Measuring Price Discovery between Nearby and Deferred Contracts in Storable and Non-Storable Commodity Futures Markets

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Abstract:
In futures markets, contracts with varying maturities are traded simultaneously and it is often of interest to determine which contract leads price discovery. Using price discovery share measures, including Putniņš’ (2012) information leadership share, we measure the proportional contribution of price discovery between nearby and deferred futures for corn and live cattle futures. On average, the nearby contract leads all deferred contracts in price discovery in the corn market, but has a relatively less dominant role in the live cattle market. In both markets, price discovery is dominated by the nearby contract when it has more trading volume and longer time to expiration. Regressions results show that the share of price discovery is most related to trading volume but can be also affected by days to expiration, backwardation, USDA announcements and market crashes. However, these effects are less pronounced relative to the influence of trading volume, and usually differs in corn and live cattle markets because of the commodities’ difference in storability as well as other market characters.

Key words: price discovery share, commodity storability, forward curve, backwardation, USDA reports, market crash.
Introduction

Price discovery is one of the main functions of commodity futures markets. Classic research on price discovery in agricultural futures markets focused in one of three veins: determining which dominates, cash or futures price (Garbade and Silber 1983; Schroeder and Goodwin 1991; Weaver and Banerjee 1982); which of several geographically differentiated cash or futures markets dominate (Koonz, et al. 1990; Janzen and Adjemian 2017); and whether there is a difference in the quality of price discovery in storable versus non-storable commodities (Gray and Rutledge 1971; Leuthold et al. 1989; Yang et al. 2002).

The overwhelming evidence suggests that futures markets are the nexus of price discovery, and the cash markets play a lessor role as long as there is a liquid futures market available. Despite the overwhelming evidence that price discovery takes place in futures markets, we know little about where along the futures forward curve new information gets impounded into prices. With few exceptions (Garcia and Leuthold, 1992; Sanders et al., 2008; and Schnake et al., 2012), only the nearby futures contract is considered in most studies; or, the impact along the forward curve is averaged away (Garbade and Silber, 1983). In futures markets, contracts are listed with several maturities per year. Knowing how each contract maturity contributes to price discovery is vital for market participants. For example, commercial firms need price information at multiple horizons to guide their strategic business decisions and therefore may want to know how much information is incorporated by contracts expire at varying distances (Sanders et al. 2008).

The reality of price discovery along the forward curve, however, is likely to be complex. The forward curve is constantly shifting as days to expiration decrease for each contract on the board and new contracts are added to the back of the board. As this happens the nearby contract
loses importance as the delivery period approaches, evidenced by falling volume and open interest. It is not known, however, how rapidly price discovery fades and whether it happens at the same rate as volume leaving the nearby contract. Knowing when the leadership of price discovery switches from the nearby contract to the next nearby contract is particular important for making contract rolling decisions that is faced by academic researchers as well as futures users like commodity index funds. For instance, commodity indices based on futures prices need to include contracts that provide the most price discovery because they are often used as benchmarks by policymakers. A contract rolling strategy that causes including contracts that do not provide the most price discovery can mislead policymakers to costly decisions and harm social welfare (Rosegrant et al. 2008).

The location of price discovery along the forward curve may vary for a number of other reasons as well – some predictable and some unpredictable. For storable commodities, futures prices along the forward curve are linked by storage arbitrage (working 1948, 1949). Thus, a breakdown in the price discovery linkage between nearby and deferred futures is likely to occur when the market for a storable commodity is in backwardation. In contrast, for non-storable commodities, the presence of backwardation possibly has no impact at all as the prices are not affected by storage arbitrage. Additionally, USDA reports are released on a predetermined schedule and have been shown to impart important information about fundamentals that are quickly reflected in prices (e.g. Adjemian, 2012; Karali, 2012; Lehecka, 2013; Lehecka et al., 2014; Dorfman and Karali, 2015; Mattos and Silveira, 2016). The way this information gets incorporated into prices may be substantially different than the information that trickles into the market on a daily basis. Therefore, it is possible that information will impact the forward curve on these days differently than the typical day. Moreover, when periods of extreme price volatility
arise, price discovery may shift toward the front end of the forward curve or the back end, depending on changes in liquidity condition and market expectations.

This paper measures price discovery between nearby and deferred futures each day from 2008 to 2015 using transactions data for corn and live cattle time-stamped to the second from CME Group’s BBO dataset. The two commodities provide a useful comparison because Corn and Live Cattle are storable and non-storable, respectively. The prices along the forward curve are linked by storage arbitrage in the case of corn (Working 1948, 1949), while in the case of live cattle prices are not linked by storage arbitrage. This perhaps creates a need for prices to be discovered in multiple locations along the forward curve in the non-storable case whereas this effect may not exist in storable commodities (Tomek, 1997).

The period examined can be characterized by the growing relevance of electronic trading in agricultural commodity futures markets. Advances in electronic trading have dramatically changed the landscape of agricultural commodity futures markets in recent years (Irwin and Sanders, 2012). Some contracts, like corn, have flourished and others, like live cattle, have floundered in terms of public trust and measures of market quality like volume and volatility (WSJ 2016). Despite the importance of the transition to electronic trading, however, little work has been done to update the extant literature on price discovery in agricultural commodity markets since this dramatic change in market structure. The period examined also includes the periods when corn and live cattle prices were extremely volatile, as well as when markets were in backwardation. These characters enable us to reveal how price discovery relationships in the forward curve change in different market situations.

This article is the first to use high-frequency data for studying price discovery between nearby and deferred contracts in electronic commodity futures markets. Previous studies
typically used data at a daily frequency, which did not permit a dynamic characterization of how futures price discovery rolls from one contract to the next as the nearby nears expiration. We employ a recently developed price discovery metric, information leadership share (Putniņš, 2013), which is designed to be used on higher frequency data samples. While previous research has focused on price forecasts of nearby and deferred futures (Sanders et al. 2008; Schnake et al. 2012), the ILS enables us to directly measure the relative proportion of information impounded in nearby and deferred futures prices. In addition, compared to conventional price discovery measures, the ILS is more robust to differences in noise levels that present in nearby and deferred futures prices.

We begin our analysis by documenting patterns in daily price discovery shares between nearby and deferred futures in the whole sample period as well as in the nearby period of each contract month. Subsequently, we conduct regressions models to investigate determines of price discovery between nearby and deferred futures. The analysis provides important implications on price discovery dominance along futures forward curve that is useful for researchers making research decisions and market participants identifying business strategies. Findings suggest the nearby contract dominates deferred contracts in price discovery when it has more trading volume, which typically happens before enter the delivery period. The nearby contract plays a more important role in terms of price discovery in the corn market than in the live cattle market, reflecting the difference between the price discovery process along the forward curve in storable and non-storable commodity futures markets.

**Literature review**

There is a large body of literature on price discovery in futures markets (Garcia and Leuthold, 2004). Researchers have shown that new information typically is reflected in futures markets
first, then transmitted to cash markets. (e.g. Garbade and Silber 1983; Schroeder and Goodwin 1991; Yang et al. 2002). Research on the impounding of information to different futures contract maturities has a long history as well. Working’s (1948, 1949) theory of storage arbitrage predicts good price discovery in futures markets for storable commodities. In Working’s view, contracts with different maturities are linked by storage price except in periods of backwardation when low inventories break down normal price linkages. As explained in Tomek (1997), Woking’s theory for storable commodities is that deferred futures prices only make random adjustments to nearby futures prices and hold no additional value for price discovery when market is in contango. For non-storable commodities, the economic theory of intertemporal price relationships is less developed. Because non-storable commodities do not have arbitrage-enforced linkage through storage, different contract maturities are not as strongly linked as they are in futures on storable commodities (Gray and Rutledge, 1971; Schroeder and Goodwin, 1991). Leuthold et al. (1989) argued that for non-storable commodities, futures contracts for different delivery months should have unique information value as they represent market expectations of equilibrium conditions at different horizons.

