performed to assess if the relationship between futures and boxed beef prices has changed over the period. Bierens and Martins test the null hypothesis that the cointegrating vector $\beta$ is constant against the alternative hypothesis that $\beta$ is a function of time, $\beta_t$. Specifically, the time-varying vector error correction model (TV-VECM) is

$$\Delta Y_t = D + \alpha \beta_t' Y_{t-1} + \sum_{j=1}^{p-1} \Gamma_j \Delta Y_{t-j} + \epsilon_t.$$  

$\beta_t$ is implemented by a series of Chebyshev time polynomials:

$$\beta_t = \xi_0 + \xi_1 P_{1,T}(t) + ... + \xi_m P_{m,T}(t),$$  

where $P_{i,T}(t)$ is a Chebyshev time polynomial of order $i$ i.e.,

$$P_{0,T}(t) = 1, P_{i,T}(t) = \sqrt{2}\cos(i\pi(t-.5)/T),$$  

where $t = 1, 2, ..., T$, $i = 1, 2, 3, ...$, and $\xi_i$ are the Fourier coefficients. The null hypothesis of time-invariant cointegration corresponds to the hypothesis that $H_0 : \xi_i = 0$ for $t = 1, 2, ..., m$. 

51
Under this null hypothesis the test statistic involved has a $\chi^2$ distribution.

3.3.2 Innovation Accounting

We then investigate the dynamic relationships among the series through innovation accounting, as recommended by Sims (1986) and Swanson and Granger (1997). Forecast error variance decompositions and impulse response functions are generated from the residuals of the VAR, or a VECM, to summarize the short-run dynamic linkages among various markets. Following Phillips (1998), we use an equivalent level VAR representation of the VECM imposing cointegration constraints and derive consistent results on forecast error variance decompositions and impulse response functions.

3.3.3 Granger Causality Tests

Granger causality tests are usually performed on VAR models to summarize the dynamic interactions that each market price has with other market prices. Toda and Yamamoto (1995) suggest that if the coefficients are from a VAR equation and if any of the variables are non-stationary (whether or not they are cointegrated) the usual Wald test statistic for this testing will not have an asymptotic Chi-Square distribution. For cointegrated variables, a Granger causality test involves the coefficients of $\pi$, which are multiplied by non-stationary variables. Enders (2008) notes that if rank of $\pi \neq 0$, it is impossible to write the restrictions of the test as restrictions on a set of I (0) variables and it is not appropriate to use an F-test for Granger causality. An alternate way to deal with this econometric issue is to use the procedure proposed by Toda and Yamamoto (1995) and Dolado and Lutkepohl (1996). Toda and Yamamoto (1995) demonstrate that in integrated and cointegrated systems, the Wald test for linear restrictions on the parameters of a VAR ($k$) has an asymptotic distribution for the estimated $(k + d_{max})$, where $d_{max}$ is the maximum order of integration in the system. The value of $k$ can be determined using SBIC. Suppose SBIC chooses a VAR (3) and $d_{max} = 1$, we estimate a VAR (4) model and test the coefficients of the first 3 lagged terms for each variable in the model for causality. A detailed description of Granger causality testing us-
ing the Toda and Yamamoto lag augmented procedure is available in Rambaldi and Doran (1996).

### 3.3.4 Price Discovery Measures

Finally, we employ two popular price discovery measures—Harris–McInish–Wood’s Component Share \((CS)\) and Hasbrouck’s Information Share \((IS)\), and use the specification by Yan and Zivot (2010) modified by Putnins (2013) to derive the Information Leadership Share \((ILS)\) metric.\(^{10}\) Both \(CS\) and \(IS\) rely on the notion that prices can deviate from each other in the short run due to market frictions, but their connection to the fundamental value will force them to converge in the long run (Lehman 2002). These measures are particularly useful when the price leadership among futures and boxed beef prices are assessed without involving cash price interactions. Similar to the classic Garbade and Silber (1983) price discovery approach, these price measures are based on an implicit unobservable efficient price common to all the underlying asset prices. The \(CS\) and \(IS\) price discovery measures therefore extend the Garbade and Silber (1983) formulation by allowing for cointegration between price series under the assumption of an underlying common random walk efficient price. The advantages of these metrics are that they can provide a measure of the proportional contribution to price discovery which VECM formulations are incapable of revealing.\(^{11}\)

While the application of price discovery models beginning with the Garbade and Silber (1983) approach have been in arbitrage linked markets, the general principle outlined here does not hinge on the presence of standard arbitrage. Rather, we assume that information is assimilated and transferred among the futures and boxed beef markets when market participants trade in these markets with a rational view of the fundamental value of the asset. For instance, market participants are aware of average processing margins and would demand

\(^{10}\) As is common in the literature, the \((CS)\) is referred to as the Harris–McInish–Wood component share because of their role in popularizing this measure along with others such as Booth, So, and Tse (1999) and Chu, Hsieh, and Tse (1999). The measure is also known as the Permanent Transitory Model \((PT)\) and is based on work by Gonzalo and Granger (1995).

\(^{11}\) An application of the \(PT\) and \(IS\) measures to identify price discovery of floor and electronic traded corn, soybeans, and wheat futures contracts can be found in Martinez et al. (2011).
higher prices for cattle if wholesale prices keep rising. Similarly, packers would be unwilling
to pay higher prices for cattle at lower wholesale prices as it would lower the margin. In short,
an efficient price is discovered establishing middle ground between buyer-seller outlook con-
sistent with the prevailing demand and supply situation, allowing farm and wholesale prices
to move together in the long run. Information may be incorporated into the futures market
when market participants use the futures price as a hedging tool.

CS and IS differ in how they measure price discovery. Gonzalo and Granger (1995) divide
a price vector into two parts, a permanent component interpreted as the implicit common
efficient price (the driving force behind cointegration), and the temporary component reflect-
ing the deviations due to market frictions. The authors show that the permanent component
is a linear combination of all variables in the cointegrated system that can be easily esti-
imated from a fully specified error correction model. The contribution of a price series to
price discovery (CS) is then its normalized weight in the linear combination of prices that
forms the common efficient price (Booth, So, and Tse 1999; Chu, Hsieh, and Tse 1999; Har-
riss, McInish, and Wood 2002a). In contrast, Hasbrouck defines price discovery in terms of
variance of an efficient price. Specifically, his (IS) measure identifies the proportion of the
efficient price innovation variance that can be attributed to that price.\(^{12}\)

To develop these price discovery measures, we follow Baillie et al. (2002) and calculate
IS\(_1\), IS\(_2\), CS\(_1\), and CS\(_2\) from the error correction parameters and variance-covariance of the
VECM error terms. Component shares are computed from the normalized orthogonal to the
vector of error correction coefficients, \(\alpha_\perp = (\gamma_1, \gamma_2)'\), and are

\[
CS_1 = \gamma_1 = \frac{\alpha_2}{(\alpha_2 - \alpha_1)}, \quad CS_2 = \gamma_2 = \frac{\alpha_1}{(\alpha_1 - \alpha_2)},
\]

where \(\alpha_1\) and \(\alpha_2\) are the coefficients of the error correction term. A small (large) value CS is
directly related to a small (large) contribution of market to the Gonzalo-Granger permanent
component of prices (Booth, So, and Tse 1999; Chu, Hsieh, and Tse 1999; Harris, McIn-
ish, and Wood 2002a). If \(\alpha_1 = 0\), market 1 does not respond to a lagged disequilibrium error

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\(^{12}\) See Appendix A for the representation of efficient price innovation.
which reflects transitory movements away from the permanent component and $CS_2$ is zero.\footnote{This interpretation of $CS$ links price discovery to weak exogeneity for the cointegrating parameters in a market (Zivot 2000).} Hence, $CS_1$ reflects how sensitive market 2 is relative to market 1 to lagged transitory shocks and vice versa (Yan and Zivot 2010).

Since $IS$ measures are defined as the proportion of the efficient price innovation variance that can be attributed to specific prices they must include information from the covariance matrix. The reduced form VECM covariance matrix of the error terms $\epsilon_t = (\epsilon_{1t}, \epsilon_{2t})$, is
\begin{equation}
\Sigma = \begin{bmatrix}
\sigma_1^2 & \rho \sigma_1 \sigma_2 \\
\rho \sigma_2 \sigma_1 & \sigma_2^2
\end{bmatrix} = \begin{bmatrix}
m_{11} & m_{12} \\
m_{21} & m_{22}
\end{bmatrix} = M,
\end{equation}
where $\sigma_1^2(\sigma_2^2)$ is the variance of $\epsilon_{1t}(\epsilon_{2t})$ and $\rho$ is the correlation. To establish the importance of the each series independently in price discovery, assume that $\Sigma$ is diagonal. In this case, the $IS$ measures are
\begin{equation}
IS_1 = \frac{(\gamma_1 m_{11})^2}{(\gamma_1 m_{11})^2 + (\gamma_2 m_{22})^2}, IS_2 = \frac{(\gamma_2 m_{22})^2}{(\gamma_1 m_{11})^2 + (\gamma_2 m_{22})^2},
\end{equation}
which shows the measures are the proportion of the total variance attributed to each price weighted by their respective $CS$ measures. In effect, $IS$ is the contribution of each price to the efficient innovation variance scaled or weighted by the response of each series to deviations or transitory movements from the equilibrium relationship.\footnote{Bailie et al. (2002) show that the vector of permanent component weights ($\gamma$) in the Gonzalo-Granger PT decomposition and the vector of long-run impact coefficients ($\psi$) that make up the efficient price innovation in Hasbrouck’s $IS$ framework are equal up to a scale factor. Hence, $IS$ measures can also be defined in terms of elements of $\gamma$. See Appendix A for more detail.} A low (high) information share for a market implies a small (large) reaction to the arrival of new information about fundamental value. To implement the $IS$ measures, researchers use the Choleski factorization which will be identical to the measures presented when the correlation in the error terms is zero. In the presence of correlation, average measures are calculated based on different orderings of the VECM. Several studies have compared the $CS$ and $IS$ measures in practical applications. Studies by Baillie et al. (2002), Harris, McInish, and Wood (2002b), and Lehman (2002) indicate that $CS$ and $IS$ measures differ most when the error terms from the
VECM are correlated. Hasbrouck (2003) also suggests that the results from price discovery metrics should be similar to those from impulse response functions because both measures are non-linear functions of the same parameters.

Recently, Yan and Zivot (2010) argue that the two methods alone cannot distinguish the price discovery dynamics between markets and show a method to use the $CS$ and $IS$ to disentangle the impact of permanent and transitory shocks.\textsuperscript{15} They interpret $CS$ as a measure of relative noise where the price with a lower $CS$ is relatively more sensitive to transitory shocks. This interpretation is consistent with the Putnins’ (2013) definition of $CS$ as a measure of relative noise, and $IS$ as a combination of relative noise and relative leadership in reflecting innovations in the fundamental value. In this situation, the Yan and Zivot provide an information leadership metric which combines both $CS$ and $IS$ to cancel out the relative noise and identify which series provides more information to the efficient price. Yan and Zivot’s metric is

\begin{equation}
IL_1 = \left| \frac{IS_1 CS_2}{IS_2 CS_1} \right|, \quad IL_2 = \left| \frac{IS_2 CS_1}{IS_1 CS_2} \right|
\end{equation}

Unlike the $CS$ and $IS$, these measures are not shares because $IL_1$ and $IL_2$ do not add to one. $IL_1$ has the range $[0, \infty)$, and values of $IL_1$ above (below) one indicate that the price leads (does not lead) the process of incorporating new information into prices. To make the information leadership metric comparable to $CS$ and $IS$, Putnins (2013) defines informational leadership shares ($ILS$)

\begin{equation}
ILS_1 = \frac{IL_1}{IL_1 + IL_2}, \quad ILS_2 = \frac{IL_2}{IL_1 + IL_2}
\end{equation}

We use the above $ILS$ metric to measure proportional contribution to price discovery between live cattle futures and boxed beef prices. The $ILS_1$ has the range $[0, 1]$, and values of $ILS_1$ above (below) .5 suggests that the first price leads (does not lead) the process of incorporating new information (Putnins 2013).\textsuperscript{16}

\textsuperscript{15} For further details see the work by Baillie et al. (2002), Harris, McInish, and Wood (2002a), Lehman (2002), Yan and Zivot (2010), Putnins (2013), and the original work by Hasbrouck (1995) and Gonzalo and Granger (1995).

