The Impact of Futures Contract Storage Rate Policy on Convergence Expectations in Domestic Commodity Markets

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Abstract

Grain futures contracts that permit physical delivery do so through an exchange of delivery instruments. Because delivery instruments can be held indefinitely, extant research shows that futures contracts that assign inflexible and low storage rates relative to the market price of storage facilitate basis nonconvergence. In response to the notable episode of non-convergence in the mid- to late-2000s, the Chicago Mercantile Exchange (CME) introduced variable storage rate (VSR) policies in the soft red winter (SRW) wheat and hard red winter wheat markets. The VSR mechanism functions by adjusting the storage rate to the price spread between sequential futures contract deliveries in the period right before the expiration of the nearby contract. In contrast, CME did not introduce a VSR to corn and soybean markets but chose to increase their fixed storage fees in 2008 and later in 2020. We study convergence performance for each of these markets from 2006-2020 and use time series techniques to show that flexible storage fee policies like the VSR reduce the magnitude and therefore the expected duration of nonconvergence in wheat markets. On the other hand, we do not find evidence that CME's higher fixed storage rates likewise reduce the expected duration of nonconvergence episodes in corn and soybeans markets—although perhaps not enough time has passed to evaluate the effectiveness of the most recent changes—or that index trader activity causes basis nonconvergence.

Key words: Basis, commodity futures, convergence, grain, storage.

JEL codes: G13, G14, Q11, Q13, Q14, Q18.

Introduction

One of the most important functions of futures markets for storable commodities is the transmission of storage signals, generally represented by the difference between the prices for sequential contract deliveries (Working 1949). These prices of storage guide consumption and production plans of market participants. However, during the mid- to late-2000s, the cash and futures prices for U.S. corn, soybeans, and wheat markets failed to converge, or equilibrate, at contract expiration—disconnecting the cash and futures markets and undermining the storage signal function. At the time, expiring futures prices exceeded cash grain price by up to 35% (Garcia, Irwin, and Smith 2015). Observers advanced several theories to explain nonconvergence, including that financial investment-induced price pressure causes limits to delivery arbitrage (USS/PSI 2009) investment behavior of a relatively new class of large traders referred to as index traders (who operate by entering and holding long positions in commodity futures contracts) raises the risk premium in the market and biases the futures prices away from cash prices (Acharya et al. 2013; Guilleminot et al. 2014; Mayer 2012). Adjemian et al. (2013) argued, and Garcia, Irwin, and Smith (2015) theorized that convergence failures were instead due to inflexible exchange-set storage rates on the delivery instruments. Plentiful inventories raise the demand of storage, and therefore the market price of storage if the supply of storage has positive elasticity. When the storage-rate is set too low relative to this market price of storage, then the "wedge" between them can widen the delivery period basis and lead to significant nonconvergence.

As a result, the Chicago Mercantile Exchange (CME) first introduced a seasonal storage rate (SSR) in soft red winter (SRW) wheat and hard red winter (HRW) wheat markets in 2009 and 2011, respectively. Subsequently, it introduced a variable storage rate (VSR) to the SRW wheat and HRW wheat markets in 2010 and 2018, respectively. The VSR revises the storage rate on delivery instruments in response to changes in the spread between the prices for sequential contract expiries, as a way to manage the wedge. In contrast, CME did not introduce a VSR to the corn and soybean markets but chose to increase the fixed storage fees for those contract markets in 2008 and later in 2020.

Still, the debate over the impact of commodity index traders on convergence continues: van Huellen (2018) introduces a model that explains the scale of nonconvergence by augmenting the mismatched storage rate theory with a price pressure component. She argues that during periods with a positive wedge index traders disconnect futures and cash prices by bidding the price of futures higher relative to cash, and fits her model to the data using both standard linear and regime-switching specifications.[1] On the other hand, Garcia, Irwin, and Smith (2015) assert that the scale of nonconvergence can be explained by a rational expectations model: the difference between the price of expiring futures and cash prices represents the amount of time the market expects the wedge to persist. We test empirically for the suitability of both theories in explaining observed expiring basis levels in four major domestic commodity markets, and exploit the fact that CME applied different storage fee regimes in different markets to study their effectiveness.

To test the relevance of each model, we use cash price bids from the United States Department of Agriculture's (USDA) Agricultural Marketing Service (AMS), trader positions' data from Commodity Futures Trading Commission's (CFTC) Commodity Index Traders (CIT) supplemental reports, and CME futures price data for wheat, corn, and soybeans from 2006-2020 and specify the expiring basis in each market as a function of the wedge and the change in trader positions (when either (1) their total number of contracts, or (2) their long minus short positions are represented as a percentage of open interest—the total number of outstanding futures contracts). We find no evidence to support van Huellen's price-pressure theory with respect to nonconvergence: changes in different sorts of trader positions do not explain variation in the basis.[2] Instead, as predicted by Garcia, Irwin, and Smith (2015) the wedge is highly significant and explains a large fraction of the observed variation in the basis for all the commodities. We also find that the relationship between the basis and the wedge changed when CME introduced the VSR to the SRW and HRW wheat markets; but no similar change is observed for CME's increase of the fixed storage rate in corn market. Even with CME's increase in the fixed storage rate in soybeans in 2008, a heightened impact of the wedge on the basis is observed 2009 onwards. This, in turn, underscores how an increase in the fixed storage rate fails to reduce nonconvergence in corn and soybeans markets. Because we find no evidence for van Huellen's price pressure theory, we interpret this change in the basis/wedge relationship as a revision in the market-expected duration of non-convergence. Modeling the wedge as a coupon on a bond, we recover the market's

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[1] Van Huellen's (2018) model presumes the existence of a significant risk premium in agricultural commodity futures. However, the empirical evidence for such a premium is at best mixed (Chang 1985; Fishe and Smith 2011; Frank and Garcia 2009).