Empirical studies, on balance, find nearby futures prices provide large price discovery, and less conclusive evidence exists for valuable incremental price information in deferred futures prices. Sanders et al. (2008) tested the incremental forecast ability of deferred futures for two non-storable commodities, hog and live cattle. They find deferred futures prices provide unique information in both markets. Schnake et al. (2012) studied information content in deferred futures contracts for both storable (soybean) and non-storable (live cattle) commodities. They found in both markets deferred contracts only contain some incremental informational value for forecasting price trend, but not for providing accurate point estimates. Outside of agricultural
commodities, Chen and Tsai (2017) examined price discovery shares between the VIX and VIX futures and find the price discovery contribution of VIX futures relative to the VIX index decreases as contract maturity increases. Mizrach and Neely (2008) found a similar term structure in the U.S treasury futures market.

The hypothesis that time to delivery has an impact on the price discovery process was not commonly tested in previous studies, because the frequency of their data (daily) did not allow them to reveal a dynamic characterization of price discovery process. Schroder and Goodwin (1991) regressed squared residuals from cointegration equations for hog cash and futures prices against week to contract expiration to study the time to maturity effect. They showed that the farther from delivery, the more the futures and cash prices diverge from each other. Hence, they suggested hedgers to liquid positions in maturity months when basis risk is smaller. In contrast, Irwin et al. (2011) and Garcia et al. (2015) documented sustained non-convergence between cash and futures prices in delivery periods in grain markets during most of 2005 - 2010. This non-convergence called into question the role of grain futures as venues for the efficient discovery of cash prices.

Price discovery of agricultural commodity futures has also been examined using event studies focusing on the effects of USDA reports. Overall, recent empirical studies have shown that USDA livestock and crop reports, especially for reports that release unexpected information, have significant price and volatility impacts on agricultural commodity markets, and markets react to USDA announcements rapidly (e.g. Adjemian, 2012; Karali, 2012; Lehecka, 2013; Lehecka et al., 2014; Dorfman and Karali, 2015; Mattos and Silveira, 2016).

Recent turbulence in commodity prices have raised concerns on whether the price discovery function of commodity futures has been harmed by financial speculations. There is a
growing body of literature on the financialization of commodity markets (e.g. Tang and Xiong, 2012; Silvennoinen and Thorp, 2013; Hamilton and Wu, 2015). Research on the financialization of commodity markets that focuses on agricultural commodities have found that grain and livestock futures prices are not significantly affected by the intensity of financial speculation and instead still mainly reflect supply and demand relationships in underlying cash markets (Irwin et al., 2009; Irwin 2013; Bruno et al. 2016).

**Price discovery measures**

Garbade and Silber (1979, 1982) are the first to develop a measure (the GS measure hereafter) for determining where price discovery is being produced. Their price discovery measure for commodity markets, cash and futures in their case, assumes that the prices in diverse markets for the same commodity share a common implicit efficient price. This assumption is appealing because it supports the economic intuition that prices for the same commodity in different markets are related by the same underlying common fundamental value and are linked by price arbitrage. Garbade and Silber propose the following model of price behavior

\[
\begin{bmatrix}
  p_{c,t} \\
  p_{f,t}
\end{bmatrix} = \begin{bmatrix}
  \alpha_c \\
  \alpha_f
\end{bmatrix} + \begin{bmatrix}
  1 - \beta_c & \beta_c \\
  1 - \beta_f & \beta_f
\end{bmatrix} \begin{bmatrix}
  p_{c,t-1} \\
  p_{f,t-1}
\end{bmatrix} + \begin{bmatrix}
  \omega_{c,t} \\
  \omega_{f,t}
\end{bmatrix}
\]

where \( p_{c,t} \) and \( p_{f,t} \) are cash and futures prices at time \( t \), respectively. The coefficients \( \beta_c \) and \( \beta_f \) are the effect of one period lagged price in one market on the current price in the other market. The shares

\[
G_{S_f} = \frac{\beta_c}{\beta_c + \beta_f}, \quad G_{S_c} = \frac{\beta_f}{\beta_c + \beta_f}
\]

are used for measuring the proportional contribution of futures and cash prices to the price discovery process, respectively. Since cash and futures price are for the same commodity, it is
reasonable to expect $\beta_c$ and $\beta_f \geq 0$. If $\beta_c = 0$, then $GS_f = 0$ and $GS_c = 1$, and the result can be interpreted as 100% of the new information is reflected first in cash market. On the other hand, if $\beta_f = 0$, then price discovery is total dominated by futures market.

While this measure has been originally applied to cash and futures prices, it can be generalized to determine price discovery between other closely linked prices that share the same fundamental value, for example, nearby and deferred futures prices in our case. Suppose the two prices in equation (1) are nearby and deferred futures prices $p_{1,t}$ and $p_{2,t}$, then the coefficients can be estimated via the OLS by rearrange equation (1) algebraically as follow

$$
\begin{bmatrix}
\Delta p_{1,t} \\
\Delta p_{2,t}
\end{bmatrix} =
\begin{bmatrix}
\alpha_1 \\
\alpha_2
\end{bmatrix}
+ \begin{bmatrix}
\beta_1 \\
-\beta_2
\end{bmatrix}
[p_{1,t} - p_{2,t}]
+ \begin{bmatrix}
\omega_{1,t} \\
\omega_{2,t}
\end{bmatrix}.
$$

The applications of the $GS$ measure, particularly in the area of commodity cash and futures markets, often suggest economically reasonable results that futures lead the cash (e.g. Oellermann, Brorsen, and Farris, 1989; Schroeder and Goodwin, 1991). However, from an econometric viewpoint, the $GS$ measure is derived from simple lead-lag regressions and only gives rough statements about temporal precedence. The advances in multivariate cointegration and error correction modeling introduced by Engle and Granger (1987) made it possible to constrain multiple prices to share a common efficient price in a cointegration framework. Hasbrouck information share ($IS$), and Harris-McInish-Wood component share ($CS$)$^2$ are the most widely used price discovery measures in the literature that are based on cointegration and error correction model. Without losing the functional generality of the lead-lag regression approach of the $GS$ measure, both $IS$ and $CS$ depend on the notion that prices for different

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$^2$ Following Putniņš (2013), we refer the $CS$ to the Harris–McInish–Wood component share to consist with the terminology used for the $ILS$. However, we also note that this measure has been introduced by others in earlier time (e.g. Gonzalo and Granger, 1995).
contracts (or in different markets) for the same commodity (or other asset) can deviate from each other in the short term, but will converge to their common fundamental value in the long term.

Assume the fundamental value of a commodity follows a random walk:

\[ w_t = w_{t-1} + \mu_t, \quad \mu_t \sim N(0, \sigma_\mu), \quad (3) \]

where \( w_t \) is the fundamental value at time \( t \), and \( \mu_t \) is i.i.d. The price series for futures contract with maturity \( i \) tracks the fundamental value \( \delta_t \) periods lagged and reflects a random error \( s_{i,t} \):

\[ p_{i,t} = m_{t-\delta_t} + s_{i,t}, \quad s_{i,t} \sim N(0, \sigma_{s_i}), \quad (4) \]

where \( p_{i,t} \) is the price series for contract maturity \( i \) at time \( t \), and \( s_{i,t} \) is i.i.d and uncorrelated across contracts. Thus, price deviations from the fundamental value are transient and the prices for contracts with different maturities are cointegrated.