\textsuperscript{16} The $ILS$ measure has the advantage of not producing extreme values which occur in IL when both IS
3.4 Empirical Results

3.4.1 Diagnostic Testing

We conduct unit root tests to identify the order of integration in futures and boxed beef prices. Augmented Dickey Fuller (ADF) tests are performed with the number of lags chosen using the Schwarz Bayesian Information Criterion (SBIC). For the ADF test, where the dependent variable is differenced, we focus on the specification with a constant (Wang and Tomek 2007). ADF-GLS tests (Elliot, Rothenberg, and Stock 1996) are also used, which are ADF tests on GLS de-trended data. A specification with only a constant is used for the ADF-GLS test and Modified Akaike Information Criterion (MAIC) is used to identify lags for the tests. The null for ADF and ADF-GLS is that the series is non-stationary. The Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests which has a null hypothesis that the time series is stationary around a deterministic trend is also used. Finally, variants of the Zivot-Andrews (ZA) test which allows for one possible shift in the mean, trend or both mean and trend are also used (Zivot and Andrews 2002). The ZA test has the null hypothesis of a unit root process with drift that excludes exogenous structural change. The alternative hypothesis is that a structural break may be present. The rejection of the null would imply rejection of a unit root without breaks. Both futures and boxed beef prices are tested for stationarity and analysis is performed on the full sample of 508 observations spanning ten years.

Table 3.1 (panel A) presents the results of unit-root tests for contemporaneous Friday futures and boxed beef series. ADF, ADF-GLS, and KPSS tests on futures price series and boxed beef prices indicate a non-stationary process. The conclusions drawn from different specifications of the ZA test are mixed. The ZA test with a break in both intercept and trend rejects the null hypothesis that futures price in levels contains a unit root. However, the specifications with either a break in the intercept or trend indicate that futures price series has a unit root. In the case of boxed beef, ZA test specifications with an intercept and CS approaches the value 1 (Putnins 2013).
or trend rejects the null hypothesis of the unit root at the .05 level. On the other hand, ZA test allowing a break in both level and trend fails to reject the null hypothesis of unit root. Figure 3.1 presents the nominal price series for contemporaneous futures and boxed beef price for the 1/9/2004-9/27/2013 period. Visual inspection of figure 3.1 reveals that the relationships among the futures and boxed beef markets may have varied over time with the futures more consistently above the boxed beef prices after 2011. Based on test results we conclude that both price series are non-stationary in levels and stationary in first differences. The results are consistent for Friday boxed beef prices and one day lagged futures prices (panel B).

3.4.2 Cointegration and Weak Exogeneity

We focus on the cointegration relationship between futures and boxed beef prices for the full period and then test further for structural stability in the cointegration relationship. Enders (2008) suggests using a drift term outside the cointegrating relationship if the variables exhibited a decided tendency to increase or decrease. This allows the rank of $\pi$ to be viewed as the number of cointegrating relationships after purging any linear trend in the data generating process. Hence, the maximum-likelihood estimation procedure by Johansen and Juselius (1990) is performed with an unrestricted intercept term, where a drift term appears in the level series (Luthkepohl 2006; Enders 2008). Based on SBIC, we use specification with 3 lags for the test. The results are presented in table 3.2, panel A for the Friday futures and boxed beef prices, and panel B for Friday boxed beef prices and the Thursday futures prices. Both trace and the $\lambda$-max tests indicate that there is one cointegrating vector at the .10, .05, and .01 levels of significance in both panels. The cointegration properties are also assessed using the Engle and Granger (1987) two-step procedure and the null of no cointegration is rejected in panel A and panel B. Next, we apply the Bierens and Martins (2010) procedure

17 The break dates identified in the ZA test are not consistent across the different specifications. Nonetheless, the financial market crash in October 2008 is observed to have a large impact on the futures price series. In contrast, a period of rising beef demand towards the end of 2010 appears to have an impact on boxed beef prices.

18 These results are not reported, but are available on request.
which tests the null of a time invariant cointegrating vector. Since the futures and boxed beef price appear to follow a unit root with drift process, the test is conducted under the drift case assumption. We fail to reject the null of a time invariant cointegrating vector at the .05 significance level in both panels. These results are robust to several lags lengths (SBIC specified number of lags 3) and to Chebyshev polynomials up to 15 which was viewed as reasonable given the use of weekly observations.

Based on the cointegration test, a VECM is estimated for the full period using both samples imposing one cointegrating vector. While the SBIC chose 3 lags, an additional lag is included to control autocorrelation. Results of weak exogenetiq tests are presented in table 3.3. We fail to reject weak exogeneity of futures prices at .01 level in panel A., indicating that the current futures price does not make short-run adjustments to the long-run disequilibrium. In contrast, weak exogeneity of boxed beef market is rejected at the .01 level, reflecting the adjustments to the disequilibrium. The results are consistent for current boxed beef prices and one-day lagged futures prices in panel B. The speed-of-adjustment parameter for boxed beef is substantially higher than that for futures prices in both samples reflecting the responsiveness of boxed beef prices to last period’s equilibrium error.

3.4.3 Innovation Accounting

Forecast error variance decompositions and impulse response functions are employed to reveal the magnitude of short-run linkages between markets. The Choleski factorization is employed to assign the causal ordering recursively for futures and boxed beef. The innovation vector from an equivalent levels VAR model can be written as $Aυ_t = ε_t$ where $A$ is a

19 There is no serial correlation in the residuals up to 6 lags for both models at the .05 level. While mild ARCH effects are present in the residuals of the equivalent level VAR with the cointegration restriction imposed, Gonzalo (1994) demonstrates that cointegration conclusions based on Johansen’s maximum-likelihood estimation procedure are robust.

20 An Autoregressive Distributed Lag (ARDL) model is also estimated imposing the weak exogeneity. The model with SBIC selected 2 lags has an $R^2 = .39$ indicating a reasonable statistical relationship between futures and boxed beef prices. The residuals of the model are homoscedastic with no autocorrelation up to 10 lags. The speed of adjustment parameter for boxed beef price estimated in the ARDL model is .08 which similar to our estimates from the VECM. The results for Friday boxed beef prices and one-day prior futures price are similar with a marginally higher $R^2 = .41$ and some residual heteroskedasticity.
(2 × 2) matrix and \( \nu_t \) is a vector of orthogonal shocks. Ordering the futures price first, the A matrix gives the following representation on innovations in contemporaneous time

\[
\begin{bmatrix}
1.0 & 0.0 \\
\alpha_{21} & 1.0
\end{bmatrix}
\begin{bmatrix}
u_{f,t} \\
v_{b,t}
\end{bmatrix} =
\begin{bmatrix}
\epsilon_{f,t} \\
\epsilon_{b,t}
\end{bmatrix},
\]

where \( \epsilon_{i,t} \) terms are the observed innovations from VECM, \( \nu_{i,t} \) are the orthogonal innovations from each market, and \( i = \text{futures} (f) \) and \( \text{boxed beef} (b) \) respectively. Enders (2008) and Luthkepohl (2006) note that the ordering of the variables can influence forecast error variance decompositions and impulse response functions particularly if the correlations between the innovations exceed \(|0.20|\). We find that the correlation between the VECM residuals is \(.26\) for the first sample and \(.35\) for the second sample which are significant at the \(.01\) level. Hence, we also assess the sensitivity of our results ordering boxed beef price first which restricts the contemporaneous effect of futures price on boxed beef prices allowing boxed beef price to be “causally prior” to the futures price.

The 15-week forecast error variance decompositions for the full sample are reported in table 3.4. The forecast error variance decompositions identify the proportion of the movement in a particular sequence due to its “own” shocks versus shocks to other variables (Enders 2008). Since it is common for a variable to explain almost all of its own forecast error variance at short horizons and smaller proportions at longer horizons, the real test in terms of market dominance lies in the longer horizons. The forecast error variance in each price series (listed vertically) is decomposed into proportions due to shock in futures and boxed beef and reported for a 15 week horizon. For the contemporaneous futures and boxed beef price sample (panel A), futures price contributes 100% of its own forecast error variance at the first-week horizon and 99.7% of its own forecast error variance at the longer 15-week horizon. This implies that the futures market is highly exogenous i.e., the futures price evolves independently of the forecast error shocks from the boxed beef market. In the case of the boxed beef market, the forecast errors in the first week horizon (93.4%) can be largely attributed to its own innovations in the first week. However, as we move towards the 15-week
horizon, the futures price dominates by explaining 60% of the variance in the boxed beef market, with boxed beef explaining only 40% of its own variance. The results for the Friday boxed beef and one-day prior futures price sample in panel B are consistent with panel A. Alternate ordering with boxed beef prices ordered first marginally increases the contribution of boxed beef in its own variance decomposition with the futures price dominating in the longer horizon for both panels.

The impulse response functions are plotted with 95% bootstrapped confidence intervals (2000 runs) for the 15-week horizon and presented for the contemporaneous futures and boxed beef price (figure 3.2). Impulse response functions trace the time path of the various shocks on the prices included in the VAR system. The responses to a one standard deviation shock in the futures market are presented in the first row, followed by responses to shocks from the boxed beef market. The responses obtained are consistent with the results observed from forecast error variance decompositions. The futures and boxed beef markets respond significantly to the shocks from the futures markets i.e., a one standard deviation shock in the futures market produces responses that are significantly different from zero at the .05 level in the boxed beef market at all horizons. In contrast, the shock in the boxed beef market does not influence the futures market at any horizon. The results are consistent for the Friday boxed beef price and one-day prior futures price series and are not reported. Further assessment ordering the boxed beef price first does not appear to cause any difference in the impulse response functions. Overall, the results of innovation accounting remain robust and support the dominant role of futures prices.

3.4.4 Granger Causality Tests

Granger causality tests are performed for the full sample on a VAR (4) model using the Toda and Yamamoto lag augmented approach. These results are presented in table 3.5. Hamilton

\[21\] The impulse responses may also be interpreted in percentage terms after scaling with the corresponding VECM residual standard deviation (SD) for futures (.0229) and boxed beef price (.0195). For example, a 1-SD shock in the futures price innovation causes a response of .015 in boxed beef price which is equivalent to a 1% shock in futures causing a response of .66% in the boxed beef price.
(1994) recommends that “Granger causality” be interpreted as whether one variable helps forecast another variable rather than one variable causes another. Bidirectional causality among contemporaneous futures and boxed beef prices cannot be rejected for the first sample (panel A). However, the lags of futures prices are strongly significant in the boxed beef equation. In the case of current day boxed beef prices and one-day lagged futures prices (panel B), the causal direction is only from futures to boxed beef as expected. Prior day futures settlement price is able to predict information contained in the current day boxed beef report.

3.4.5 Price Discovery Measures

Examination of equations (7), (8), (10), and (11) reveal the importance of weak exogeneity in the price discovery metrics. When a price series is weakly exogenous, its corresponding $\alpha$ in the VECM is equal to zero which using (7) translates into a $CS$ equal to zero ($\gamma = 0$) for the other price series. Because these gammas are embedded in the $IS$ measures, the complete dominance of a series reflected in $CS$ is transmitted to the IS measures, and because one of the $IS$ measures will be zero, interpretation of (10) and (11) becomes problematic. In our situation, the weak exogeneity test statistically attributes all weight in price discovery to the cattle futures market using either the Friday or Thursday data.