[2] As we explain in the data and methodology section below, we suspect that some of van Huellen's (2018) original results may be spurious. That paper discloses that 11 out of 12 of commercial and index trader position levels are non-stationary (table A2). However, the paper attempts to address this by using heteroscedasticity and autocorrelation consistent standard errors for variables in the levels. When we transform the original data to ensure stationarity, we are unable to replicate the statistically significant effect of index trader positions on the basis.

expectation of non-convergence duration. We demonstrate that, in each of the wheat markets where it was introduced, CME's VSR implementation almost immediately reduced the expected duration of nonconvergence relative to its expectation during the previous storage-rate regime(s). On the other hand, CME's changes to fixed rates in corn and soybeans did not likewise reduce the expected duration of nonconvergence durations in those markets.

Related Literature

Convergence of futures prices to cash prices at contract expiration is central to the functionality of futures markets. The basis, or the difference between futures and cash prices, narrows as a futures contract nears maturity. At expiration the futures contract price and the cash price should equilibrate (Paul 1986; Thompson, Eales, and Hauser 1990). This predictability of basis patterns is central to hedging decisions of a range of market participants such as producers, processors, and merchants, who use futures markets as risk management tools. Hieronymous (1963) states that futures markets offer agricultural entities the opportunity to operate at near-guaranteed prices, but this remains the case only in a world where the basis converges. Unpredictable convergence threatens the traditional price discovery and risk management roles of futures markets. The decoupling of futures and cash prices impairs the transmission of storage signals via the term spread as basis ceases to represent the supply-demand determined market price of storage space.

The extant literature considers two general views for the causes of nonconvergence: flaws in delivery market design, and the price pressure effects of index trader activity. The former attributes nonconvergence at delivery locations to the institutional structure of the delivery market (Adjemian et al. 2013; Garcia, Irwin, and Smith 2015), including concerns about the possibility of structural imbalances in the ability of markets to arbitrage futures and cash discrepancies, given a declining number of commercial flows through delivery locations (Irwin 2018). On the other hand, others attribute nonconvergence to excessive speculation by index traders. CITs enter into long positions in futures contracts in order to gain passive exposure to commodity price movements. About 85% of index related positions in agricultural futures markets are held by swap dealers (Sanders, Irwin, and Merrin 2010). Because futures contracts have a defined life, to maintain their commodity exposure over time CITs offset their position in expiring contracts and open new positions in later-expiring contracts, a behavior known as "rolling over". According to the proponents of this theory, CIT rolling behavior puts pressure on futures prices, biasing grain futures away from cash prices (U.S. Senate 2009) and constituting "excessive speculation". These two opposite views are at the center of conceptualizing and formalizing the properties of nonconverging grain markets. Most recently, van Huellen (2018) attempts to reconcile both the viewpoints. We review these perspectives, below.

Grain futures contracts that can be satisfied by physical delivery, including all the contract markets we consider in this article, do not terminate in actual physical transfer of the commodity. Rather, for even the small fraction of contracts that reach the delivery process,[3] traders satisfy those requirements using a delivery instrument, either a warehouse receipt or shipping certificate depending on the commodity in question. The warehouse receipt is a legal document stipulating the ownership of actual physical grain in an exchange-approved warehouse, whereas a shipping certificate is a negotiable instrument issued by an exchange-approved delivery facility and represents a commitment by the facility to deliver the underlying commodity to the certificate's

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[3] Traders offset the vast majority of agricultural futures contracts prior to the delivery period by taking the opposite position (Hieronymus 1977).

holder upon request (*Source:* CME). Both kinds of delivery instruments are transferrable and can be held indefinitely as long as the holder pays a storage fee, i.e., the cost of holding the instrument. The maximum fee for holding an instrument is set by the exchange. These delivery instruments offer the crucial link between the delivery process and actual physical grain storage at terminal elevators (in the case of warehouse receipts), or the flow of grain through the marketing channels (in the case of shipping certificates) (Irwin 2018). The firms involved, referred to as "regular", are located inside a specified delivery territory and allowed by the exchange to issue warehouse receipts and shipping certificates. Regular firms satisfy the short side of expiring futures contracts by making delivery, whereas the financial firms may settle the long side of an expiring futures contract by paying the futures price for immediate delivery and accepting the delivery instrument (Adjemian et al. 2013). In case the financial firm decides to hold the delivery instrument indefinitely, it must pay the exchange-set storage fee to the regular firm. The delivery market design perspective is concerned with interaction between these two types firms under different market conditions given the exchange-set storage fee.