Suppose there are two futures contracts, i.e. nearby and deferred contracts, then both IS and CS are derived by estimating the following (bivariate) VECM:

\[ \Delta p_t = \alpha (\beta' P_t - \mu) + \sum_{j=1}^J \Gamma_j \Delta p_{t-1} + e_t, \quad (5) \]

where \( p_t = (p_{1,t}, p_{2,t})' \) is a vector of futures prices for nearby and deferred futures contracts at time \( t \), respectively. The \( \beta \in \mathbb{R}^2 \) is a cointegrating vector. Following Figuerola-Ferretti and Gozalo (2010), we relax the assumption of \( \beta = (1, -1) \) that is formally used in the literature and specify a constant term \( \mu \) in the long run equilibrium to incorporate carrying charge. The parameter vector \( \alpha = (\alpha_1, \alpha_2)' \) contains error correction coefficients that measure the adjustment speed at which violations of the long run price equilibrium are corrected. The parameter \( J \) is the number of lags included and \( \Gamma_j \in \mathbb{R}^{2 \times 2} \) is a vector of coefficients for the autoregressive terms.
representing short-run dynamics. The error term $e_t$ is a zero-mean vector of white noise residuals with the covariance matrix,

$$
\Sigma = \begin{pmatrix}
\sigma_1^2 & \rho \sigma_1 \sigma_2 \\
\rho \sigma_1 \sigma_2 & \sigma_2^2
\end{pmatrix}.
$$

(6)

Harris et al. (2002) showed that the CS can be calculated from the normalized orthogonal to the vector of error correction coefficients, $\alpha_\perp = (y_1, y_2)'$. By noting that $CS_1 + CS_2 = 1$,

$$
CS_1 = y_1 = \frac{a_2}{a_2 - a_1}, \quad CS_2 = y_2 = \frac{a_1}{a_1 - a_2},
$$

(7)

where $CS_1$ and $CS_2$ are the CS measures for nearby and deferred contracts, respectively. Thus, the CS measure defines each price series’ contribution to the common factor as a function of error correction coefficients.

In Hasbrouck (1995) and other studies, information shares are estimated using the Vector Moving Average (VMA) representation of the VECM. However, Baillie et al. (2002) show that the IS can be directly derived from the error correction coefficients and the variance-covariance matrix of the error terms, which makes the estimation much easier. Given the Cholesky factorization of the VECM residual covariance matrix, $\Sigma = MM'$, where,

$$
M = \begin{pmatrix}
\sigma_1 & 0 \\
\rho \sigma_2 & \sigma_2 (1 - \rho^{1/2})^{1/2}
\end{pmatrix} = \begin{pmatrix}
m_{11} & 0 \\
m_{12} & m_{22}
\end{pmatrix},
$$

(8)

the IS measures for nearby ($IS_1$) and deferred ($IS_2$) contracts can be calculated using,

$$
IS_1 = \frac{(y_1 m_{11} + y_2 m_{12})^2}{(y_1 m_{11} + y_2 m_{12})^2 + (y_2 m_{22})^2}, \quad IS_2 = \frac{(y_2 m_{22})^2}{(y_1 m_{11} + y_2 m_{12})^2 + (y_2 m_{22})^2}.
$$

(9)

Essentially, the IS measures each price series’ relative contribution to the variance of the innovations to the common factor. Following Baillie et al. (2002), Booth et al. (2002), and
others, we calculate the IS measures using each of the two alternative orderings of price series and then take the average to avoid the effect of the ordering of the variables in the VECM.

In the conventional sense, price discovery metrics aim to measure the leadership in impounding new information. The majority of price discovery studies consider that a price series dominates price discovery if it incorporates new information about the fundamental value faster. Recent studies (Yan and Zivot, 2010; Putniņš, 2013) have showed that IS and CS are only consistent with this “who moves first” view of price discovery when the levels of noise in the price series are similar. In particular, using IS and CS may result in overstating the price discovery contribution of the less noisy contract.

Yan and Zivot (2010) employed a structural cointegration model to analytically demonstrate what exactly IS and CS measure. They show that the IS measures a combination of leadership in impounding new information and the relative level of avoidance of noise, while the CS merely measures the relative response to transitory frictions. Yan and Zivot (2010) proposed to use the combination of IS and CS such that the response to transitory frictions can be net out.

The measure of the relative impact of a permanent stock, developed by Yan and Zivot (2010) and termed “information leadership” (IL) in Putniņš (2013), is expressed as follows:

\[
IL_1 = \left| \frac{IS_1 \cdot CS_2}{IS_2 \cdot CS_1} \right|, \quad IL_2 = \left| \frac{IS_2 \cdot CS_1}{IS_1 \cdot CS_2} \right|, \quad (10)
\]

where \(IL_1\) and \(IL_2\) are the IL measures for nearby and deferred contract, respectively. Since the IL is not a “share”, to make it comparable to the existing shares (CS and IS) and easy to interpret, Putniņš (2013) defines the information leader shares for nearby (ILS\(_1\)) and deferred (ILS\(_2\)) contracts as:
Using a simulation study, Putniņš (2013) shows that $IS$ and $CS$ are biased when price series differ in noise levels because they both jointly measure relative speed in reflecting innovations in the fundamental value and relative avoidance of noise\(^3\), while the $ILS$ is robust to differences in noise levels. The levels of noise in prices for nearby and deferred futures contracts are very different considering their differences in trading volume and bid-ask spread (Wang et al., 2013). Therefore, the $ILS$ is a more appropriate measure than $IS$ and $CS$ for cointegrated nearby and deferred futures prices. Thus, when prices are cointegrated $I(1)$ series, we use the $ILS$ as our preferred measure.

In this article, we restrict our analysis to bivariate comparisons between nearby and deferred futures. This is because the $ILS$ measure relies on the assumption that the model only contains two price series (Yan and Zivot, 2010 and Putniņš, 2013). Moreover, if all the contracts are used (5 for corn and 4 for live cattle), prices may have different number of cointegrating vectors on different days which makes the application of price discovery measure complicated. Hence, we conduct our price discovery analysis between the nearby and each deferred contract, separately.

**Data**

Our analysis focuses on corn and live cattle futures contracts traded at the Chicago Mercantile Exchange (CME). These markets represent the most actively traded storable and non-storable agricultural commodities, respectively. The sample period studied for corn is from January 14, 3

\[^3\] Different form Yan and Zivot (2010), Putniņš (2013) finds the $CS$ does not just measure the relative avoidance of noise, it also measures the leadership in reflecting new information to some extent.
2008 through December 14, 2015, and the period used for live cattle ranges from January 1, 2008 to December 31, 2015. The period examined can be characterized by the growing relevance of electronic trading in agricultural commodity futures markets. The electronic platform’s shares of corn and live cattle futures trades were about 80% and 10% at the beginning of 2008 (Irwin and Sanders, 2012), and both rose to over 95% in 2015 (Gousgounis and Onur, 2016).