Despite these findings, we use the estimated speed of adjustment coefficients to calculate the price discovery measures, generating a maximum boxed beef price effect in the price discovery process. Based on the estimated coefficients, the $CS$ values computed are 90.5% for the Friday futures and 9.5% for boxed beef. For Thursday futures and Friday boxed beef, the $CS$ values are 92.2% and 7.8% respectively. In both cases $CS$ identifies the dominance of the futures price in the price discovery process. The $IS$ for Friday futures and boxed beef is 94% and 6% respectively. For Thursday futures price and Friday boxed beef price, futures continue to dominate contributing 91.5% of price discovery and boxed beef the remaining 8.5%.\footnote{The $IS$ values reported are the averages from alternate ordering of futures and boxed beef prices. For}
new information compared to boxed beef price. The close approximation of proportional contributions by both CS and IS measures point to the relatively similar variances and rather low contemporaneous correlation in the reduced form residuals. As Hasbrouck (2003) suggests, the results from price discovery metrics are quite similar to those from the impulse response analysis. In both analyses, the change in the boxed beef price does not have an effect on the futures price.

Based on the Yan and Zivot (2010) and Putnins (2013) approaches, we use these CS and IS measures to derive the ILS measures. The computed ILS measures confirm the dominance of futures price in reflecting new information.\(^{23}\) The ILS for the Friday futures price in the boxed beef price is 73.1%, with the boxed beef price contributing only 26.9% to the price discovery. A smaller ILS value for futures compared to CS and IS is attributed to the elimination of the relatively higher transitory noise from the boxed beef price. When the sample of Friday boxed beef prices and Thursday futures price is compared, the contribution to price discovery from boxed beef price increases to 54.9% which is marginally higher than the 45.1% contribution of futures price. While this change in the importance of futures prices in price discovery might be attributed to a loss of information by using the Thursday rather than the Friday price as well as the elimination of noise from the Friday boxed beef price, the magnitude of the reduction seems large. Recalculation of highly non-linear IL on which the ILS is based, and examination of their components also suggest that IL is highly sensitive near the bounds to even small changes in CS and IS values. In short, the new price discovery measures that allow for a maximum advantage to boxed beef price in the pricing process still identify the dominance of the current futures price, and about equal weighting for the lagged one-day futures price. Nevertheless, recall that the results of the weak exogeneity tests attribute all the weight in the price process to the futures price.

\(^{23}\) The IL values are not reported, but are available on request.
3.4.6 Robustness Check

While the cointegrating vector appears to be time invariant, it may still be useful to examine the evolution of price relationships in a market known to be under transition. To assess the sensitivity of the results, data are split into two equal halves (1/9/2004-11/14/2008; 11/21/2008-9/27/2013) allowing the assessment of market relationships using data of reasonable sample size. Unit root tests identify that both prices are stationary in first period and non-stationary in the second period. Johansen’s tests identify one cointegrating vector in the second period. We model the first period as a stationary VAR process and use a first differenced VAR model for the second period because stable parameter estimates could not be obtained from an error correction model. Results of Granger causality tests and innovation accounting for both sub-periods are identical to the full period. However, in the second period we find that the responses to shocks die out more quickly compared to the first period. These results are consistent for both Friday and Thursday futures prices. In addition, we performed the analysis with a contract roll dummy. The results are robust to the inclusion of a contract roll dummy for the full period and the two sub-periods for both samples used.24

3.5 Conclusions

We investigate the relationship between the CME live cattle futures price and the boxed beef price for the 2004-2013 post-LMRA period to identify the price market participants should watch for timely and reliable cattle price information. Our findings indicate that the live cattle futures price is considerably more informative than the boxed beef price. The two series are cointegrated by one long-run time-invariant vector. The dominance of the futures price in the price relationship is supported by weak exogeneity tests which indicate that the futures price does not adjust to the discrepancy from long-run equilibrium. The importance of the futures price is strengthened by innovation accounting using the structural VECM.

24 The results for the analysis by sub-periods and robustness checks using contract roll dummies are not reported, but are available on request.
Forecast error variance decompositions reveal that the futures market is not affected by shocks in the boxed beef market, and plays a dominant role in boxed beef decompositions at distant horizons. Shocks to the futures price innovations also exhibit a relatively strong and lasting effect in the boxed beef market. In contrast, shocks to the boxed beef innovations do not influence futures prices, and boxed beef forecast errors contribute practically nothing to the error variance in the futures market. We observe bidirectional Granger causality between same day futures and boxed beef prices with the futures price strongly significant in the boxed beef equation. While the boxed beef price is significant in the futures price equation, its predictive power is low. Based on the weak exogeneity tests, newly-developed price discovery metrics attribute the dominate role to the futures market. Even when these metrics are interpreted to allow for a maximum boxed beef effect in the pricing process, the dominance of the current futures price emerges, and about equal weighting for the lagged one-day futures price. Our results indicate that the futures price adjusts to new fundamental information quicker than boxed beef price.

While we do find that the boxed beef price enters into the long-run cointegrating relationship, its limited importance in short-run dynamics was somewhat unexpected. Since the boxed beef prices are important in calculating processing margins, this disconnect in the short-run may be related to episodic non-competitive changes in processing margins documented by Cai, Stiegert, and Koontz (2011a, 2011b). From a different perspective, the limited importance also may be due to shortcomings in reported boxed beef cutout values. Wholesale cutout values do not include prices for the growing and variable exported beef products that on average are higher value cuts. For instance, branded products such as the Certified Angus Beef brand which uses the upper 2/3 Choice make up a significant volume of beef trade and is not included in Choice boxed beef cutouts. Such reporting issue may cause the wholesale values to underestimate the true, but more volatile value of wholesale meat. It also remains uncertain whether the thinness of the reported wholesale boxed beef prices resulting from the shift to contracting at retailer/wholesaler level (Koontz and Ward
2011) have contributed to the limited representativeness of reported boxed beef prices.

In sum, the futures price has a strong predictive influence on the boxed beef price and appears to assimilate fed cattle price information quicker than both current and one-day ahead boxed beef prices. From a weekly pricing perspective, the boxed beef prices computed from cutout values do not inform the live cattle futures price. The implication for a producer marketing cattle in the coming week is that the futures price provides the most relevant and timely source of fundamental information. While the boxed beef price appears to have limited value in short-term price discovery, the extensive information available in boxed beef reports is valuable in understanding general patterns in beef demand and supply along the marketing chain. For instance, the spread between the Choice and Select cutout informs market on the relative supply of each grade informing about packer demand for cattle with specific characteristics. Information on changes in volume and price may also reflect market dynamics including changing buyer preference, price resistance along the marketing chain, as well as glut or products backing-up in distribution pipeline (USDA-AMS). Regardless, the beef markets have evolved over time and there may be need to evaluate the way in which boxed beef cutout values are developed to make prices more timely and informative.
3.6 References


### Table 3.1. Unit Root Tests: Weekly U.S. Cattle Prices

<table>
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<tr>
<th>Market</th>
<th>Test</th>
<th>Level</th>
<th>First Difference</th>
<th>Level</th>
<th>First Difference</th>
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<tr>
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<td></td>
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<tr>
<td>Futures</td>
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<td>-23.73 **</td>
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<td>-21.51 **</td>
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<td>-4.95</td>
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Notes: Data: 1/9/2004-9/27/2013. Panel A: Friday futures and boxed beef price. Panel B: Thursday futures price and Friday boxed beef price. Futures denotes CME live cattle futures price. Boxed beef denotes the boxed beef cutout values multiplied by 63% to reflect the average hot yield. C denotes a specification with a constant. T denotes a specification with a trend. CT denotes a specification with both constant and trend. The τ-stat is the test statistic for the ADF test. Lag lengths for the ADF test are based on SBIC. ADF-GLS (C) is specified with an intercept. The test statistic for ADF-GLS is t-stat. Lag lengths for ADF-GLS are based on the MAIC. ZA test is specified with one time break in both intercept and trend. Lags for ZA test are based on SBIC. For the ZA test, the test statistic is t-stat. ** Significant at \( \alpha = 0.01 \), * Significant at \( \alpha = 0.05 \), * Significant at \( \alpha = 0.10 \).
Table 3.2. Johansen Test for Cointegration

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>Alternate Hypothesis</th>
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<th>Panel B.</th>
<th>Critical Value</th>
</tr>
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<td>(\lambda_{\text{trace}} ) tests</td>
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<td>(\lambda_{\text{trace}} ) value</td>
<td>(\lambda_{\text{trace}} ) value</td>
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<tr>
<td>(r=0)</td>
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<td>30.18</td>
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<td>(r&lt;=1)</td>
<td>(r&gt;1)</td>
<td>1.4</td>
<td>1.22</td>
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<td>(\lambda_{\text{max}} ) value</td>
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Notes: Data: 1/9/2004-9/27/2013. Panel A: Friday futures and boxed beef price. Panel B: Thursday futures price and Friday boxed beef price. Futures denotes CME live cattle futures price. Boxed beef denotes the boxed beef cutout values multiplied by 63% to reflect the average hot yield. LR test of the null hypothesis that there are at most “r” cointegrated vectors against the alternative that there are “k” cointegrated vectors (\(\lambda_{\text{trace}}\)) and, that there “r+1” cointegrated vectors (\(\lambda_{\text{max}}\)). The model is specified with an unrestricted constant term to account for possible trend (drift) in level series (Enders 2008).
Table 3.3. Weak Exogeneity Test

<table>
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<th>Panel A.</th>
<th>Panel B.</th>
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<td></td>
<td>∆F (t)</td>
<td>∆B (t)</td>
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<tr>
<td>Coefficient (α)</td>
<td>-0.008</td>
<td>0.081 ***</td>
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</table>

Notes: Data: 1/9/2004-9/27/2013. Panel A: Friday futures and boxed beef price. Panel B: Thursday futures price and Friday boxed beef price. Futures (F) denotes CME live cattle futures price. Boxed beef (B) denotes the boxed beef cutout values multiplied by 63% to reflect the average hot yield. SBIC chosen lags are 3 for models in panels A and B. An additional lag is included to control autocorrelation. Test statistic is the Z statistic. ***Significant at $\alpha = 0.01$, **Significant at $\alpha = 0.05$, *Significant at $\alpha = 0.10$. 