Garcia, Irwin, and Smith (2015) formalize a rational expectations commodity storage model to explain the occurrence, persistence, and magnitude of nonconvergence. In a normal functioning market, the futures term spread—the difference in price of futures contracts with sequential expirations—is expected to reflect the price of storage, or the return to physically storing grain (Working 1949). During a good harvest year, plentiful inventories drive up the demand for, and therefore the market price of, storage. If the exchange-set storage fee is too low, the market price of storage can exceed it. When this difference (called the "wedge") is positive, holding delivery instruments is cheaper than storing grain physically, incentivizing financial firms to hold them. As a result, the term spread, capped by the low storage fee, can understate the expected price of storage following a good harvest. Because both delivery instruments and cash grain represent the same amount of future grain, and their storage prices differ, their present values disconnect leading to a positive basis at futures contract termination. Even a relatively small wedge can generate a large nonconvergence if it is expected to persist for a long period of time (Adjemian et al., 2013; Garcia, Irwin, and Smith, 2015).

Those studying delivery market design have also focused on declining activity at delivery locations. In the past, the declining commercial importance of delivery territory markets at Chicago and Toledo was attributed to the decline in the relative production of corn, soybeans, and wheat in adjoining states (Peck and Williams 1991). In 2000, the exchange replaced Toledo as a delivery location with the Illinois Waterway Delivery system for the corn and soybean futures contracts in view of the growing representativeness of Illinois locations as cash grain trade centers. In 2008, CME added new delivery points (in Northwest Ohio, the Ohio River, and the Mississippi River) for SRW wheat contracts in wake of the poor convergence performance, although nonconvergence for that contract remained notable even after the change. Irwin (2018) points out the changes to wheat production patterns, transportation logistics, and trade flows as the possible underlying causes for the low representativeness of delivery locations as commercial hubs. This underscores the point made by Peck and Williams (1991) that the addition of primary markets as alternative delivery locations can only ensure short-run support but cannot really solve the longer-run issues caused by declining cash markets everywhere. Waning commercial importance of such delivery points can further impact the price relationships between the delivery point markets and the non-delivery markets. Such unpredictable price relationships can heighten basis-risk for hedgers even in non-delivery locations (Irwin 2018; Pirrong et al., 1993). Given that hedging effectiveness of futures contracts is closely related to predictable basis patterns, during such bouts of nonconvergence, the traditional role of futures as a risk-management tool is threatened for both hedgers near delivery locations and at non-delivery locations.

Another section of the literature, termed the index trader pressure hypothesis, is inspired by Keynes' (1930) classic theory of normal backwardation and emphasizes the role of different trader types in altering the risk-premium component of prices in grain commodity markets. Keynes (1930) argues that hedgers compensate speculators for taking on their risks through futures market transactions. Hedgers take the short side of futures contracts at a price below the expected spot price, in order to draw long speculators into the market. The result is that hedgers lock in a price (and lay off their risk) using futures, while speculators realize a profitable price rise, on average. Masters (2011) suggests that excessive speculation can bias futures prices away from the levels determined by supply and demand fundamentals. The United States Senate Permanent Subcommittee on Investigations (USS/PSI, 2009) likewise identified excessive speculation arising from index trader activity as the possible cause of nonconvergence. It is true that the nonconvergence episode of 2005-2010 coincided with the advent of large but passive order flows from commodity index traders, who sought exposure to commodity price changes but had no underlying commercial interest in grain markets. According to this hypothesis, the tendency of the commodity index traders to purchase long positions in futures markets increases the demand for long futures contracts. Without any increase in the demand for the underlying physical commodity, this speculative activity might lead to widening of futures term spreads thereby incentivizing grain hoarding by commodity holders (for greater profits as the bubble inflates) rather than facilitating convergence through arbitrage. The bubble-induced theory views index trader rolling behavior as responsible for decoupling cash and futures, and generating nonconvergence.

In the past, studies have failed to find empirical support for a causal link between commodity index trading and the rise in futures prices (Buyuksahin and Harris 2011; Irwin and Sanders 2011). Irwin et al. (2011) do not find statistically significant evidence for increase in term spreads during the period when the index traders roll their positions. Adjemian et al. (2013) raise questions over this argument as they emphasize that the hoarding of the commodity by grain elevators should, in turn, raise cash prices, while the tendency of index traders to roll positions should reduce the expiring futures price; together, these behaviors would facilitate convergence.

Van Huellen (2018) attempts to reconcile the delivery market design and index trader pressure theories in an attempt to explain the scale nonconvergence observed from 2005-2010. Her price pressure-augmented storage model reconceptualizes the basis at maturity as the effect of both the wedge and the discounted risk premium, where the latter is defined by both the hedging and index pressure prevalent in the market. This approach contradicts the work of Garcia, Irwin, and Smith (2015), who predict that the scale of nonconvergence depends on the size of a wedge and the duration the market expects it to persist.