We use high frequency trade data obtained from the CME Group’s Top-of-Book database. Our data include transaction prices that are time stamped to the second and ordered chronologically by sequence numbers. We aggregate the data to one second frequency by taking the first transaction when multiple transactions have the same time stamp. If there is no transaction within a second, we create an entry for that second with the most recent transaction information. The benefit of using a short sampling interval is that it helps eliminate the contemporaneous correlation between innovations in nearby and deferred prices, so that the sequence of price response can be better determined (Hasbrouck, 1995). The CME electronic trading system (Globex) is open nearly 24 hours, however, we only consider the day-time trading session when the most active trading occurs. The CME used different trading hours for corn and live cattle futures during the sample period for this analysis and the trading hours we use for the two markets reflect these changes.

Corn futures have five delivery months: March, May, July, September, and December. Live cattle futures have six delivery months: February, April, June, August, October, and December. For both corn and live cattle futures, multiples contracts with different maturity dates are traded each day. To avoid sporadic trades, we use the first five nearby contracts for corn, and refer to them as the nearby, deferred 1, deferred 2, and so on. For live cattle futures, the first four nearby contracts are considered, and we refer to them similarly for the rest of this paper.
Corn futures contracts expire on the business day prior to the 15th calendar day of the delivery month and live cattle futures contracts expire on the last business day of each maturity month. We define a contract to be the nearby from the business day after the previous nearby contract expiration through the current nearby contract expiration. We refrain from rolling the nearby contract to the next to expire to the last possible date so we can show how price discovery share in the nearby falls off as expiration approaches.

**Empirical results**

Because the *ILS*, as well as *CS* and *JS*, is based on cointegration, we test for cointegration first. Cointegration is often achieved in the literature on studying intertemporal price relationship for the same commodity when using daily price data. However, intraday prices for nearby and deferred futures are not necessarily cointegrated. For example, intraday nearby and deferred futures prices for a storable commodity may not be cointegrated in days when the market is in backwardation and prices for different maturities are not linked by storage. For a non-storable commodity, prices for different maturities do not have arbitrage enforced linkage through storage and therefore are not necessarily cointegrated every day. Other possible reasons include market being inefficient for a short period, prices for nearby and deferred futures representing information of different crop years, etc.

We employ Johansen cointegration tests to examine cointegration relationships between the nearby and each deferred contract on a daily basis. Because prices can vary very little when the market was tranquil or if there was a price limit move, we have certain amount of days in which prices were “stale”. These days are excluded because price updates are too infrequent to enable us to do statistical tests or estimation. The days excluded from the analysis account for about 1.8% of the sample for corn. For live cattle, we have about 3% of the total trading days
excluded for the first and second contract pairs, and about 10% for the third contract pair. For corn futures, nearly all of the excluded days are in the period of 2008 through 2010 when the share of electronic trading was relatively small. We have more days excluded for live cattle than corn because it is a much less active market than the corn market. Since the days excluded from our analysis is only a small proportion of the whole sample and they are excluded because of lack of enough trading activities, this procedure does not cause selection basis of our sample.

Based on Johansen cointegration rank test results, we group our data into three categories:

1) Stationarity: intraday nearby and deferred futures prices are both stationary \( I(0) \) series, in which case we fail to reject the null of hypothesis of a rank of 2 at the 5% significance level.

2) Conintegration: intraday nearby and deferred futures prices are cointegrated \( I(1) \) series, in which case we fail to reject the null hypothesis of a rank of 1 at the 5% significance level.

3) Non-cointegration: intraday nearby and deferred futures prices are not both stationary and they are not cointegrated, in which case we fail to reject the null hypothesis of a rank of 0 at the 5% significance level.

Table 1 summarizes the percentage of days that belong to each category for each contract pair. In both markets, we fail to reject the null hypothesis that intraday nearby and deferred futures prices are both stationary in about 20% of the days. The only exception occurs in the nearby and deferred 1 contract pair for corn, where the percentage of both prices being stationary is about 27%. The percentage of the days where we reject the null hypothesis of no cointegration is about 70% across all contract pairs for both commodities, suggesting nearby and deferred futures share a common value most of the time. The percentage of non-cointegration days ranges
from 3% to 5% for corn and 7% to 13% for live cattle. Nearby and deferred futures prices are less likely to be cointegrated in the live cattle market than in the corn market, which reflects their difference in storability. The result also suggests that the percentage of non-cointegration tends to be larger between the nearby and a more distant contract. This is as expected because contracts with a larger maturity gap represent more different price information.

Figure 1 and 2 present the distribution of Johansen test results through the whole sample period for corn and live cattle, respectively. Each category of the data is represented by a unique color and the level of the square represents the volume share of the nearby contract which equals the volume of the nearby contract divided by the total volume of the nearby and deferred contracts on the same day. Shaded areas represent backwardation periods when nearby prices were above deferred prices. In both figures, we can see volume share presents a cyclic pattern, and the nearby contract’s volume share decreases as expiration approaches. An obvious pattern for corn is that nearly all of the non-cointegration days (red squares) are in backwardation periods. In contrast, figure 2 shows non-cointegration in the live cattle market does not necessarily concentrate in backwardation periods. The contradict performance is consistent with two commodities’ difference in storability.

To look more closely when the non-cointegration as well as the stationarity days occur, we present the histograms of the non-cointegration and stationarity days and arrange them by days to expiration. Figure 3 shows the histograms of the non-cointegration days. The number of non-cointegration days increases as expiration approaches and trading gets less active in the nearby contract. Figure 4 shows the histograms of the stationarity days. As we can see from figure 4, intraday nearby and deferred futures prices are less likely to be stationary in the first month for corn and first week for live cattle, in which trading is less active. The results suggest
that non-cointegration and stationarity are affected by the trading activeness. The non-cointegration relationship between nearby and deferred contract is more likely to be a result of lack of enough active trading in the nearby contract, while the prices are less likely to be stationary when the contract is actively traded.

By comparing non-cointegration days across contract pairs, we find that when non-cointegration occurs in at least one contract pair, the probability that non-cointegration also occurs in all the other contract pairs is about 20% in both markets\(^4\). This evidence provides support for restricting the price discovery analysis to a bivariate framework since prices for different maturities may share more than one common trend on a given day. Compared to cointegration, the stationarity relationship is more consistent across contract pairs as when nearby and deferred price are each stationary in at least one contract pair, the probability that all the other contract pairs present stationary relationship is 50%. By comparing non-cointegration and stationarity patterns between contract pairs, we find contract pairs with closer maturities are more often to have the same stationarity or cointegration pattern in both markets.

*Price discovery shares for the nearby contract versus deferred contracts*

Because the *ILS* is based on cointegration, we calculate the *ILS* for each of the days in which intraday transaction prices for nearby and deferred contracts were cointegrated \(I(1)\) series. For days in which intraday prices for nearby and deferred futures were both stationary \(I(0)\) series, we use the *GS* measure. Hereafter, we refer price discovery share to the combination use of *ILS* and *CS*. Because prices do not share common value when they are not cointegrated, and therefore no

\(^4\) Details for this section can be found in the online appendix.
“share” exists in such case, we exclude those days from the price discovery share analysis in the following sections.

We calculate daily price discovery shares for the nearby contract versus each deferred contract separately. For the ILS, we estimate VECMs with two different ordering and select the number of lags based on the BIC. On average, the BIC selects a VECM between 1 and 10 lags for both commodities. Following Garbade and Silber (1983), we set negative estimates of $\beta_1$ and $\beta_2$ to 0 before averaging for the GS measure, as the theoretical reason for negative values does not exist.