74
### Table 3.4. Forecast Error Variance Decompositions From Level VAR

<table>
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<tr>
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Notes: Data: 1/9/2004-9/27/2013. Panel A: Friday futures and boxed beef price. Panel B: Thursday futures price and Friday boxed beef price. Futures denotes CME live cattle futures price. Boxed beef denotes the boxed beef cutout values multiplied by 63% to reflect the average hot yield. The forecast error variance decompositions in each row sum to 100.
Table 3.5. Toda and Yamamoto Granger Causality Test

<table>
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<tr>
<th>Panel A</th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F(t)</td>
<td>B(t)</td>
<td>F(t)</td>
<td>B(t)</td>
</tr>
<tr>
<td>All Boxed Beef = 0</td>
<td>8.88 **</td>
<td>All Futures = 0</td>
<td>77.21 ***</td>
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<tr>
<td>All Futures = 0</td>
<td>4.53</td>
<td>All Futures = 0</td>
<td>59.56 ***</td>
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Notes: Data: 1/9/2004-9/27/2013. Panel A: Friday futures and boxed beef price. Panel B: Thursday futures price and Friday boxed beef price. Futures (F) denotes CME live cattle futures price. Boxed beef (B) denotes the boxed beef cutout values multiplied by 63% to reflect the average hot yield. SBIC chosen lags is 3 for models in panels A and B respectively. Test statistic is the $\chi^2$ statistic. ***Significant at $\alpha = 0.01$, **Significant at $\alpha = 0.05$, *Significant at $\alpha = 0.10$. 
Figure 3.1. U.S. Fed Cattle Prices, January 2004-September 2013

Notes: Data: 1/9/2004-9/27/2013. Futures price denotes CME live cattle futures price. Boxed Beef price denotes the boxed beef cutout values multiplied by 63% to reflect the average hot yield.
Figure 3.2. Impulse Response to One SD Innovations

Notes: Data: 1/9/2004-9/27/2013. Impulse response with 95% bootstrapped confidence intervals from level VAR. SD denotes standard deviation. Impulse response functions are reported for Friday futures and boxed beef prices.
CHAPTER 4
INTRADAY MARKET EFFECTS IN ELECTRONIC SOYBEAN FUTURES
MARKET DURING NON-TRADING AND TRADING HOUR
ANNOUNCEMENTS

4.1 Introduction
Beginning January 11, 2013, the United States Department of Agriculture (USDA) began releasing several of its important market reports at 11:00 a.m. during Chicago Board of Trade (CBOT) trading hours. These reports include the World Agricultural Supply and Demand Estimates (WASDE), Acreage (AC), Crop Production (CP), Grain Stocks (GS), and Prospective Planting and Small Grains Summary (PPL). While the change in report release became effective in January 2013, the CBOT had already extended its electronic-only (Globex) trading hours from May 21, 2012 allowing trade during USDA report releases. Figure 4.1 depicts the changes in CBOT trading hours and USDA report release times from June 2010-May 2014. Market participants closely monitor these reports as they reflect changes in market fundamentals which can cause significant price movements (Isengildina-Massa et al. 2008a, 2008b; Karali 2012; Adjemian 2012).

Following the extension of trading hours, concerns have emerged that the arrival of information during trading hours leads to higher and protracted volatility. Proponents of pre-opening report releases argue that informal price discovery prior to the opening contributes to a quicker and efficient price adjustment to critical information release. Many demand that reports be released during non-trading hours or a trading pause be established

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1 Time in Central Standard Time (CST).
2 Kauffman (2013) documents the events that lead to the change in release time for major USDA reports. The highlight was the strategic move by the Inter Continental Exchange (ICE) to extend trading to 22 hours per day and the CBOT followed suit.
during USDA report releases allowing time to process the fundamental information. Supporters of the change contend that releasing reports during the high volume, deeply liquid trading hours is beneficial. In their view, when prices are determined during more liquid trading hours, it dampens volatility, allowing information shocks to be readily absorbed.  

Markets assimilate information at different speeds and the patterns of return movements may vary based on the timing of report arrival. Most studies on the effect of USDA report releases have been performed using daily open and close prices. These studies including Milonas (1987), Sumner and Mueller (1989), Garcia et al. (1997), McKenzie 2008, Isengildina-Massa et al. (2008a, 2008b), and Adjemian (2012) identify significant impact from USDA report releases on commodity prices. Intraday studies in corn futures markets by Kauffman (2013) and Lehecka, Wang, and Garcia (2014) indicate that the strongest market reactions to news release are observed immediately after market open and that information is quickly incorporated into prices when USDA reports are released before the trading session. Kauffman (2013) indicates that analysis of report releases using corn futures data post-May 2012–after the start of Globex extended trading hours which led to the release of the WASDE report during trading–reveals heightened volatility with extended price adjustments over 30 to 60 minutes. He also argues that these extended periods of volatility could pose challenges for producer’s risk-management during the day of report release.

Studies that focus on daily close and open price data do not entirely capture the magnitude of these important intraday effects concentrated around the report release (Kauffman 2013; Lehecka, Wang, and Garcia 2014). For instance, estimates on event days using daily returns employed in previous studies completely miss the price reversals and continued price adjustments within the report day. More importantly, for CBOT electronic futures markets, the daily opening price corresponds to the opening price from the electronic trading session of the previous calendar day (Lehecka, Wang, and Garcia 2014). Hence, it is not

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4 The supporters of the change also argue that intraday report releases may facilitate price discovery in the futures market rather than in unregulated over-the-counter (OTC) swap markets.
clear whether the traditional approach precisely estimates the initial market impact from reports released at 7:30 a.m. during non-trading hours and at 7:30 a.m. and 11:00 a.m. during trading hours (See figure 4.1). The availability of high frequency transaction data for CBOT soybean futures contracts provide an opportunity to examine the intraday dynamics of futures markets which was not previously possible. The paper offers pioneering work in evaluating the release of critical USDA reports during non-trading and trading hours, quantifying its effects on intraday volume, volatility, speed of price adjustment, trading intensity, and efficiency in the CBOT electronic soybean futures market.

There are several reasons to expect different price adjustments to report releases during non-trading and trading hours. First, non-trading releases permit broader dissemination of the information and allow traders to more carefully assess the pricing implications of the news (Greene and Watts 1996; Brooks, Patel, and Su 2003). Studies including Cao, Ghysels, and Hatheway (2000), Barclay and Hendershott (2003, 2008) Moshiran, Nguyen, and Pham (2012) among others have attributed the efficiency of the pre-open period (a period without trading when traders can submit and revise orders for possible execution at the market open) during news arrivals to the time available for market participants to evaluate the news. Second, increased asymmetry in information during trading hour releases may motivate traders to delay or reduce the size of orders to learn more from prices or conceal information from others delaying the true equilibrium.

The debate on the optimal time for report release is rooted in the disparate nature of the market participants involved in trading and the way in which they conduct their business. Report arrival in the midst of trading implies less time for market participants to make informed decisions. Farmers, grain elevators, processors, and agribusiness companies use futures contracts to hedge against shifts in the price of crops/raw materials which involves decisions that require time to process information in the report, understand its implications, and adjust futures market positions. In contrast, automated trading firms are typically focused on arbitrage and seek to profit from buying and selling contracts. This implies that
the financial risk and costs of holding a futures position (e.g., maintaining a margin account) during report release may be borne more by a hedger/commercial trader who seeks price protection by locking in a price and less by a high frequency trader who is in and out of the market quickly (Welch et al. 2012). The major criticism is that the latter specializes in quick arbitrage and have access to faster information processing systems, quicker data-feeds, proximity to the exchange, with a time advantage to place orders quickly (latency), and benefit from the excessive short-run volatility.\(^5\) Closely related is the issue of limited bandwidth at USDA facilities that can disproportionately affect the market participant’s ability to access information quickly.\(^6\) As noted by Kim and Verecchia (1994) information asymmetry is usually higher around news announcements than during non-announcement periods. For agricultural futures markets, the assumption in general is that markets are less than strong form efficient during news announcement (Sumner and Mueller 1989; Isengildina-Massa et al. 2008a; Lehecka, Wang, and Garcia 2014).

While there is substantial work on the impact of reports, only a few relate the effects directly to the risks associated in the market and discuss implications for producers. Kauffman (2013) argues that producers whose long-term trading strategies are not sensitive to brief spikes in intraday volatility are unlikely to be adversely affected by the change to trading hour releases. However, the conflicting sentiments among market participants over the timing of information arrival in agricultural markets indicate that not everyone views this change as a win-win situation (See footnote 3). Price fluctuations in the soybean market affects livestock feed producers, elevators, exporters, processors, and consumers, among others. McKenzie and Singh (2011) point out that a change in futures prices during announcement days can lead to losses to the agribusiness community even on hedged positions. Kauffman (2013) identifies the possible risks in using trading strategies such as stop-loss orders on report days during periods of extended volatility. For instance, if markets take longer time

\(^5\) Baron, Brogard, and Kirilenko (2012) identify that in some instances, hedge funds and high-frequency traders earn higher returns than smaller traders and attribute it to their distinct comparative advantage.

\(^6\) Kauffman (2013) points out anecdotal evidence that not everyone could access reports due to bandwidth problems at USDA facilities.
to adjust back to the equilibrium price levels, exacerbating price or basis volatility, it may induce costly margin calls and/or enhance the risk in hedging. In sharp contrast, the negative sentiment associated with the release of reports during trading hours may be totally unwarranted if information is incorporated quickly into prices. These concerns motivate us to investigate volatility and price movement in soybean futures markets during USDA report releases. Given their critical nature, extensive use, and potential impact on the market, the effect of the timing of report releases warrants attention.

Using microstructure data on CBOT soybeans we explore the speed and magnitude at which the market adjusts to USDA report releases during non-trading and trading hours focusing on volume, volatility, and market under- and overreactions. We separate report releases into two distinct periods. The first period is June 2010-May 2012, when reports were released during non-trading hours (table 4.1, panel A). The second period is June 2012-May 2014 when reports were released during trading hours (table 4.1, panel B). The data consist of all WASDE, CP, GS, AC, and PPL reports, second-by-second prices, and trade volumes for soybean nearby futures contracts in both periods. Some of the reports overlap and isolating their individual impact is difficult (See table 4.1). Wang, Garcia, and Irwin (2014) find GS and CP/WASDE reports have different effects on corn bid-ask spreads. Isengildina-Massa et al. (2008a, 2008b) identify separate effects for WASDE report releases with and without NASS U.S. production estimates. In light of the modest sample size, we pool all reports released and focus on the differences in market reactions between non-trading and trading hour releases. Statistical tests are performed on this pooled sample.

On report days, prices can be observed at very high frequency (e.g., multiple prices per second). This implies that market reactions and trading profits can disappear very quickly during a report release (Ederington and Lee 1993). We use a 15-second interval which provides a reasonable balance between market reactions from the arrival of information and the microstructure noise.\footnote{Microstructure noise may arise at higher frequencies due to periods of no trade as well as bid-ask bounce.} Average estimates of 15-second return variances and trade volumes
are computed for report release days, pre-/post-report release days (five days before and after the report day), compared, and examined using non-parametric procedures. Volatility on report days is then standardized by corresponding pre-/post-report day volatilities, computing average normalized volatility which is compared across policy periods. The analysis is complemented by investigating trading intensity, measured by the number of contracts traded per transaction in each 15-second interval. These effects are measured in a window 15 minutes before and 60 minutes after the report release where most market reactions are expected. Finally, the systematic under- and overreactions in returns following report releases are assessed by computing sequential and cumulative return correlations. Combined assessment of return variances and market under- and overreactions for release types will reveal the speed at which information is incorporated into the soybean futures market, reflecting the quality of the price discovery during alternate releases.

4.2 Literature Review

The impact of USDA reports on agricultural commodities is well documented. Milonas (1987) studies the value of USDA reports for corn, soybeans, and wheat, and finds that reports facilitate producer’s resource allocation decisions and provide increased reliability in the markets. Sumner and Muller (1989) report that release of USDA harvest forecasts, particularly for the months of August, September, and October, impact daily corn and soybeans futures prices. Using market survey data, Colling and Irwin (1990) show that live hog futures prices react significantly to the unanticipated components of the Hogs and Pigs report. McNew and Espinosa (1994) note that implied volatility of corn and soybean options decline significantly after the release of USDA forecasts as they reduce the uncertainty of market participant’s expectation of prices. Fortenbery and Sumner (1993) find that the effects of CP reports and WASDE have diminished relative to earlier periods during the 1985-1989 periods. Garcia et al. (1997) compare the informational value of USDA corn and soybean production forecasts to private forecasts and conclude that USDA forecasts are valuable as they are perceived less risky relative to private forecasts.
Isengildina-Massa, Irwin, and Good (2006) assess the effect of selected USDA reports on volatility of live/lean hog and live cattle futures markets using a univariate TARCH-in-mean model and find increased volatility from report release. Isengildina-Massa et al. (2008a) find that WASDE reports containing crop production estimates and other domestic and international situation and outlook information have the largest impact on corn and soybeans markets. Isengildina-Massa et al. (2008b) identify that WASDE reports produce significant reductions in implied volatility of corn and soybeans due to resolution of price uncertainty. McKenzie (2008) compares USDA production forecasts to private information and identify that August reports carry valuable information. McKenzie and Singh (2011) find that hedged positions are safer compared to unhedged positions during report release. They argue that report release can cause asymmetric responses in cash and futures prices increasing the variability in basis and compromising hedging effectiveness. The authors note that feed-mills and poultry firms are often forced to purchase grain to feed and supply livestock irrespective of market conditions which makes them vulnerable to large price moves resulting from report release. Adjemian (2012) measures WASDE announcement effects on cotton, soybeans, and hard red winter wheat for multiple delivery months and find significant effects on nearby and more distant maturity contracts for report release days.