Basis, the wedge, the VSR, and the index pressure

Garcia, Irwin, and Smith (2015) introduce a rational expectations storage model where a representative agent in the storage industry behaves competitively, is risk neutral, and faces cash market net demand:

(1) $P_t = f(s_{t-1} - s_t, \epsilon_t)$

where P_t is the cash/spot price for a commodity. The firm enters period t with an endowment of s_{t-1} units of the commodity and chooses to store s_t for possible sale in the next period. The firm chooses the amount $s_{t-1} - s_t$ to sell in the current period, while ϵ_t is the net demand shock which is stationary and ergodic.

Convenience yield, denoted by $y(s_t)$, when combined with the warehousing cost δ_t, gives the market price of storage in the model as $\delta_t - y(s_t)$. Garcia, Irwin, and Smith (2015) following Williams and Wright (1991), Kaldor (1939), and Working (1948, 1949), specify total cost of storing an amount s_t for a competitive storer as:

(2) $K[s_t] = \delta_t - y(s_t)$

The central condition for a competitive equilibrium with storage requires:

$$(3)\ P_t = \frac{E_t[P_{t+1}]}{1+r_t} - K[s_t] \quad if\ s_t > 0$$

$$= \frac{E_t[P_{t+1}]}{1+r_t} - \delta_t + y(s_t) \quad if\ s_t > 0$$

where r_t is the cost of capital.

The delivery process requires that each expiring futures contract be converted into a delivery instrument. These delivery instruments provide the holder with access to grain and do not require load-out within a specified timeframe if the holder pays a storage fee (Adjemian et al. 2013).[4] The holder of the instrument decides to either convert it into cash grain or hold on to it depending upon the profitability of either alternative. In case she decides to hold the delivery instrument, then according to Garcia, Irwin, and Smith (2015) its present value equals the discounted expected value of the delivery instrument in the next period minus the exogenous storage fee denoted by γ_t. In another scenario, if the agent converts the instrument to grain, then its present value equals the cash grain price, P_t. Therefore, the expiring futures price is:

$$(4)\ F_{t,t} = \max\left(\frac{E_t[F_{t+1,t+1}]}{1+r_t} - \gamma_t, P_t\right)$$

Nonconvergence occurs when $\gamma_t < \delta_t - y(s_t)$. This nonconvergence is captured in the expiring basis, B_t as follows:

$$\begin{aligned}(5)\ B_t &\equiv F_{t,t} - P_t \\ &= \max\left(0, \frac{E_t[F_{t+1,t+1}]}{1+r_t} - P_t\right) \\ &= \max\left(0, \frac{E_t[F_{t+1,t+1}]}{1+r_t} - \gamma_t - \frac{E_t[P_{t+1}]}{1+r_t} + \delta_t - y(s_t)\right) \\ &= \max\left(0, \frac{E_t[F_{t+1,t+1}] - E_t[P_{t+1}]}{1+r_t} + \delta_t - y(s_t) - \gamma_t\right) \\ &= \max\left(0, \frac{E_t[B_{t+1}]}{1+r_t} + W_t\right)\end{aligned}$$

where the wedge, $W_t = \delta_t - y(s_t) - \gamma_t$.

Equation (5) confirms that the basis in period t depends upon the expected basis in the next period $t+1$, plus the wedge in period t. The basis in period $t+1$, in turn, depends upon the basis in the period $t+2$ (plus the wedge in the period $t+1$), and so on. Hence, the basis in a period is the

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[4] The maximum allowable storage fee on a delivery instrument is set by the futures exchange.

expected present discounted value of future wedges for as long as they are expected to persist. Therefore, a relatively small wedge term in period t can have a large impact on the basis in that period given that it is expected to last for an extended period. Garcia, Irwin, and Smith (2015) assume that positive wedges continue until the next harvest. This assumption emphasizes the temporary nature of supply shocks such as e.g., good harvests, as shocks can cause inventories to rise (and the convenience yield to fall) sharply and then draw down over time. Since basis equals the present value of future wedges, it is expected to decline steadily as the harvest (and the prospect of a short one) approaches, since there are fewer wedges to earn as inventories are depleted over each successive contract expiry.

As shown in Garcia, Irwin, and Smith (2015), the term spread, Z_t , is intimately related to the basis as shown below:[5]

$$\begin{aligned}(6)\ Z_t &\equiv \frac{F_{t,t+1}}{1+r_t} + F_{t,t} - \gamma_t \\ &= \min\left(0, \frac{E_t[F_{t+1,t+1}]}{1+r_t} - P_t - \gamma_t\right) \\ &= \min\left(0, \frac{E_t[B_{t+1}]}{1+r_t} + W_t\right) \le 0\end{aligned}$$

Equation (6) shows that the term spread is capped by the storage rate, γ_t . Therefore, if $\frac{E_t[B_{t+1}]}{1+r_t} + W_t > 0$, the futures market is at full carry ($Z_t = 0$). Under such a scenario the term spread ceases to reflect the actual market price of storage. Nonconvergence implies that the term spread understates the price of storage, as the basis widens.

The role of VSR mechanism is to trigger higher storage rates by widening the term spreads when the spreads are near full carry due to high inventories. This way, the term spread begins to track the market price of storage. Therefore, VSR reduces the magnitude of the wedge and fosters convergence.