To begin we trace the daily price discovery share for the nearby contract versus each deferred contract, separately. We only plot price discovery shares for the nearby contract since price discovery shares of the two contracts add up to one. Figure 1 and 2 present price discovery shares for corn and live cattle, respectively. The shaded areas represent backwardation periods when deferred prices were below nearby prices. In both figures, the price discovery share presents a cyclic pattern, and the nearby contract’s price discovery decreases sharply as expiration approaches.

In Figure 1 and to a lesser extent Figure 2, the nearby contract clearly dominates price discovery when not near expiration and the price discovery share decreases as expiration approaches, which is similar to the behavior of volume share. Table 2 reports the daily averages of price discovery and volume shares for the nearby contract versus deferred contracts for corn and live cattle. In both markets, different measures of price discovery give very similar results and they are all very closely related to volume shares. Both price discovery and volume shares for deferred (the nearby) contract relative to the nearby (deferred) contract decreases (increases) as the distance of deferred contract increases, showing a clear term structure. This term structure
is expected because volume and liquidity at a longer horizon are usually worse, so that more distant futures contain less information. Similar term structure of price discovery shares is also found in the VIX futures market by Chen and Tsai (2017).

For corn futures, the nearby contract only slightly dominates the first deferred contract in price discovery with an average price discovery share of 52%. However, the nearby contract’s price discovery share rises dramatically as the maturity gap between the nearby and deferred contracts gets larger, with the average price discovery share for the nearby contract increases to 78% when it is compared to deferred 4 contract. In general, these findings are consistent with Working’s theory for storable commodities that less price discovery exists outside the nearest maturity.

In the live cattle market, on average the nearby contract does not provide more price discovery than the next nearby contract with an average price discovery of 42%, and the nearby contributes about 56% and 64% of the price discovery compared to the second and the third deferred contract, respectively. Compared to corn futures, the live cattle nearby contract has a weaker dominance in price discovery, reflecting their difference in storability. For live cattle futures, there is no storage arbitrage to link the contracts with differing maturities, and contracts for different delivery dates provide information of equilibrium conditions at different future date (Leuthold et al. 1989). We find that deferred contracts for live cattle contribute more to the price discovery process relative to the corn deferred contracts.

*Price discovery shares in the nearby period for each contract month*

To take a closer look at the behavior of price discovery share in the nearby period, we plot daily price discovery shares averaged over all years for the nearby contract relative to the next nearby
contract by maturity months. We plot the nearby contract’s volume share with the price
discovery share in order to reveal the relationship between price discovery and trading volume.
The x-axis of all plots are days to expiration (Hereafter, we refer days to expiration to trading
days to expiration). Because in the corn market the December contract becomes important early
in the year, we also compare the July contract to the December contract in the nearby period of
the July contract (panel 6, figure 3).

Figure 3 presents the shares for corn. The price discovery shares in the six panels in
Figure 3 exhibit similar patterns. The nearby contract has a price discovery share around 0.8 at
the beginning and dominates (i.e. share higher than 0.5) price discovery during most of the
nearby period, with an exception being when September is the nearby month. In general, the
price discovery share moves in tandem with the volume share and declines sharply as trading
volume decreases dramatically in the nearby contract. The nearby contract loses its dominant
role in price discovery nearly at the same time as it loses dominance in volume share. This
typically happens 2-3 weeks prior to contract expiration which roughly coincides the beginning
of the delivery window.

Panel 4 of figure 3 is notably different from the others. It depicts the shares of the
September expiration compared to the December expiration. While most contracts begin their
nearby status commanding nearly 80% ILS, the September contract only briefly breaks 50% on
average, indicating that even when it is the nearby contract it is not dominant in price discovery.
Because of the September effect, we produced in panel 6 the price discovery and volume shares
for the July versus December contract. This exhibits a pattern more typical in the other panels,
and we see that as the July contract approaches expiration, price discovery shifts rapidly to the
December contract. This finding is consistent with the notion that the September contract
matures during the transition between two crop years and its price is dominated by the new crop year prospects (Leath and Garcia, 1983). Because the December contract reflects information for the new crop year, it is not surprising to see it leads price discovery in such a long period.

Figure 4 plots the shares for the live cattle market. Both price discovery and volume share exhibit a similar general downward trend across all contract months, albeit the shares follow each other less closely in the second half of the nearby period. In general, the price discovery share decreases faster in the first half of the nearby period and relatively slowly in the second half, while the volume share decreases linearly through the whole nearby period. Although the price discovery share follows the volume share less closely in the live cattle market relative to in the corn market, the live cattle nearby contract loses its dominance almost the same time as it is no longer the most active contract. Both the dominance of price discovery and trading volume of contracts switch to the next nearby contract about 2-3 weeks after entering the nearby period, which is much earlier compared to corn futures. It may be pertinent to note that in both the case of corn and live cattle, the shift in dominance from the nearby seems to roughly coincide with the first of the contract expiration month. Though in live cattle, contract expiration occurs later in the calendar month, so the nearby loses dominance with more days to expiration than corn.

For some contract months like July and August, the price discovery share gets more volatile and can even exceed 0.5 in the last 1 or 2 weeks of the nearby period. However, on average, the nearby contracts still do not contribute more to the price discovery in these periods. The volatility of price discovery share in the last few days reflects the unstable intertemporal price relationships near the expiration point in the live cattle market that has been widely identified in the literature (e.g. Leuthold, 1979; Naik and Leuthold, 1988, Liu et al. 1994).
Table 3 reports the daily averages of price discovery and volume shares for individual contracts in their nearby periods. In general, the results are consistent with figure 7 and 8. Price discovery shares are follows volume shares more closely in the corn market than in the live cattle market. The September contract in the corn market has the lowest price discovery share as well as the smallest volume share, reflecting the seasonal production cycle of corn. In the live cattle market, price discovery shares as well as volume shares for different contract months are very close. The shares for live cattle do not present seasonality because live cattle are affected by the biological cycle which is less affected by the change of seasons.

**Determines of price discovery between nearby and deferred contracts**

In this section, we test various determines of price discovery between nearby and deferred contracts in corn and live cattle futures markets, adding statistical evidence to support some our early findings in previous sections. We also examine how price discovery reacts in different market situations. To do this, we regress nearby contract’s price discovery share \((PS)\) on volume share and days to expiration whose effects have been identified in previous sections, as well as dummy variables that capture the effects of backwardation, USDA announcements, a market crash, and prices being stationary.

The results in previous sections suggest that the nearby contract’s price discovery share drops as trading volume falls in the nearby contract and contract maturity approaches. Therefore, we introduce the two variables *Volume share* and *Expiration* that are the nearby contract’s volume share and days to expiration to the regression. Because in both markets the price discovery share does not decrease linearly in the nearby period, we also include the quadratic term of the maturity effect variable *Expiration*\(^2\).
To show the impact of backwardation on the price discovery process in the forward curve, particularly for corn which is a storable market, we create a dummy variable *Backwardation* that equals one on days in which deferred futures settlement price was below the nearby futures settlement price. For corn, we have shown in figure 1 that the breakdown in cointegration relationship between nearby and deferred prices is most likely to happen when the market is in backwardation. However, it is not clear which contract dominates price discovery when the market is in backwardation but the cointegration relationship still exists. For live cattle futures, we expected the presence of backwardation has no impact since live cattle are non-storable.