More recently, researchers have studied market microstructure to understand the impact of USDA reports. Using intraday corn futures data Kauffman (2013) finds that extended trading hours which led to WASDE reports being released during trading hours have increased volatility briefly around report release. He finds that increased volatility has not extended beyond 30 to 60 minutes and argues that producers whose risk management strategies are not influenced by intraday price swings may not be affected by this change. Lehecka, Wang, and Garcia (2014) investigate the announcement effects of major USDA reports (WASDE, CP, GS, AC, and PPL) released during non-trading hours using intraday CBOT corn futures prices. Strongest market reactions to news release are found immediately after the market opens and market reactions persist for about 10 minutes. Their assessment of returns using
measures of correlation indicate that prices oscillate in the first few minutes following the market open, and the decrease in volatility after the open is not explained by under- and overreactions. They conclude that the corn futures market is efficient in incorporating new information. In a recent article, Wang, Garcia, and Irwin (2013) find that GS, CP, and WASDE reports have significant effects on the CBOT corn bid-ask spreads on announcement days. The authors note that this increase may be due to uncertainty in the direction and magnitude of subsequent price adjustments following report release which are resolved within the day.

While the existing work is valuable in understanding the impact of USDA reports on commodity markets, studies using daily close and open price data have limitations because the magnitude of news effect cannot be assessed when the impact of the report subsides within the day (Kauffman 2013; Lehecka, Wang, and Garcia 2014). More to the point, no work has compared the differential impact of report release in agricultural commodity markets during non-trading and trading hours. While several microstructure studies have examined the impact of USDA report release in corn, none has discussed how the reports affect soybean intraday returns. Our work fills this gap by providing pioneering work on the intraday market dynamics of the U.S. soybean market for USDA report release during non-trading and trading hours.

4.3 USDA Reports and Price Data

The report data set consist of WASDE, CP, GS, AC, and PPL reports from June 2010-May 2014. Hence, we have a sample of 30 days when reports are released during non-trading hours and 29 days when reports are released during trading hours. WASDE reports provide monthly USDA forecasts of U.S. and world supply-use balance of soybeans, meal, and oil. CP reports contain U.S. crop production information, including acreage, area harvested and yield for soybeans and are released monthly along with WASDE. GS reports provide estimates of soybean stocks at the state and national level and by on-farm and off-farm positions.

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8 The October report for 2013 was not released due to government shut-down.
and are released in January, March, June, and September. The AC report provides soybean planted and/or harvested acreage by state and is released yearly by the end of June. PPL provides the U.S. soybean planted acreage and is released yearly by the end of March.

Government statistical agencies impose “lock-up” conditions the night before report release to ensure that the information is released to the public at the scheduled time. The time and date for USDA report release are known in advance and are anticipated by the market. Prior to the change in release time, GS, WASDE, CP, AC, and PPL reports were released at 7:30 a.m. after the early morning electronic-only trading session and before the start of the floor/electronic day trading (See figure 4.1, panel A). From May 21, 2012 CBOT extended its electronic-only (Globex) trading hours allowing trade when USDA reports are released (See figure 4.1, Panel B). From January 2013, reports are released by USDA at 11:00 a.m. during day trading hours (See figure 4.1, panel B). To assess the effects of report release during trading and non-trading hours, we categorize June 2010-May 2012 as one policy period, and June 2012-May 2014 as the second policy period. Table 4.1 presents the reports, dates, and soybean futures contracts by release time. All report dates are compiled from World Agricultural Outlook Board (WAOB) and National Agricultural Statistical Service (NASS) archives at the USDA Economics, Statistics, and Market Information System located at Albert R. Mann Library, Cornell University.

The price data consist of second-by-second transaction prices and volumes on each day of trading session on report and pre-/post-report days for CBOT soybean futures contracts from June 2010-May 2014. Nearby contracts for soybeans are used because they are the most heavily traded and liquid contracts and are not in delivery (Isengildina-Massa et al. 2008a, 2008b). Prices for soybean futures are specified in cents/bu. with a quarter cent minimum tick size ($12.50 per 5000 bu. contract). The data are from Time and Sales data (Globex prices) from the CME historical data mine. Prior research by Martinez et al. (2011)

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9 This should not be confused with the change in USDA policy to move the release of select reports from 8:30 a.m. to 11:00 a.m.
have found that electronic markets for soybean futures reflect new information more quickly compared to floor trading which makes Globex the ideal market to assess reactions to news. The Globex trading sessions for which prices are available are presented in figure 4.1. The study also uses the CBOT soybean futures daily open and close prices from the Commodity Research Bureau (CRB) database for the June 2010-May 2014 period to compare report effects using traditional open and close prices with those of intraday 15-second volatility impact of news.

While the focus is on 15-second volatility, it is important to understand that the soybean price levels have varied considerably over the sample period making comparisons across policy periods more challenging. The price level at the beginning of our sample period, on June 3, 2010 is 955 cents/bu. which increases to 1107 cents/bu. by the middle of December 2011, reaching 1438 cents/bu. by 5/17/2012. Prices begin on a high note at 1349.5 cents/bu. on 6/5/2012 during the second policy period, increasing further to 1770.25 cents/bu. by 8/30/2012, and declining to 1256.5 cents/bu. by 8/12/2013. After that, prices rose to 1465 cents/bu. at the end of the sample. Detailed assessment of the number of transactions, trade volume, and returns variances 15 minutes before and 60 minutes after report release follows in the results section.

4.4 Results

We start the analysis by examining returns for nearby soybean futures contracts for different policy periods. Returns are computed as follows

\[ r_{i,t} = \ln \left[ \frac{P_{i,t}}{P_{i,t-1}} \right] \times 100, \]

with \( P_{i,t} \) being the last price of the nearby soybean futures contract in each 15-second interval \( i \), on trading day \( t \). The first return of each trading session is calculated using the last price from the previous trading session. When no trading occurs during an interval, the return is not calculated and the observation is considered as a missing value.

Since trading clock times differ in the sample, a common window is used for analysis.
Previous studies (Andersen et al. 2007; Christiansen and Ranaldo 2007) use a window 10 minutes before and 90 minutes after news announcement. Prior to report release, Lehecka, Wang, and Garcia (2014) and Kauffman (2013) find significant market reactions in corn markets as traders adjust their positions to manage market exposure. In addition, Kauffman (2013) identifies that volatility may extend over 30 to 60 minutes when USDA reports are released during trading hours. To capture these market reactions, we compute returns from 15 minutes before report release to 60 minutes afterwards i.e., 300, 15-second intervals. For report releases in the first policy period (non-trading hour report release–June 2010-May 2012), this implies concatenating 15 minutes of data closest to report release from the previous electronic-only trading session with 60 minutes of day trading data after the report release from June 2010-May 2012 i.e., the first return is measured at 7:00:15 a.m. and the last return measured at 10:30 a.m. For report releases in the second policy period (trading hour report release–June 2012-May 2014) two event windows exist. For reports released at 7:30 a.m. when Globex markets are open (June 2012-December 2012), the first return is computed at 7:15:15 a.m. and the last return is computed at 8:30 a.m. For reports released at 11:00 a.m. (January 2011-May 2014), the first return is computed at 10:45:15 a.m. and the last return is computed at 12:00 p.m. We follow the convention used in Sumner and Mueller (1989), Isengildina-Massa et al. (2008a), and Lehecka, Wang, and Garcia (2014) and include pre-/post-report days as a measure of normal market conditions around the report day. Hence, for every report released, 15-second returns are computed from nearby soybean futures contracts for five days before the release date, the day of the release, and five days after the report release.\footnote{While the number of pre-/post-report days is restricted to five to avoid overlap with previous/subsequent report release days, including all GS, AC, and PPL report days cause a few days to overlap.}

Summary statistics for 15-second returns and volume on report and pre-/post-report days are presented for non-trading hour releases (table 4.2, panel A) and trading hour releases (table 4.2, panel B). Mean return are zero across both policy periods for report and pre-/post-report days. Report day returns in general exhibit higher variance and increased skewness
and kurtosis. Returns in the first policy period (panel A) exhibit relatively higher variance, skewness, and kurtosis compared to the second policy period (panel B). While the standard deviation of returns in panel A exceeds the standard deviation of returns in panel B, the standardized ratio of report and pre-/post-report day standard deviations is smaller in panel A (0.13/0.05=2.6) compared to panel B (0.09/0.03=3). This suggests that once the volatility on report days is standardized with the corresponding average pre-/post-report day volatility (which measures the normal market conditions), market reactions may be more pronounced for trading hour releases. The pattern for trade volume is similar to the returns. Both returns and volume during report and pre-/post-report days are not normally distributed, suggesting the need to use non-parametric methods to test various hypotheses.

Before analyzing the announcement impact on market prices, we investigate soybean futures returns for missing observations as periods of no trading are correlated to volume which may affect both price variance as well as the speed of price adjustment (Easley and O’Hara 1992; Blume, Easley, and O’Hara 1994). Moreover, a large number of missing observations may affect our modest sample size (particularly for report days) and reduce the accuracy of our estimates. In the first policy period, all 15-second intervals without trading for report and pre-/post-report days amount to 10.8% and 14.6% of the sample respectively. In the second policy period, missing observations reach 9% and 21.5% for the report and pre-/post-report days. However, for the first 15 trading minutes following releases in the first policy period, only a negligible 2.6% of observations on report days and 3.5% on pre-/post-report days are missing. For the second policy period, 2.9% and 18.5% of observations are missing on report and pre-/post-report days respectively during the first 15 minutes following release. Separating report and pre-/post-report day data in the second policy period further based on the 7:30 a.m. and 11:00 a.m. release indicates that the larger proportion of missing observations are from the 15 minutes period following the 7:30 a.m. releases. The difference can be attributed to the increased trading activity during the more liquid trading hours which may have influenced the USDA decision to move the releases into the day trading session.
at 11:00 a.m.\textsuperscript{11} While the large number of missing observations in the pooled sample for pre-/post-report days (18.5\%) in the second policy period may appear alarming, this period represents sessions of intraday trading with very little price variation, where the missing observations have only negligible impact on measured volatility.

The market reactions in a futures market may be complicated by limit price moves (Isengildina-Massa et al. 2008a; Adjemian 2012). For a large part of our sample, price limit for CBOT soybean futures contract was $0.70/bu. expandable to $1.05/bu. and then to $1.60/bu. Starting May 1, 2014, the daily price limit has been variable and reset every 6 months in May and November (CBOT Rulebook, Chapter 11 Soybean Futures). This variable price limit for soybean futures during was $1/bu. expandable to $1.50/bu. We examined report days for large moves in soybean futures prices and find three limit move days in the first policy period and no limit moves in the second policy period. The small number of limit move days in the first policy period is unlikely to have a substantial impact on market reaction test results and is left unadjusted (McKenzie, Thompson, and Dixon 2004; Adjemian 2012).