With the intention of offering an alternative explanation for the magnitude of nonconvergence, van Huellen (2018) augments the commodity storage model above with a price-pressure component. She incorporates a risk premium, ρ_t, a consequence of index pressure and hedging pressure. In van Huellen's model, which is motivated by Keynes' (1930) theory of normal backwardation, index trader activity can raise the risk premium by making large liquidity demands on commercial traders (commonly referred to as "hedgers"), raising the futures price.[6] In this framework, the futures price is a biased estimate of the future cash price:

$$(7)\ F_{t,t+1} = E_t[S_{t+1}] + \rho_t$$

Given the prevalence of this risk-premium in the market, equations (5) and (6) now contain a price bubble component (instead of the expected basis component) as shown below:

$$(8)\ B_t = \max\left(0, \frac{\rho_t}{1+r_t} + W_t\right)$$

$$(9)\ Z_t = \min\left(0, \frac{\rho_t}{1+r_t} + W_t\right) \le 0$$

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[5] Using the equilibrium condition $F_{t,t+1} = E_t[F_{t+1,t+1}]$.

[6] This effect works in the opposite direction to the one discussed by Keynes, however, since it is long speculators that must offer a higher futures (than expected cash) price to attract short hedgers into the market.

Equation (8) implies that the current basis is a function of both the discounted risk premium and the current wedge. Van Huellen (2018) uses linear regressions to test for constant index trader effects, and Markov-switching specifications to determine the impact of trader pressure during nonconvergence regimes, with the idea that the risk premium is more easily observable when the market is not converging. However, van Huellen's model implicitly relaxes Garcia, Irwin, and Smith's (2015) transversality condition, which along with the stationary equilibrium in equation (3) ensure that convergence is guaranteed in future. On the other hand, van Huellen's equation (8) includes a bubble component in the basis, so nonconvergence should increase over time rather decrease steadily as predicted by Garcia, Irwin, and Smith (2015).[7] In addition, the equations (8) and (9) imply that the introduction of a mechanism like VSR can only be partially effective since it corrects the current wedge, while the risk premium continues to raise the futures price.

In our study, we explore if—in addition to the wedge—financial investment by index (or other sorts of) traders help explain basis variations in the corn, soybean, SRW wheat, and HRW wheat markets, and whether these effects differ at all during nonconvergence regimes. We then compare the effectiveness of flexible storage rate mechanisms such as the SSR or VSR in the wheat markets to inflexible, fixed storage fee policies in corn and soybean markets over the period 2006-2020.

Data and methodology

We focus on the CME markets for corn, soybeans, SRW wheat, and HRW wheat from 2006 to 2020. We source futures prices from Bloomberg, and cash prices from the United States Department of Agriculture's Agricultural Marketing Service (AMS). In the literature, basis is calculated both as futures minus cash price and the reverse. Without loss of generality we follow Garcia, Irwin, and Smith (2015) and choose the former method. To calculate the expiring basis in each market, we use the cheapest-to-deliver location in each market after adjusting all AMS cash prices for delivery location and grade differentials found in CME's futures contract rulebooks. Following Irwin (2018), we calculate the basis at maturity by averaging over the first five days of the delivery month for each futures contract, and calculate the wedge as the difference between the market price of storage and the storage fee set by the futures exchange, where the market price of storage is the sum of the current futures term spread and the change in the basis (i.e., the current basis in the delivery period minus the basis in the next delivery period). We likewise apply a centered three-contract moving average to the basis time series to filter out delivery period noise.

The Commodity Futures Trading Commission's (CFTC) weekly Commodity Index Traders (CIT) supplement futures and delta-adjusted options positions reports indicate the number of end-of-Tuesday open positions by trader type (commercial, noncommercial, and index) and direction (long, short, and spreading) in each market.[8,9] Following van Huellen (2018), we use the CIT to

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[7] The omission of this condition in the price-pressure augmented storage model aligns it with models that describe the explosive nature of rational bubbles (e.g., Diba and Grossman 1988).

[8] By applying delta – a measure of the rise or fall in option premium due to variations in the price of the underlying asset – the options positions are converted into equivalent futures positions.

[9] We do not use spreading positions in calculation of our two types of trader pressure indicators as these spreading positions represent equal number of combined-long and combined-short positions held by a noncommercial trader.

calculate, by trader type, both the (1) net long positions (total long minus total short) as percentage of total open interest, and (2) the trader weights, calculated as the percentage share of trader types—commercial, noncommercial, and index—of total open interest, as an alternative indicator of trader pressure. We source historical storage fees in each market from CME.

Table 1 shows the summary statistics for corn, soybeans, SRW wheat, and HRW wheat. The average basis and wedge levels are highest for SRW wheat (46.11 cents/bushel and 12.04 cents/bushel/month), while they are lowest for corn (18.65 cents/bushel and 2.63 cents/bushel/month). The average wedge levels seem to be similar in case of soybeans (4.40 cents/bushel/month) and the HRW wheat markets (4.60 cents/bushel/month), but the average basis levels in the HRW wheat market (34.92 cents/bushel) are much higher than that in the soybean market (21.52 cents/bushel). Unsurprisingly, across commodities commercials are strongly net short, while noncommercials (except for SRW wheat where they are net short over the sample period) and index traders are net long. Index traders are strongly net long in all markets observed.