Price discovery in agricultural commodity futures markets is affected by USDA market reports that carry important information on market fundamentals. For the corn market, we consider three important USDA grain market reports: the World Agricultural Supply and Demand Estimate report (WASDE), Crop Production report and Grain Stocks report. Usually, the WASDE and Corp Production reports are released in the second week of each month. The USDA started to release the WASDE and CP reports during regular trading hours after July 2012. Before this time, these two market reports were released before market opening. Because these two reports are released on the same day, we create a single dummy variable *WASDE&CP* for the two reports. The Grain Stocks report releases quarterly and release days are usually in mid-January, and the end of March, June and September. In our sample period, Grain Stocks reports are released at 12 p.m. in the regular trading hours. Similarly, we use a dummy variable *Grainstocks* for Grain Stocks reports. For live cattle, we use the Cattle on Feed report that has the largest impact on the live cattle market among all USDA reports (Isengildina et al., 2006). During the sample period of this study, Cattle on Feed reports are released on the third Friday of
each month after day time trading session. Similarly, we create a dummy variable $CF$ for Cattle on Feed reports. The grain market reports are either released before market opening or during the regular trading session, thus we would expect to observe their impacts on the release day.

Similarly, Cattle on Feed reports are released after regular trading hours and their effects would be observed on the next trading day. Therefore, the dummy variables for the grain market reports take 1 on the exact release date and the dummy variable for Cattle on Feed reports equals 1 on the trading day following the release.

Futures prices react differently to positive and negative news. To examine the effect of a market crash, we introduce a dummy variable $Crash$ that equals to one in the market crash period. The corn market crash period is defined from July 03, 2008 when corn prices peaked, to December 08, 2008 when the prices fell to the bottom in the 2008 great recession. For live cattle, the recent 2015 collapse in cattle prices has caused concerns about the price discovery function of the live cattle futures market. Hence, we use the entire year of 2015 as the crash period for live cattle.

Because we use a combination of $GS$ and $ILS$ as our price discovery measure, it is possible that the magnitude of the price discovery share on a given day is affected by the price discovery measure applied. Thus, we introduce a dummy variable $stationary$ that takes one if the prices are both stationary and the $GS$ is used as the measure of price discovery.

By employing the variables described above, we estimate the following regression for corn:
\[ PS_{\text{corn},d} = b_0 + b_1 Volumeshare_{d} + b_2 Expiration_{d} + b_3 Expiration^2_{d} + \\
\quad b_4 Backwardation_{d} + b_5 WASDE&CP_{d} + b_6 Grainstocks_{d} + \\
\quad b_7 Crash_{d} + b_8 Stationarity_{d} + \epsilon_d, \]  
(12)

and the similar regression for live cattle:

\[ PS_{\text{livecattle},d} = b_0 + b_1 Volumeshare_{d} + b_2 Expiration_{d} + b_3 Expiration^2_{d} + \\
\quad b_4 Backwardation_{d} + b_5 CF_{d-1} + b_6 Crash_{d} + \\
\quad b_7 Stationarity_{d} + \epsilon_d, \]  
(13)

where the daily price discovery share \( PS \) for the nearby contract relative to a deferred contract is regressed on a series of contemporaneous variables on the same day \( d \), except for the \( CF \) variable which uses it one-day lagged variable in the live cattle equation. We mainly focus on the contemporaneous effects because they reflect the daily price discovery relationships that are most relevant for market participants. Table 5 and 6 report the regression results for corn and live cattle, respectively. The regression is estimated separately for each pair of contracts. Newey-West standard errors that correct for serial correlation and heteroscedasticity are reported with coefficient estimates. The lag length used for the Newey-West estimator is selected using the method described in Newey and West (1994). Model 1 includes all the determines of price discovery. Model 2 and 3 exclude volume share and days to expiration variables, respectively. Adjusted \( R \)-squared values and number of observations for each equation are reported in the lower panel in each table.

The adjusted \( R \)-squared values in the corn models are consistently higher than in the live cattle models suggesting the price discovery relationship in the live cattle market is more complicated than in the corn market. Within each market, \( R \)-squared value increase as the
maturity gap between the nearby and deferred contracts gets wider indicating the model fits better for contract pairs with closer maturities.

In general, the results suggest the model fit the data reasonably well and the coefficients have expected signs for both commodities. As anticipated, the coefficient of volume share is significantly positive across contract pairs in both markets, which is consistent with the economic intuition that a higher trading volume facilitates information processing in terms of both speed and amount. Among all the variables, volume share has the largest influence in both markets. A 1% increase in the nearby contract’s volume share increases the nearby contract’s share of price discovery by 0.6% to 0.7% relative to deferred contracts in the corn futures market, and 0.3% to 0.4% in the live cattle market, after controlling all the other effects.

The coefficients of the days to expiration variable and its quadratic term are all significant and positive in the corn futures market which is consistent with our early observations in figure 5. However, the relationship between days to expiration and price discovery share is less pronounced in the live cattle market. If controlling for the volume share effect, the days to expiration variable in the nearby and deferred 1 contract pair is significantly negative and its quadratic term has a significantly positive coefficient. The estimated coefficient of $Maturity^2$ in the live cattle nearby and deferred 1 contract pair is 0.00033 after rounded to the fifth decimal, suggesting the overall effect of days to expiration is positive only when days-to-contract maturity is roughly larger than 24\textsuperscript{5}. This evidence supports our early observation in figure 6 that the price discovery share for the live cattle nearby contract tails up in the last few weeks in nearby periods.

\textsuperscript{5} The overall effect of days to expiration based on the coefficient estimates is $-0.008\cdot\text{Expiration}_d + 0.00033\cdot\text{Expiration}^2_d$ which is greater than 0 when $\text{Expiration}$ is greater than 24.
The days to expiration effect is even weaker in the other two contract pairs and are not significant when controlling the volume share effect.

The presence of backwardation only has significantly effect on price discovery between nearby and deferred 1 contract in the corn market. Considering we have excluded days in which prices were not cointegrated, this result suggests that the corn nearby contract’s share of price discovery relative to deferred 1 contract increases about 7% relative to the first deferred contract when the prices are cointegrated in backwardation period. As expected, the coefficients of the backwardation dummy variables in the live cattle market are all insignificant reflecting the non-storability of live cattle.

We observe some significant effects of the USDA grain market reports only in contract pairs that include relatively more deferred contracts in the corn market, while Cattle on Feed reports have no significant influence on the price discovery across all contract pairs in the live cattle market. The USDA announcement effects on price discovery are less pounced than our expectations. One possible reason could be that electronic futures markets incorporate information in the reports quickly, for example 10 minutes in the corn market as shown in Leheka, Wang and Garcia (2014), so that the effects may not be fully captured when using daily observations. In the corn market, price discovery shares for the nearby contract, especially relative to more deferred contracts, tend to be lower on grain market report days. This is probably because the information provided in the releases affect more on market participants long-term business decisions, so that deferred prices impounded the information in the reports more than the nearby prices.

For corn, the coefficient of the market crash dummy is significantly positive in the third and fourth contract pairs suggesting larger proportion of information was reflected first in the
nearby contract which provided more liquidity. In contrast, the nearby contract’s contribution to
the price discovery process relative to deferred contracts decreased by 4% to 7% in the year of
2015. Considering the live cattle nearby contract loses its dominance in price discovery and
volume early in the nearby periods, it is not surprising to see its contribution decreases in a
market crash when liquidity and price discovery become more important than usual.

In both markets, the coefficients of the stationarity dummy, although can be significant in
some contract pairs, is not statistically significant in all contract pairs and economically small in
magnitude (less than 4%). Hence, the combining use of two different price discovery measures
does not cause inconsistence to our measure of price discovery.