4.4.1 Trade Volume and Return Variance on Report and Pre-/Post-Report Days

We now relate USDA report release to measures of aggregate market activity. Both trade volume and volatility reflect the impact of public information arrival. Since trade volume is viewed as a noisy measure of public information arrival, studies have often used return variance along with volume to assess market reactions.\textsuperscript{12} Volume and return variance are first graphically examined and then statistical analysis is performed for each interval to compare volume/return variances across report and pre-/post-report days in each policy period. The average number of contracts traded in the 15-second intervals around report releases

\textsuperscript{11} The number of missing observations after 7:30 a.m. on report days is 7.4\% and 36.4\% on pre-/post-report days. The corresponding numbers decrease to .9\% and 10.5\% on report and pre-/post-report days for the 11:00 a.m. releases.

\textsuperscript{12} Kalev et al. (2004) points out that trade volume is also be driven by private information, liquidity trading, heterogeneous investor beliefs, and the degree of asymmetric information. See Kalev et al. (2004) for detailed description of limitations of using trade volume alone as a measure of public information arrival and related literature.
are plotted for non-trading hour (figure 4.2, panel A) and trading hour (figure 4.2, panel B) releases. For both policy periods, trading volume is negligible in the 15 minute period before the releases. However, volume increases substantially after the report is released and remains elevated for 15 to 20 minutes. In the first policy period, an average 2,293 contracts are traded during the first 15-second trading interval after the releases compared to 1,104 contracts in the same interval on pre-/post-report days. In the second policy period, trading volume in the first interval after report release is substantially smaller at 1,014 contracts on report days and 36 contracts in the same interval on pre-/post-report days. While the average difference on report days for the first interval is larger for non-trading (1189 = 2293-1104) compared to trading hour (978 = 1104-36) releases, the report and pre-/post-report trading volume differential quickly becomes larger for the trading hour releases (figure 4.2). The relatively larger spike in volume in the non-trading period is consistent with a quick response to new information discussed earlier. The larger relative volume in the trading period after the initial spike is also consistent with expectations related to protracted trading. However, notice that this pattern is also influenced by the pattern of information arrival during pre-/post-report days. For non-trading hour releases, trading volume on release days is compared to the market open when there may be information arriving in the pre-/post-report days. In contrast, for trading hour releases report days, volumes are compared to regular trading volumes on pre-/post-report days which are characterized by only limited information arrival.

The hypothesis that volumes on report and pre-/post-report days for each 15-second interval are equal is tested using the Wilcoxon rank-sum framework since the general characteristic of the data support the use of non-parametric procedures. Here we test the hypothesis that two independent samples are from populations with the same distribution (Wilcoxon 1945). The results are graphically presented in figure 4.3, panel A for the first policy period and panel B for the second policy period. On the Y-axis, the left scale represents the Z statistic and the right scale represents the 95% significance level. The p-values greater than .05 are
scaled to .05 so that the intervals where differences in volume are significantly different can be easily identified. While the difference in trade volume subsides within the first 15 to 20 minutes for non-trading hour report releases, it persists for approximately 60 minutes for trading hour releases.

We measure the return variance in a given interval as research identifies volatility to be closely associated with information arrival (Ederington and Lee 1993; Fleming and Remonola 1999; Kalev et al. 2004; Riordan et al. 2013). To measure volatility, we use a measure similar to Entorf, Gross, and Steiner (2012) and Lehecka, Wang, and Garcia (2014). Volatility for time interval $i$ at day $t$ is computed as

$$V_{i,t} = |r_{i,t} - r_{i}^{m}|,$$

where $r_{i,t}$ denotes the soybean futures returns for each 15-second time interval $i$ at day $t$ and $r_{i}^{m}$ is the median return for time interval $i$ in each policy period. Volatility on report and pre-/post-report days are computed using the median return $r_{i}^{m}$ for time interval $i$ measured separately for those days. The average intraday volatility for each interval $I$ ($i=1,..., 300$) is formulated as

$$V_{i,t} = \frac{1}{T_i} \sum_{t=1}^{T_i} V_{i,t},$$

where $T_i$ is the number of observations in interval $i$ for report and pre-/post-report days separately in the policy period under review.\footnote{The median is used as it is more robust to outliers. However, volatility calculated using the mean, and standard deviation of returns exhibit similar behavior.}

Figure 4.4, panel A compares the volatility on report and pre-/post-report days for non-trading hour releases, and panel B compares them for trading hour releases. In both policy periods, volatilities peak immediately following the report release and major market reactions persist for about 10 to 15 minutes. For non-trading hour releases, the magnitude of volatility at 1.43 is highest in the first 15-second interval. However, the high volatility is short-lived, quickly dropping to .10, and then stabilizing above .05. In contrast, for trading hour releases, the volatility in the first 15-seconds peaks at a lower level, .51, but persists at
.15 for the first two minutes, and .10 for the next 5 to 6 minutes before stabilizing at .05. The volatilities during the same period on pre-/post-report days, immediately after report arrival are .23 and .02 in the first and second policy periods respectively. In the first period, the higher volatility during pre-/post-report days persists for 5 to 6 minutes and then stabilizes. In contrast, in the second period, the volatility on pre-/post-report days remains low and more or less stable throughout. Visual comparison of the two plots indicates that report day’s for trading hour releases exhibit extended volatility relative to pre-/post-report days when compared to non-trading report releases. This difference emerges partly because in panel A, the period examined follows market open at 9:30 a.m., whereas for the second policy period in panel B the volatilities are not affected by market open. Hence, similar to the volume traded, the pre-/post-report days for the first policy period show some effect from information arrival during market open which is absent in the pre-/post-report days for the second policy period.

The differences in volatility on report and pre-/post-report days are statistically compared employing non-parametric Kruskal-Wallis tests (Isengildina-Massa et al. 2008a; Lehecka, Garcia, and Wang 2014). Kruskall-Wallis tests the hypothesis that samples are from the same population (Kruskall and Wallis 1952; 1953). Results of the analysis are presented in figure 4.5, panel A for non-trading hour report releases and panel B for trading hour report releases. Similar to the volume graphs, the left scale on the Y-axis represents the test statistic which is a Chi-Square statistic here, and the right scale represents the 95% significance level. The p-values values greater than .05 are scaled to .05. A p-value less than .05 represents the statistically different volatility on report and pre-post report days for the interval. The results support earlier visual comparison and indicate that USDA reports produce substantial market reactions on report release days regardless of the timing of release. The non-parametric tests reveal significant difference between volatility on report days and pre-/post-report days. While the difference in return variance is short lived in the first policy period, it is significant in the second policy period for 30 to 40 minutes after the release.
and appears to persist intermittently for nearly 60 minutes. The increased persistence in volatility during trading hour releases corresponds with the notion that full implication of the report is known only after initial search and analysis which is revealed through trading. (Ederington and Lee 1993).

Despite their smaller sample sizes, market reactions to report release are also assessed for WASDE only days, and for WASDE sub-groups with and without the NASS U.S. production estimates.\textsuperscript{14} In general, the pattern of volatility is similar to those in the pooled analysis already presented. However, the initial impact of the report release varies considerably among the groups. For the WASDE only group, average volatility for the first 15-second interval after the report release is 1.24 and .47 for the first and second policy periods respectively. This is lower than the pooled analysis which also includes the GS reports. The reduced impact of the WASDE group compared to the pooled group is consistent with the findings by Wang, Garcia, and Irwin (2014) who report that GS reports have the strongest effect on corn bid and ask spreads. In the WASDE sub-group without NASS U.S. production estimates, the report impacts are .91 and .36 for non-trading and trading hour report releases respectively. For the WASDE sub-group with NASS U.S. production estimates, the report impacts following report release is 1.89 for non-trading releases and .71 for trading release, consistent with the increased impact in these select reports identified by Isengildina-Massa et al. (2008a). The similarity of our findings with previous studies indicate that despite small sample sizes our volatility measure is able to correctly identify differences in market impact across different groups of reports adding credibility to the approach.\textsuperscript{15}

To test the hypothesis that traditional open and close prices do not precisely estimate market effects, we calculate close-to-close returns and open-to-close returns using prior day Globex close/open prices and report day closing prices. The traditional method overesti-

\textsuperscript{14} For the first and second periods, the sample of report days are (24 and 23) for the WASDE group, (8 and 7) for the WASDE sub-group with NASS production, and (16 each) for the WASDE sub-group without NASS production. Plots of these volatilities are not presented, but are available.

\textsuperscript{15} Further analysis of the reports in the second policy period, differentiating them into groups released at 7:00 a.m. and 11:00 a.m. identify a volatility pattern similar to the pooled analysis.
mates modestly the market impact from news for the first policy period at 1.43 calculated in the first 15-second interval, with a close-to-close estimate of 1.72 and an open-to-close estimate of 1.88 respectively. For the second policy period, the volatility estimates using close-to-close and open-to-close returns are 1.48 and 1.73 respectively, which are substantially higher than .51 measured using intraday data. Hence, traditional procedures using close and open prices appear to overestimate market impact, particularly in the current trading hour report release environment.

4.4.2 Report Effects across Policy Periods using Normalized Volatility

It is difficult to compare report release effects across policy periods because differences may be due to the timing of the release and/or inherent volatility differences in the periods. To address this point, we compute a normalized volatility by standardizing the volatility on each report day by its average pre-/post-report day volatility. Pre-/post-report day volatility should not be affected by the policy change related to information release and should reflect prevailing market conditions. Therefore, standardizing with pre-/post-report day volatility should help separate volatility inherent to the period from report day return variance, making comparisons between the different policy periods more meaningful.\(^\text{16}\)

The normalized volatility on report days for the time interval \(i\) at day \(t\) is computed as

\[
NV_{i,t} = \frac{\left| r_{i,t} - r^m_i \right|_{\text{Report Day}}}{\sum_{n=1}^{N} \left| r_{i,t} - r^m_i \right|_{\text{Pre-/Post-Report Day}}} / \frac{n - 1}{n}.
\]

where \(r_{i,t}\) denotes the soybean futures returns for each 15-second time interval \(i\) at day \(t\), \(r^m_i\) is the median return for time interval \(i\) over all trading days measured separately for report and pre-/post-report days in each policy period, and \(n\) is the number of pre-/post-report days around each report day such that \(\text{Min}(n) = 1\) and \(\text{Max}(n) = 10\).\(^\text{17}\) When the return on a report day in an interval is missing, the \(\text{Min}(n) = 1\) criterion is not met for pre-/post-

\(^{16}\) While this approach does not remove all inherent volatility effects during the period, it provides a more reasonable measure of comparing report effects across policy periods.

\(^{17}\) We use “\(n - 1\)” instead of “\(n\)” in equation due to our small sample size and to better approximate the true variance.
report days, and/or average volatility on pre-/post-report days is zero, the observation is dropped from the sample. The average normalized volatility for each interval \( i = 1, \ldots, 300 \), is computed as

\[
\overline{NV}_{i,t} = \frac{1}{T_i} \sum_{t=1}^{T_i} NV_{i,t},
\]

where \( T_i \) is the number of observations in interval \( i \) for report and pre-/post-report days separately in the policy period under analysis.

Average normalized volatility represents the standardized volatility on report days during report releases (figure 4.6). To facilitate comparison, the figure contains a reference line with a base value one which reflects equality between report and pre-/post-report day volatility (Lehecka, Wang, and Garcia 2014). For the non-trading hour release period, normalized volatility spikes to slightly above 5 in the first 15-second interval, but then is negligible. For the trading hour release period, normalized volatility reaches 29.34 in the first 15-second interval and remains persistently higher for 30 to 40 minutes following the release.