Our objective is to ascertain to what extent the wedge and the trader positions explain basis variations over the period of 2006-2020. Table A1 displays the results for a series of tests (with and without possible unknown structural breaks) to check for the stationarity of our basis, wedge, and trader positions' data. For every market, our tests mostly reject the presence of unit root in both the basis and wedge, while they generally fail to reject the presence of a unit root at commonly-accepted significance levels in both the weights and net long positions for index traders; this is the case for several other trader classes, too. Therefore, for consistency and following best practices we use first-differenced trader positions in all our analyses. Table A2 shows the results of similar tests on van Huellen's (2018) original trader positions dataset; they likewise generally fail to reject the presence of a unit root in her index trader (and several other trader class) positions data. We therefore replicate her original results using first-differenced trader positions, and describe the results of that effort below.

Based on equations (5) and (8), we estimate the following regression equation:

$$(10) \qquad y_{i,t} = \beta_0 + \beta_1 x_{i,t} + \beta_2 z_{i,t} + \varepsilon_{i,t}$$

where $y_{i,t}$ is the expiring basis for commodity i at time t, $x_{i,t}$ is the wedge and the vector $z_{i,t}$ includes the first-differenced proxies for traders' net long positions as a percent of open interest (or, alternatively, trader weights). According to equation (5), if they are effective in reducing the expected duration of non-convergence, CME storage fee policy changes should be observable a structural break in β_1, the relationship between the basis and the wedge. In case we find evidence for structural breaks in the regression for a commodity market, we run separate regressions for the time periods identified by the breakpoints. The sign and significance of the vector of coefficients β_2 indicates whether trader pressure likewise affects the expiring basis. We use Newey and West (1987) heteroscedasticity and autocorrelation consistent (HAC) standard errors for proper statistical inference. The results for the regression equation (10) are available in tables 2-5. For robustness check, we estimate equation (10) using trader weights as alternative indicator of trader pressure, and report those results in tables A3-A6. As we describe in the previous section, van Huellen (2018) provides two sets of empirical results. Her linear results correspond to our equation (10); her regime-switching specifications further estimate the relationship between the basis at

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Therefore, they are a means to reduce risk for a trader by offsetting losses in one position by gains in another. They are unlikely to represent the speculative-pressure component associated with noncommercial traders.

maturity and trader positions when the market isn't converging. In line with her regime-switching approach, we also conduct Markov-switching dynamic regression (MSDR) as shown in equation (11). MSDR models allow the parameters to vary across the unobserved regimes. Following van Huellen (2018), in our MSDR model the wedge is assumed to stay identical across the two regimes (convergence and nonconvergence), denoted by s, while the intercept μ_s and the first-differenced trader net long positions in vector $z_{i,t}$ vary across the two regimes. We also relax the assumption of constant variances over the two regimes, and $\epsilon_{s,i,t}$ is an independently and identically distributed normal error term with mean zero and state dependent variances, σ_s^2.

(11) $$y_{i,t} = \mu_s + \alpha x_{i,t} + \beta_s z_{i,t} + \epsilon_{s,i,t}$$

The results for MSDR are available in table 6. For robustness, we also estimate equation (11) using trader weights instead of net long positions as an alternative indicator of trader pressure, and report those results in table A7.

Calculation of the expected duration of nonconvergence

If the basis is just the present value sum of current and future wedges for as long as they are expected to persist, as explained by equation (5), then we can exploit that relationship to identify the market's implied expected duration of the average nonconvergence during each storage fee policy regime. Assuming that warehousing costs and convenience yield are constant (at least over each nonconvergence period), then the relationship between the basis and the wedge can be represented as a constant-coupon bond valuation, and the average expected duration (i.e., the approximate number of contract deliveries) for which nonconvergence is expected to persist is given by:

(12) $$E[\text{duration}] = -\ln(1-(r/(1+r)) * x_t) / (\ln(1+r))$$

where x_t is the coefficient on the wedge in equation (10), and r is average the market interest rate over the regime.[10] Consequently, breaks in x_t indicate changes in the market's expectation of nonconvergence duration, and become significant in a policy sense if they line up with CME storage fee policy changes. The calculations of the expected duration of nonconvergence are available in table 7.

Results

Figures 1-4 show graphically the behavior of the basis, the wedge, and index trader net long positions (as percentage of open interest) over the sample period. The shaded areas in the figures represent different storage fee regimes. For corn and soybeans in figures 1 and 2, respectively, basis levels exhibit notable, periodic rises that tend to occur alongside wedges. For example, a wedge appears just as the soybean basis widens significantly after China imposed a 25% additional tariff on soybean exports in response to 2018 U.S. tariff actions, leading to that commodity's largest ever domestic storage levels (Adjemian et al. 2019). But index trader net long positions do not track basis changes as closely. Notice how, although basis levels trend upwards for both commodities from 2013-2020, index trader levels trend downwards for corn, and are relatively flat in the case of soybeans. Another important observation for both commodities is that the basis tends to spike and then fall gradually. This is in line with Garcia, Irwin, and Smith's (2015) prediction,

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[10] Like CME (2017) and Garcia, Irwin, and Smith (2015), we use the U.S. dollar London Interbank Offered Rate plus 2%.

since they define a nonconverging basis as the present value of the sum of the current and expected wedges. In contrast, van Huellen (2018) conceives of a nonconvergence as the sum of the current wedge and the risk premium; it should therefore decline with both the wedge *and* index trader pressure. However, the latter effect is not at all evident. For example, the soybean wedge and basis spike in 2011, and the basis falls very quickly even as the wedge declines but index trader net longs positions rise. This is far from an isolated case. Finally, it is not obvious that the relationship between the basis and the wedge changes very much as the storage fee regimes change for corn and soybeans.