**Discussions and conclusions**

Information content in the forward curve is important for market participants to make sound
business, investment and policy decisions. This is the first article studying where price discovery
occurs along the futures forward curve. By using price discovery share metrics, we first measure
to what extent nearby and deferred contracts contribute to the price discovery process, and when
the dominance of price discovery switches from the nearby contract to the next nearby contract
for the most traded storable and non-storable agricultural commodities, corn and live cattle.
Then, we investigate the determines of price discovery between nearby and deferred contracts.

The evidence demonstrates that the importance of the nearby contract in providing price
discovery differs in the corn and live cattle futures markets which reflects their difference in
storability. The corn futures nearby contract, although only slightly dominate the first deferred
contract, makes more contributions to price discovery than all deferred contracts, while the
nearby contract in the live cattle futures market plays a less dominate role in price discovery
relative to the corn futures nearby contract. This finding suggests futures users in corn market should give more weight to the nearby contract when making their decisions. In contrast, the reliance on the nearby live cattle contract can be misleading for live cattle futures users. The results also reveal that price discovery shares in the two markets present a similar term structure that the price discovery contribution of deferred futures contract relative to the nearby contract decrease as the contract maturity increases, which implies information is incorporated faster by more actively traded contracts in both markets. This term structure is also similar to the term structure of implied forward volatility (Egelkraut and Garcia, 2007) and Bid-Ask spread (Wang et al. 2013) in agricultural commodity futures markets.

In both markets, the relative amount of new information reflected in the nearby contract decreases as expiration approaches and trading becomes less active. In the corn futures market, the price discovery share for the nearby contract declines substantially and falls below 50% about 2-3 weeks before contract expiration, except for the September contract which barely impounds more information than the next nearby contract. For live cattle, the nearby contract no longer leads the next nearby contract in price discovery as early as 2 weeks after entering the nearby period across all contract months. Importantly, these results indicate that neither the signal day rolling strategy that is widely used in the academic literature (e.g. roll over contract on the first day of the delivery month) nor the multiple day rolling strategy that is used by commodity index funds (e.g. Goldman roll)\(^6\) picks the contract that provides the most price discovery. This finding is consistent with Taylor (2016), who finds both single day and multiple day rolling strategies exhibit considerable inefficiency in agricultural commodity futures

\(^6\) The Goldman roll refers to the rolling strategy used by the Goldman Sachs Commodity Index (S&P-GSCI), which involves rolling forward of the underlying futures contracts once each month, on the fifth through ninth business days, at a rate of 20% per day for the five days of the roll period. Similar rolling strategies are also used by other commodity indices such as the Dow Jones-UBS Commodity Index.
markets. Our results reveal a close relationship between price discovery share and trading volume. The nearby contract loses its dominance in price discovery to the next nearby contract when it is less actively traded, which may imply trading volume reflects market’s opinion on price discovery leadership of futures contract. Thus, we advocate rolling a series of nearby prices when the nearby is no longer the most actively traded contract.

The regressions provide results that are consistent with our early observations of the behavior of price discovery share. In both markets, price discovery share is most related to volume share. After controlling for the effect of trading volume, price discovery share is still positively related to days to expiration in the corn market, while this relationship is less pronounced in the live cattle market. Other factors including backwardation, USDA reports and market being in a crash period are less predominant as they do not show statistical significance across all contract pairs. The evidence also shows that price discovery shares for corn and live cattle futures respond differently to these factors which is due to their difference in storability as well as other market characters.

While our research only focuses on daily price discovery dynamics, future research could investigate intraday price discovery dynamics, especially for USDA announcement days. Such an effort would complement the work of Adjemian (2012) and Lehecka, Wang, and Garcia (2014).
References:


Irwin, Scott H. "Commodity index investment and food prices: does the “Masters Hypothesis” explain recent price spikes?" *Agricultural Economics* 44, no. s1 (2013): 29-41.

Irwin, Scott H. "Commodity index investment and food prices: does the “Masters Hypothesis” explain recent price spikes?" *Agricultural Economics* 44, no. s1 (2013): 29-41.


Table 1. Distribution of Days Based on Johansen Rank Test Results, 2008 –2015

<table>
<thead>
<tr>
<th></th>
<th>Stationarity</th>
<th>Cointegration</th>
<th>Non-cointegration</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearby and Deferred 1</td>
<td>27.86%</td>
<td>68.93%</td>
<td>3.21%</td>
<td>1960</td>
</tr>
<tr>
<td>Nearby and Deferred 2</td>
<td>23.93%</td>
<td>71.17%</td>
<td>4.90%</td>
<td>1960</td>
</tr>
<tr>
<td>Nearby and Deferred 3</td>
<td>21.38%</td>
<td>73.83%</td>
<td>4.80%</td>
<td>1960</td>
</tr>
<tr>
<td>Nearby and Deferred 4</td>
<td>22.13%</td>
<td>72.39%</td>
<td>5.48%</td>
<td>1952</td>
</tr>
<tr>
<td><strong>Live Cattle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearby and Deferred 1</td>
<td>20.87%</td>
<td>71.85%</td>
<td>7.28%</td>
<td>1950</td>
</tr>
<tr>
<td>Nearby and Deferred 2</td>
<td>19.32%</td>
<td>70.79%</td>
<td>9.89%</td>
<td>1931</td>
</tr>
<tr>
<td>Nearby and Deferred 3</td>
<td>18.63%</td>
<td>67.64%</td>
<td>13.74%</td>
<td>1820</td>
</tr>
</tbody>
</table>

Note: Results are based on Johansen rank hypothesis tests between intraday nearby and deferred futures prices at the 5% significance level using trace statistics. Percentages are given as percentage of total number of days.
Table 2. Daily Average Price Discovery and Volume Shares for the Nearby Contract, 2008–2015

<table>
<thead>
<tr>
<th>Contract Pair</th>
<th>ILS</th>
<th>GS</th>
<th>Price Discovery Share</th>
<th>Volume Share</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearby vs Deferred 1</td>
<td>0.509</td>
<td>0.554</td>
<td>0.522</td>
<td>0.532</td>
</tr>
<tr>
<td>Nearby vs Deferred 2</td>
<td>0.643</td>
<td>0.705</td>
<td>0.658</td>
<td>0.700</td>
</tr>
<tr>
<td>Nearby vs Deferred 3</td>
<td>0.728</td>
<td>0.750</td>
<td>0.733</td>
<td>0.797</td>
</tr>
<tr>
<td>Nearby vs Deferred 4</td>
<td>0.776</td>
<td>0.778</td>
<td>0.776</td>
<td>0.855</td>
</tr>
<tr>
<td><strong>Live cattle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearby vs Deferred 1</td>
<td>0.423</td>
<td>0.402</td>
<td>0.418</td>
<td>0.332</td>
</tr>
<tr>
<td>Nearby vs Deferred 2</td>
<td>0.568</td>
<td>0.543</td>
<td>0.562</td>
<td>0.504</td>
</tr>
<tr>
<td>Nearby vs Deferred 3</td>
<td>0.641</td>
<td>0.610</td>
<td>0.635</td>
<td>0.621</td>
</tr>
</tbody>
</table>

Note: Days with cointegrated I(1) intraday nearby and deferred prices are used for the ILS. Days with stationary intraday nearby and deferred prices are used for the GS. Price discovery share represents the combination of ILS and GS estimates.
Table 3. Daily Average Price Discovery and Volume Shares for Individual Contracts in Nearby Periods, 2008 –2015