Intraday trading hour report release has a larger and more protracted effect relative to the normal volatility observed in the market. This is consistent with the notion that investors need more time to digest information and weigh the price implications of a report when it arrives during trading. In part this is also because the comparison in the second period is made relative to a time with limited information arrival. The difference in normalized volatility across policy periods can be attributed to the relatively tranquil pre-/post-report days in the second policy period. For instance, for the first policy period, volatility on pre-/post-report days in the first 15-second interval is .23 compared to .02 for the second policy period. Recall the second policy period contains a larger number of no-trade intervals (missing observations) as they reflect reduced market activity and lower levels of volatility. Nonetheless, these results reflect the current structure of market releases and identify what market participants are likely to face future.
4.4.3 Trading Intensity on Report and Pre-/Post-Report Days

Easley and O’Hara (1987) suggest that trade sizes affect prices as they change the perceived value of the underlying asset. Increased trading intensity around report announcements indicates investor’s reaction to information who trade to adjust holdings to reflect their new expectations (Berry and Howe 1994; Riordan et al. 2013). Hence, comparing trading intensity during different release periods may also provide insights into the speed of information arrival and price formation process. Here, we define trading intensity as the total number of soybean futures contracts traded divided by the number of trades. This is calculated for each 15-second interval, and averaged separately over the report and pre-/post-report days. Figure 4.7 compares the trading intensity during non-trading hour (panel A) and trading hour (panel B) releases. For non-trading hour report releases, there are an average 2 contracts per transaction for the 15-second intervals before report arrival which increases to 3 contracts per transaction after report arrival. For trading hour releases, the trading intensity during each interval is lower at approximately 1.3 contracts per transaction on report days and 1.2 contracts per transaction on pre-/post-report days. Mean trading intensities appear to be comparable for both report and pre-/post-report days in the first period, but appear to be higher on report days compared to pre-/post-report days in the second period. While a gradual decline in mean trading intensity can be noticed after initial news impact in the first policy period, no such decline is observed in the second period. The variation in trading intensity in general, is higher on report days for both policy periods and relatively higher for non-trading hour releases. Higher trading intensity during the first policy period may indicate reduced information asymmetry and increased trader confidence from quicker resolution of uncertainty.\(^{18}\)

4.4.4 Market Under- and Overreaction on Report Days

Report days are characterized by price reversals and continued price adjustments following

\(^{18}\) While it is possible that orders are being fragmented by traders in response to matching algorithms in the second policy period, further research is required to investigate this contention.
a report release (Lehecka, Wang, and Garcia 2014). USDA reports comprise several pages of complex summaries which require in-depth time-consuming analysis to understand. The increased persistence of volatility during trading hour report releases identified earlier supports this notion. The added time necessary to absorb the information may also lead to the market to under- or over-react to a report. Ederington and Lee (1993) argue that it may be possible to make profits by observing initial price response and buying (selling) if the initial return is positive (negative) because of the gradual adjustment of price to the equilibrium level. These characteristic reversals are important because most high frequency trading strategies are based on short-term intra-day reversals (Brogaard 2010). Since major reactions in the soybean futures market stabilize within the first 10 to 15 minutes, we focus only on the first 15 minutes post-report release and assess whether the market systematically under- or overreacts to news. This is statistically tested by computing correlations between the first return and subsequent returns as well as between cumulative subsequent returns. If soybean market underreacts (overreact), correlation should be positive (negative). The Spearman’s rank correlation measure which does not rely on normality is used to compute correlations.

Return correlations can detect predictable patterns in soybean futures price movements and indirectly test for possible trading profits based on initial market reaction. The results are presented for the first (table 4.3A) and second (table 4.3B) policy periods. First, the number of significant correlations is quite small for both periods. In both periods, the first significant interval correlation is negative which raises the possibility that the market overreacts to news within the first minute and then corrects quickly in later periods. A clearly persistent, but not significant pattern of negative cumulative correlation emerges for both periods. For the first policy period, significant negative correlations are observed towards the end of the first and second minutes, at the start of the fifth and sixth minutes, and at the end of the fourteenth minute. In the case of trading hour report releases, significant negative correlations exist only in the middle of the first minute and at the end of the fourth,
ninth, and eleventh minutes. Nevertheless, it is difficult to establish a solid pattern from the results. These results should be interpreted with care because: 1) the correlations are based on small sample sizes; 2) only a few intervals reflect significant correlations with the first return; and 3) the correlations are not large.

4.5 Conclusion

The paper contributes to the literature on intraday USDA announcement effects by examining trading volume, trading intensity, and return variance in the soybean futures market following non-trading and trading hour report releases. Using 15-second intervals, the effects of WASDE, CP, GS, PPL, and AC reports are assessed during non-trading hour report release for June 2010-May 2012, and trading hour report releases for June 2012-May 2014. We use an event framework by focusing on differences in market reactions 15 minutes before and 60 minutes after report releases, and compare reactions to pre-/post-report day behavior. We also investigate return correlations on report days to assess the degree of systematic under- or overreactions to new information.

In general, the soybean futures market responds quickly to information, with little evidence of under- or overreaction to news. With the introduction of new information, volatility remains high for the first 10 to 15 minutes following report releases regardless the timing of the release. For reports released during non-trading hours, a large spike in volatility at the beginning of trading emerges, which subsides quickly. For releases during trading hours, a smaller spike arises, but persists for 5 to 6 minutes at a higher magnitude. When the volatility is standardized by pre-/post-report day volatility to account for prevailing market conditions, trading hour releases generate even higher volatility both in terms of immediate response and persistence. The results are similar to Kauffman (2013) who finds that corn futures volatility on report days during extended trading hours in 2012 is higher and persists longer relative to non-report days.

Volume and volatility are as expected closely related and follow a similar pattern. For the
first 15-second interval, the volume spikes for the non-trading releases relative to the trading releases, but are basically identical after the first reaction. Since the average trade volumes in the two periods are similar and trading intensity is smaller in the second period, relatively more transactions are needed to incorporate information from reports into the prices for trading hour releases. In contrast, non-trading hour releases exhibit higher trading intensity which may be a reflection of a higher trader confidence that informal price discovery would lead to a quicker resolution of uncertainty.

Overall, our empirical findings support the notion that the soybean futures market incorporates public information in scheduled USDA announcements quickly. In the context of intraday pricing process, when markets have more time to digest the information, price reactions are more intense and marginally quicker. The results correspond to previous findings in financial markets by Cao, Ghysels, and Hatheway (2000), Barclay and Hendershott (2003, 2008), and Moshiran, Nguyen, and Pham (2012) who find quicker information assimilation when news arrives during non-trading hours. We identify the report effects that market participants are most likely to expect in future under the new trading hour report release regime. Informatively, the new release regime allows for a direct comparison between limited information arrival and USDA report releases, providing a more precise measure of USDA information effects.
4.6 References


### 4.7 Tables and Figures

**Table 4.1. Select USDA Reports and Soybeans Futures Contracts, June 2010-May 2014**

<table>
<thead>
<tr>
<th>Calendar Month</th>
<th>Reports</th>
<th>Dates of Report Release</th>
<th>Soybean Futures Contract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A. Reports released during non-trading hours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>WASDE, CP</td>
<td>7/9/2010</td>
<td>7/12/2011</td>
</tr>
<tr>
<td>August</td>
<td>WASDE, CP</td>
<td>8/12/2010</td>
<td>8/11/2011</td>
</tr>
<tr>
<td>September</td>
<td>WASDE, CP</td>
<td>9/10/2010</td>
<td>9/12/2011</td>
</tr>
<tr>
<td>–</td>
<td>GS</td>
<td>9/30/2010</td>
<td>9/30/2011</td>
</tr>
<tr>
<td>October</td>
<td>WASDE, CP</td>
<td>10/8/2010</td>
<td>10/12/2011</td>
</tr>
<tr>
<td>December</td>
<td>WASDE, CP</td>
<td>12/10/2010</td>
<td>12/9/2011</td>
</tr>
<tr>
<td>January</td>
<td>WASDE, CP, GS</td>
<td>1/12/2011</td>
<td>1/12/2012</td>
</tr>
<tr>
<td>February</td>
<td>WASDE, CP</td>
<td>2/9/2011</td>
<td>2/9/2012</td>
</tr>
<tr>
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<td>3/9/2012</td>
</tr>
<tr>
<td>–</td>
<td>GS, PPL</td>
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<td>3/30/2012</td>
</tr>
<tr>
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<td>4/10/2012</td>
</tr>
<tr>
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<td>5/11/2011</td>
<td>5/10/2012</td>
</tr>
<tr>
<td>Panel B. Reports released during trading hours</td>
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<td></td>
</tr>
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<td>6/12/2013</td>
</tr>
<tr>
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<td>7/11/2012</td>
<td>7/11/2013</td>
</tr>
<tr>
<td>August</td>
<td>WASDE, CP</td>
<td>8/10/2012</td>
<td>8/12/2013</td>
</tr>
<tr>
<td>September</td>
<td>WASDE, CP</td>
<td>9/12/2012</td>
<td>9/12/2013</td>
</tr>
<tr>
<td>–</td>
<td>GS</td>
<td>9/28/2012</td>
<td>9/30/2013</td>
</tr>
<tr>
<td>October</td>
<td>WASDE, CP</td>
<td>10/11/2012</td>
<td>*</td>
</tr>
<tr>
<td>November</td>
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<td>11/9/2012</td>
<td>11/8/2013</td>
</tr>
<tr>
<td>December</td>
<td>WASDE, CP</td>
<td>12/11/2012</td>
<td>12/10/2013</td>
</tr>
<tr>
<td>January</td>
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<td>1/10/2014</td>
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<td>March</td>
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<td>WASDE, CP</td>
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<td>5/9/2014</td>
</tr>
</tbody>
</table>

Notes: The reports above are World Supply and Demand Estimates (WASDE), Crop Production (CP), Grain Stocks (GS), Acreage (AC), and Prospective Plantings and Small Grains Summary (PPL). Futures Contracts listed above are Chicago Board of Trade (CBOT) traded with respective expirations months. *USDA reports were not released in October 2013 due to government shut-down.
Table 4.2. Summary Statistics for Intraday Soybean Fifteen-Second Returns and Volume on Report and Pre-/Post-Report Days, June 2010-May 2014

<table>
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<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A. Non-trading hour report release</strong></td>
<td></td>
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<td></td>
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<tr>
<td>Mean</td>
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<td>0.00</td>
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</tr>
<tr>
<td>Median</td>
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<td>0</td>
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</tr>
<tr>
<td>Minimum</td>
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<td>-1.17</td>
<td>1.00</td>
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<tr>
<td>Maximum</td>
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<td>0.99</td>
<td>6,467.00</td>
</tr>
<tr>
<td>Std. Dev.</td>
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<td>0.05</td>
<td>239.69</td>
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<tr>
<td>Variance</td>
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<td>0.00</td>
<td>57,450.91</td>
</tr>
<tr>
<td>Skewness</td>
<td>14.18 **</td>
<td>-0.39 **</td>
<td>9.17 **</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>698.21 **</td>
<td>35.77 **</td>
<td>155.96 **</td>
</tr>
<tr>
<td>Normality</td>
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<td>12,093.50 **</td>
</tr>
<tr>
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</tr>
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<td><strong>Panel B. Trading hour report release</strong></td>
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<td>Minimum</td>
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<td>Maximum</td>
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<td>0.36</td>
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<tr>
<td>Std. Dev.</td>
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<td>Variance</td>
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</table>

Notes: Returns are computed as the difference in the natural logarithms of nearby soybean prices multiplied by 100. Returns and trade volumes are computed for 15-second intervals during 15 minutes before and 60 minutes after report release. Tests on skewness, kurtosis, and normality are D’Agostino, Belanger, and D’Agostino (1990) test for normal samples. **Significant at $\alpha = 0.01$, *Significant at $\alpha = 0.05$
Table 4.3A. Intraday Under-/Overreaction Results for Soybean Futures Return Reactions to Non-Trading Hour Report Release, June 2010-May 2012

<table>
<thead>
<tr>
<th>Interval</th>
<th>Cumulative</th>
<th>Per interval</th>
<th>Interval</th>
<th>Cumulative</th>
<th>Per interval</th>
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<td>T31</td>
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<tr>
<td>T2</td>
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<tr>
<td>T3</td>
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<td>-0.18</td>
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<tr>
<td>T4</td>
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<tr>
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<td>T36</td>
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<tr>
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<td>T47</td>
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<td>T51</td>
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Notes: Intervals represent correlation between the first 15-second return post-USDA report release and subsequent 15-second returns as well as cumulative returns for up to 15 minutes. **Significant at $\alpha = 0.01$, *Significant at $\alpha = 0.05$. 