For the two wheat markets in figures 3 and 4, the same general effects as in figures 1 and 2 are observed: basis spikes tend to coincide with a wedge and draw down gradually, and index trader positions do not track well against basis variation. But the most striking thing about figures 3 and 4 is that the relationship between the basis and the wedge changes almost immediately after the VSR is instituted in each market—the basis follows the wedge much more closely. This graphical result foreshadows that the VSR facilitates a potential reduction in the market's expected duration of nonconvergence. This result is evident even as index trader positions routinely rise as the expiring basis draws down (and wedge is eliminated), undermining van Huellen's (2018) theorized role of index pressure as a nonconvergence determinant.

Tables 2 to 5 show the regression results for our equation (10) for corn and soybeans, SRW wheat, and HRW wheat, respectively. Across commodity markets, our base regressions produce virtually no evidence that the change in trader positions affects the expiring basis. On the other hand, the wedge is consistently and positively related to the basis level across structural breaks (in the wedge-basis relationship).[11] In addition, as the sole significant variable after the constant the wedge helps to explain a large degree of the basis movements in each table, ranging from 24% in the case of corn up to over 50% in the case of soybeans and HRW wheat. Although we do not find evidence of breaks in the relationship between the basis and the wedge in corn (so conduct a single regression in table 2), we do report one in the soybean market in January 2009, timing with CME's increase in that futures contract's fixed storage fee in later half of 2008 (so report the results of two regressions in table 3). However, the magnitude of the relationship between the wedge and the basis *increases* after the break indicating that the policy did not meaningfully reduce the market's expectation of a nonconvergence duration.

Both wheat markets exhibit structural breaks in the wedge-basis relationship. We estimate a single break in the SRW wheat market, so conduct separate regressions for the two subperiods identified by the break on May 2010—near the time when CME introduced a VSR. Following the break, the wedge coefficient in table 4 falls by about half, from 1.32 to 0.75. In the HRW wheat market, we identify two structural breaks (March 2011 and December 2017), which coincide with changes in CME storage rate mechanisms (namely, the SSR and VSR, respectively).[12] Our regression results show that the point estimate of the wedge coefficient shrinks with each successive storage fee regime change. We find similar results for all our commodities with the alternative trader position variable (appendix tables A3 to A6).

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[11] We conduct Supremum Wald tests to identify breaks in linear regressions for corn, soybeans, and SRW wheat. Results for the tests are available from the author upon request.

[12] Simultaneous estimation of multiple breaks is conducted using Bai and Perron's (2003) algorithm for the HRW wheat market. Results are available from the author upon request.

We enhance our table 2-5 regressions by applying a similar Markov-switching approach to van Huellen's (2018) and report those results in table 6 (appendix table A7 provides results of similar specifications but using alternative trader position data). In no market do these enhanced regressions produce empirical support for the argument that changes in trader positions impact the basis. Our findings conflict with van Huellen's (2018) original results (replicated in appendix table A8). However, in appendix table A9 we show that when using properly-transformed, stationary positions data the trader position effects in her paper are no longer significant.

To calculate each market's implied expected duration of an average nonconvergence (in the approximate number of contract deliveries), we exploit the relationships we estimate between the basis and the wedge across all four commodity markets and apply equation (12). Table 7 displays our calculations for each market along with their associated 95% confidence intervals. We find that for corn, where fixed storage fee regimes are a norm throughout the sample period, the number of contract deliveries for which an average nonconvergence persists is approximately one. Our point estimate for the anticipated duration of a soybean nonconvergence does not fall after the increase in that contract's fixed storage fee in 2008. However, at the mean, our results indicate that CME's change in storage rate policy affected each wheat market's expected duration of nonconvergence with each policy shift. For SRW, the expected duration of an average nonconvergence falls from 1.32 contract deliveries to 0.75 contract deliveries after VSR was introduced. For HRW this mean value falls from 1.64 to 1.26 when the SSR is introduced, to 0.71 after the VSR is implemented.

Conclusion

Nonconvergence in physically-deliverable agricultural commodities has been attributed to inflexible futures contract storage fee policy (Adjemian et al. 2013; Garcia, Irwin, and Smith 2015) and financial investment (e.g., USS/PSI, 2009). Van Huellen (2018) links these two ideas, theorizing that when the wedge exists, the price-pressure influence of commodity index traders is easier to observe, and this price pressure better explains basis levels than the rational expectations model of wedge persistence. We test empirically for the suitability of both theories in explaining observed expiring basis levels in four major domestic commodity markets, and exploit the fact that CME applied different storage fee regimes in different markets to study their effectiveness.