<table>
<thead>
<tr>
<th>Contract Month</th>
<th>Price Discovery Share</th>
<th>Volume Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>0.592</td>
<td>0.623</td>
</tr>
<tr>
<td>May</td>
<td>0.478</td>
<td>0.477</td>
</tr>
<tr>
<td>July</td>
<td>0.582</td>
<td>0.568</td>
</tr>
<tr>
<td>September</td>
<td>0.331</td>
<td>0.293</td>
</tr>
<tr>
<td>December</td>
<td>0.583</td>
<td>0.631</td>
</tr>
<tr>
<td>Live cattle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>0.399</td>
<td>0.369</td>
</tr>
<tr>
<td>April</td>
<td>0.425</td>
<td>0.363</td>
</tr>
<tr>
<td>June</td>
<td>0.426</td>
<td>0.368</td>
</tr>
<tr>
<td>August</td>
<td>0.438</td>
<td>0.355</td>
</tr>
<tr>
<td>October</td>
<td>0.407</td>
<td>0.350</td>
</tr>
<tr>
<td>December</td>
<td>0.410</td>
<td>0.359</td>
</tr>
</tbody>
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## Table 4. Regression Results for Corn Futures

<table>
<thead>
<tr>
<th></th>
<th>Nearby and Deferred 1</th>
<th>Nearby and Deferred 2</th>
<th>Nearby and Deferred 3</th>
<th>Nearby and Deferred 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
<td>Model 1</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.030**</td>
<td>0.053***</td>
<td>0.054***</td>
<td>0.056**</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.011)</td>
<td>(0.021)</td>
<td>(0.023)</td>
</tr>
<tr>
<td>Volumeshare</td>
<td>0.733***</td>
<td>0.853***</td>
<td></td>
<td>0.615***</td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.017)</td>
<td></td>
<td>(0.040)</td>
</tr>
<tr>
<td>Expiration</td>
<td>0.006***</td>
<td>0.028***</td>
<td>0.032***</td>
<td>0.010***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Expiration²</td>
<td>0.000***</td>
<td>0.000***</td>
<td>0.000***</td>
<td>0.000***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Backwardation</td>
<td>0.069***</td>
<td>0.072***</td>
<td>0.040*</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.022)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>WASDE &amp; CP</td>
<td>-0.007</td>
<td>-0.011</td>
<td>-0.018</td>
<td>-0.026</td>
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<tr>
<td></td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.014)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>Grainstocks</td>
<td>0.000</td>
<td>-0.003</td>
<td>0.046</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>(0.035)</td>
<td>(0.033)</td>
<td>(0.044)</td>
<td>(0.041)</td>
</tr>
<tr>
<td>Crash</td>
<td>-0.015</td>
<td>-0.007</td>
<td>-0.064</td>
<td>0.048</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.021)</td>
<td>(0.062)</td>
<td>(0.031)</td>
</tr>
<tr>
<td>Stationarity</td>
<td>0.014*</td>
<td>0.014*</td>
<td>0.022**</td>
<td>0.037***</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.010)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.781</td>
<td>0.776</td>
<td>0.633</td>
<td>0.693</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>1897</td>
<td>1864</td>
<td>1866</td>
<td>1845</td>
</tr>
</tbody>
</table>

Note: This table reports regression results in which the estimated price discovery share for corn is the dependent variable for all equations. *Volumeshare* is the nearby contract’s volume share. *Expiration* is the number of days to the nearby contract’s expiration. *Backwardation* is a dummy variable equals to one if deferred futures settlement price was below nearby futures settlement price and zero otherwise. *WASDE & CP* is a dummy variable equals to one on USDA WASDE and Corp Production report days, and zero otherwise. *Grainstocks* is a dummy variable equals to one on USDA Grain Stocks report days and zero otherwise. *Crash* is a dummy variable equals to one in the period of July 03, 2008 to December 08, 2008 and zero otherwise. *Stationarity* is a dummy variable equals to one if intraday nearby and deferred prices were both stationary, and zero otherwise. Newey-West standard errors are reported in parenthesis. Asterisks ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.
Table 5. Regression Results for Live Cattle Futures

<table>
<thead>
<tr>
<th></th>
<th>Nearby and Deferred 1</th>
<th>Nearby and Deferred 2</th>
<th>Nearby and Deferred 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.295***</td>
<td>0.195**</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.018)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>Volumeshare</td>
<td>0.300***</td>
<td>0.649**</td>
<td>0.388**</td>
</tr>
<tr>
<td></td>
<td>(0.080)</td>
<td>(0.032)</td>
<td>(0.078)</td>
</tr>
<tr>
<td>Expiration</td>
<td>-0.008***</td>
<td>-0.003</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Expiration^2</td>
<td>0.000***</td>
<td>*</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Backwardation</td>
<td>-0.015</td>
<td>-0.015</td>
<td>-0.014</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.013)</td>
</tr>
<tr>
<td>CF</td>
<td>0.035</td>
<td>0.035</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.028)</td>
<td>(0.028)</td>
</tr>
<tr>
<td>Crash</td>
<td>-0.044*</td>
<td>-0.042</td>
<td>-0.048*</td>
</tr>
<tr>
<td></td>
<td>(0.025)</td>
<td>(0.033)</td>
<td>(0.025)</td>
</tr>
<tr>
<td>Stationarity</td>
<td>-0.024**</td>
<td>0.026**</td>
<td>0.024**</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.011)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.294</td>
<td>0.249</td>
<td>0.288</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>1808</td>
<td>1740</td>
<td>1570</td>
</tr>
</tbody>
</table>

Note: This table reports regression results in which the estimated price discovery share for live cattle is the dependent variable for all equations. 

Volumeshare is the nearby contract’s volume share. Expiration is the number of days to the nearby contract’s expiration. Backwardation is a dummy variable equals to one if deferred futures settlement price was below nearby futures settlement price and zero otherwise. CF is a dummy variable equals to one on the trading day following the release of Cattle on Feed report. Crash is a dummy variable equals to one in the year of 2015. Stationarity is a dummy variable equals to one if intraday nearby and deferred prices were both stationary, and zero otherwise. Newey-West standard errors are reported in parenthesis. Asterisks ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.
Figure 1. Volume shares and Johansen rank test results for corn futures, 2008-2015

Note: Shaded areas represent backwardation periods. Corn futures contracts expire on the business day prior to the 15th calendar day of the maturity month.
Figure 2. Volume shares and Johansen rank test results for live cattle futures, 2008-2015

Note: Shaded areas represent backwardation periods. Live cattle futures contracts expire on the last business day of the maturity month.
Figure 3. Histograms of days when intraday nearby and deferred futures prices were not cointegrated

Note: Histograms for corn and live cattle are in the left and right panels, respectively.
Figure 4. Histograms of days when intraday nearby and deferred futures prices were both stationary

Note: Histograms for corn and live cattle are in the left and right panels, respectively.
Figure 5. Price discovery shares for the nearby contract compared to deferred 1, 2, 3, and 4 contracts in the corn futures market, 2008-2015

Note: Shaded areas represent backwardation periods. Corn futures contracts expire on the business day prior to the 15th calendar day of the maturity month.
Figure 6. Price discovery shares for the nearby contract compared to deferred 1, 2, and 3 contracts in the live cattle futures market, 2008-2015

Note: Shaded areas represent backwardation periods. Live cattle futures contracts expire on the last business day of the maturity month.
Figure 7. Price discovery and volume shares in the nearby period for each contract month in the corn futures market
Figure 8. Price discovery and volume shares in the nearby period for each contract month in the live cattle futures market.