107
Table 4.3B. Intraday Under-/Overreaction Results for Soybean Futures Return Reactions to Trading Hour Report Release, June 2012-May 2014

<table>
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<th>Per interval</th>
<th>Interval</th>
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</table>

Notes: Intervals represent correlation between the first 15-second return post-USDA report release and subsequent 15-second returns as well as cumulative returns for up to 15 minutes. **Significant at $\alpha = 0.01$, *Significant at $\alpha = 0.05$. 

108
Figure 4.1. CME Trading Hours and Select USDA Report Release Times, June 2010-May 2014

Panel A. Non-trading hour report release

June 3, 2010-May 20, 2012

12:00 a.m. 7:15 a.m. 9:30 a.m. 1:15 p.m. 6:00 p.m. 12:00 a.m.
7:30 a.m.

Panel B. Trading hour report release

May 21, 2012-June 24, 2012*

12:00 a.m. 9:30 a.m. 1:15 p.m. 2:00 p.m. 5:00 p.m. 12:00 a.m.
7:30 a.m.

June 25, 2012-January 10, 2013

12:00 a.m. 9:30 a.m. 2:00 p.m. 5:00 p.m. 12:00 a.m.
7:30 a.m.

January 11, 2013-April 7, 2013

12:00 a.m. 9:30 a.m. 2:00 p.m. 5:00 p.m. 12:00 a.m.
11:00 a.m.

April 8, 2013-May 16, 2014

12:00 a.m. 7:45 a.m. 8:30 a.m. 1:15 p.m. 7:00 p.m. 12:00 a.m.
11:00 a.m.

Notes: Time in Central Standard Time (CST). *From June 2012-December 2012, pits were open at 7:20 a.m. on USDA report days.
Figure 4.2. Trade Volume on Report and Pre-/Post-Report Days, June 2010-May 2014

Notes: Panel A: June 2010-May 2012, Panel B: June 2012-May 2014. Both plots are drawn to similar scale and the Y-axis is restricted to 1500 contracts to facilitate comparison. Zero on the X-axis represents the first 15-second interval post report release. In the first 15-second trading interval post report release, volume extends to an average 2293 contracts in panel A.
Figure 4.3. Wilcoxon Rank-Sum Test for Difference in Volume on Report and Pre-/Post-Report Days, June 2010-May 2014

Notes: Panel A: June 2012-May 2012. Panel B: June 2012-May 2014. On the Y-axis, the left scale represents the Z statistic and the right scale represents the 95% significance level. The p-values greater than .05 are scaled to .05. Zero on the X-axis represents the first 15-second interval post report release.
Figure 4.4. Volatility Evolution on Report and Pre-/Post-Report Days, June 2010-May 2014

Panel A. Non-trading hour report release

Panel B. Trading hour report release

Notes: Panel A: June 2010-May 2012, Panel B: June 2012-May 2014. Both plots are drawn to similar scale and the Y-axis is restricted to .25 to facilitate comparison. Zero on the X-axis represents the first 15-second interval post report release. In the first 15-second trading interval post report release, average volatility extends to 1.43 in panel A and .51 in panel B.
Figure 4.5. Kruskall-Wallis Test for Difference in Volatility on Report and Pre-/Post-Report Days, June 2010-May 2014

Notes: Panel A: June 2010-May 2014, Panel B: June 2012-May 2014. On the Y-axis, the left scale represents the Chi-Square statistic and the right scale represents the 95% significance level. The p-values greater than .05 are scaled to .05. Zero on the X-axis represents the first 15-second interval post report release.
Figure 4.6. Average Normalized Volatility For Non-Trading and Trading Hour Report Releases, June 2010-May 2014

Notes: The Y-axis is restricted to 15 to facilitate comparison. Zero on the X-axis represents the first 15-second interval post report release. In the first 15-second interval post report release, average normalized volatility extends to 29.34 in the first 15-second interval post trading hour report release. To facilitate comparison, the figure is provided with a reference line at the base value one, which reflects equality between report and pre-/post-report day volatility.
Figure 4.7. Trading Intensity on Report and Pre-/Post-Report Days, June 2010-May 2014

Notes: Panel A: June 2010-May 2012, Panel B: June 2012-May 2014. Zero on the X-axis represents the first 15-second interval post report release. Average trading intensity is measured as the number of contracts traded per transaction for each 15-second interval averaged separately for report and pre-/post-report days over all months. The plots are drawn to different scale to facilitate the comparison of mean trading intensity levels. Notice that the variation in trading intensities are not comparable across policy periods due to different scales.
The dissertation investigates three issues in agricultural commodity markets. The applied economic research presented should provide valuable insights for academicians, industry, and policy makers involved in these markets. Further, the findings identify the need for additional research to improve our understanding of these markets, and potential policy changes to improve their effectiveness.

The first essay examines whether the empirical curve—the Working curve—representing the relationship between intertemporal price spreads and stocks developed by Holbrook Working is a valid stylized fact in modern commodity markets. It explores whether commodity inventories are being held when the expected returns to storage are negative. Storage under negative carrying charges or backwardation has been challenged and is controversial because it appears to contradict inter-temporal arbitrage conditions. Disaggregated weekly stock data at delivery locations for CBOT corn, soybeans, and wheat, and KCBT wheat for March 1990-May 2010 periods are plotted against precisely defined price spreads. In addition, the differential holding behavior of deliverable stocks and shipping certificates (pure financial instrument lacking convenience yield) for CBOT corn and soybeans since March 2000 is investigated to validate the convenience yield portion of the Working curve. We find that storage under backwardation is pervasive both in terms of the percent of observations that exhibited storage at a loss, and the magnitude of the stockholdings. Market agents tend not to hold shipping certificates in inverted markets, but do hold physical inventories. The Working curve is a valid stylized fact in modern commodity markets. The diversity in end-users and their differential stock holding motives explain the shape of the classic Working curve. Our findings point to the need to accommodate heterogeneous end-users in inventory models.

The second essay examines the relative information content in live cattle futures and boxed
beef prices in the post Mandatory Price Reporting (MPR) period (1/9/2004-9/27/2013) to identify prices that producers should monitor as an alternative source of information to the thinly traded cash market price. In recent decades the U.S. cattle industry has experienced added vertical integration and market concentration, raising concerns about thin cash markets and the reliability of market information they contain. Here, we use the nearby CME live cattle futures prices and average cutout value for the afternoon boxed beef report to assess the relative effectiveness of these prices in incorporating market information. Consistent with the weekly fed cattle pricing process and to account for any temporal informational advantage in the futures price, the analysis is performed using Friday boxed beef prices, and both Friday and Thursday futures settlement prices. Combined analysis with multiple time series procedures identify the dominant role of the live cattle futures price in the pricing process. Futures price has a strong predictive influence on the boxed beef price and appears to assimilate fed cattle price information quicker than both current and one-day ahead boxed beef prices. From a weekly pricing perspective, the boxed beef prices computed from cutout values do not inform the live cattle futures price. The implication for a producer marketing cattle in the coming week is that the futures price provides the most relevant and timely source of fundamental information. While the boxed beef price appears to have limited value in short-term price discovery, the extensive information available in boxed beef reports is valuable in understanding general patterns in beef demand and supply along the marketing chain. Regardless, the beef markets have evolved over time and there may be need to evaluate the way in which boxed beef cutout values are developed to make prices more timely and informative.

The final essay offers pioneering work in soybean futures market microstructure and evaluates market reactions following selected United Stated Department of Agriculture (USDA) report releases during non-trading and trading hours. In a change in policy effective January 2013, USDA began releasing several important market grain reports during trading hours at 11:00 a.m. Concerns emerged that trading hour report release leads to extended
periods of volatility. Proponents of the traditional pre-opening report release argue that a period without trading when traders can submit and revise orders for possible later execution contributes to a more informative opening price, causing a quicker and efficient price adjustment to report releases. Supporters of the change argue that releasing reports during the high volume, deeply-liquid trading hours can dampen volatility, allowing shocks to be readily absorbed improving price discovery. To date, no work has compared the differential impact of report release in agricultural commodity markets during non-trading and trading hours.

Using 15-second returns and trade volumes and event study framework, we find the soybean futures market responds quickly to information, with little evidence of under- or overreaction to news. The strongest reaction to USDA reports occurs 10 to 15 minutes after news arrival regardless of the timing of release. For reports released during non-trading hours, a large spike in volatility at the beginning of trading emerges, which subsides quickly. For releases during trading hours, a smaller spike arises, but persists for 5 to 6 minutes at a higher magnitude. When the volatility is standardized by pre-/post-report day volatility to account for prevailing market conditions, trading hour releases generate even higher volatility both in terms of immediate response and persistence. It is clear that the anticipated benefits of releasing reports during highly liquid market trading hours are not evident in the evolution of trade volume or return variance as more trades are required to incorporate information in the first few minutes following the report release. These findings identify the report effects that market participants are most likely to expect in future under the new trading hour report release regime. Informatively, the new release regime allows for a direct comparison between limited information arrival and USDA report releases, providing a more precise measure of USDA information effects.
In the appendix vectors are in bold. Following Yan and Zivot (2010), consider the Beveridge and Nelson (BN) decomposition of a cointegrated bivariate price vector in levels

(1) \[ P_t = P_0 + \Psi (1) \sum_{j=1}^{t} e_j + s_t, \]

where \( \Psi (1) = \sum_{k=0}^{\infty} \Psi_k \), \( s_t = (s_{1,t}, s_{2,t})' = \Psi^* (L) e_t \sim I(0) \), and \( \Psi^*_k = - \sum_{j=k+1}^{\infty} \Psi_j, k = 0, \ldots, \infty \). The matrix \( \Psi (1) \) contains the cumulative impacts of the innovations \( e_t \) on prices. As shown in Hasbrouck (1995), since \( \beta' \Psi (1) = 0 \) and \( \beta = (1, -1)' \), the rows of \( \Psi (1) \) are identical. Therefore, the long run impacts of an innovation \( e_t \) on each of the prices are identical. Representing \( \Psi = (\psi_1, \psi_2)' \) as the common row vector of \( \Psi (1) \), the permanent innovation can be defined as follows

(2) \[ \eta^p_t = \Psi' e_t = \psi_1 e_{1,t} + \psi_2 e_{2,t}. \]

Equation (2) can be represented using the common stochastic trend representation of Stock and Watson (1988) as follows

(3) \[ P_t = P_0 + 1 m_t + s_t, \]

where \( 1 = (1, 1)' \), \( m_t = m_{t-1} + \eta^p_t \), and \( s_t = \Psi^* (L) e_t \). The relationship indicates that each cointegrated price for the same underlying asset is composed of an unobservable common fundamental full-information value \( m_t \), a transitory pricing error \( s_{i,t} \) in market \( i \), and a constant. This efficient price \( m_t \) evolves as a random walk driven by new information on the asset’s future value captured by the efficient price innovation \( \eta^p_t \). The pricing error \( s_{i,t} \) captures any deviation of the price from its unobservable efficient price and the remaining constant reflects any non-stochastic difference between the price and its efficient price. Since we are interested in how each series affects the efficient price innovation variance, Hasbrouck uses (2) to estimate the proportion of the variance of attributed to each series. This is presented in the text.
References