Our results show that the wedge is highly significant in explaining observed basis levels in each market, and our structural break findings indicate that certain CME changes to exchange storage fee policy may have affected the relationship between the wedge and the basis. Specifically, CME's introduction of more flexible policies likely reduced the market expected duration for average nonconvergence events; our calculations imply that, at the mean, implementing a VSR brought market expectations for the duration of a nonconvergence in both wheat markets under a single contract expiration. Under a VSR regime then, if the market fails to converge in the nearby contract, it expects that the first deferred contract *would* converge. CME implementation of higher fixed storage fees in its corn and soybean markets do not likewise reduce trader nonconvergence expectations. We find no evidence to support van Huellen's (2018) conclusion that index trader activity affects nonconvergence or biases futures or cash prices.

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Table 1: Summary statistics of the basis, the wedge, and trader positions for corn, soybeans, SRW wheat, and HRW wheat

	Mean	Standard deviations	Max	Min
Corn				
Basis (cents/bushel)	18.65	13.42	60.60	-38.15
Wedge (cents/bushel/month)	2.63	5.90	32.08	0.00
Commercial net long % of Open Interest	-18.76	8.77	0.42	-35.68
Noncommercial net long % of Open Interest	2.14	8.43	16.44	-15.67
Index net long % of Open Interest	21.15	4.88	32.27	10.85
Observations		72		
Soybeans				
Basis (cents/bushel)	21.52	18.43	87.60	-20.90
Wedge (cents/bushel/month)	4.40	10.27	59.49	0.00
Commercial net long % of Open Interest	-19.17	12.74	9.78	-39.78
Noncommercial net long % of Open Interest	4.34	10.18	21.53	-18.36
Index net long % of Open Interest	19.78	5.63	31.07	9.80
Observations		101		

Table 1 continued

	Mean	Standard deviations	Max	Min
SRW wheat				
Basis (cents/bushel)	46.11	54.56	252.60	-8.70
Wedge (cents/bushel/month)	12.04	22.74	100.25	0.00
Commercial net long % of Open Interest	-19.09	12.12	8.02	-38.76
Noncommercial net long % of Open Interest	-9.86	8.35	4.80	-28.32
Index net long % of Open Interest	32.09	8.28	48.41	18.82
Observations		72		
HRW wheat				
Basis (cents/bushel)	34.92	28.13	106.05	-21.85
Wedge (cents/bushel/month)	4.60	9.74	46.25	0.00
Commercial net long % of Open Interest	-24.22	14.41	6.60	-49.06
Noncommercial net long % of Open Interest	4.07	14.38	33.78	-25.54
Index net long % of Open Interest	23.36	6.52	40.27	9.90
Observations		72		

Note: Basis is calculated as futures minus cash/spot prices at cheapest-to-deliver locations. Wedge represents the difference between the market price of storage and the storage rate/fee set by CME. The trader positions are calculated in terms of their net long positions as percentage of total open interest. SRW wheat and HRW wheat stand for soft red winter wheat and hard red winter wheat, respectively.

Table 2: Equation (10) regression results for corn (2006-2020)

	Corn
Variables	Basis
Wedge	1.08^{***}
	(0.27)
△ Commercial net long % of OI	-0.13
	(0.70)
△ Noncommercial net long % of OI	0.030
	(0.69)
△ Index net long % of OI	-0.35
	(0.60)
Constant	15.8^{***}
	(1.63)
Structural break observed	No
Cumby-Huizinga test for autocorrelation	Not significant
R-squared	0.24
N	71

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
The regressions are conducted as per the equation (10). We conduct Supremum Wald tests to identify breaks in linear regressions. We use Newey and West (1987) heteroscedasticity and autocorrelation consistent (HAC) standard errors for these regressions. First-differenced variables are denoted by △. OI represents "open interest", or the number of outstanding futures contracts.

Table 3: Equation (10) regression results for soybeans (2006-2020)

	Before break	*After break*
Variables	Basis	Basis
Wedge	0.77^{***}	1.44^{***}
	(0.22)	(0.19)
△ Commercial net long % of OI	-0.34	0.38
	(1.75)	(0.87)
△ Noncommercial net long % of OI	-0.67	0.16
	(2.00)	(0.88)
△ Index net long % of OI	-1.09	0.019
	(2.19)	(0.96)
Constant	32.9^{***}	12.1^{***}
	(4.04)	(1.57)
Structural break observed	January 2009	
Cumby-Huizinga test for autocorrelation	Significant at 5%	Significant at 5%
R-squared	0.55	0.45
N	20	80

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The regressions are conducted as per the equation (10). We conduct Supremum Wald tests to identify breaks in linear regressions. We use Newey and West (1987) heteroscedasticity and autocorrelation consistent (HAC) standard errors for these regressions. First-differenced variables are denoted by △. OI represents "open interest", or the number of outstanding futures contracts.

Table 4: Equation (10) regression results for soft red winter (SRW) wheat (2006-2020)

Variables	*Before break* Basis	*After break* Basis
Wedge	1.32^{***}	0.75^{***}
	(0.25)	(0.095)
△ Commercial net long % of OI	-13.4	-0.85
	(8.26)	(1.33)
△ Noncommercial net long % of OI	-16.3^{*}	-1.24
	(9.13)	(1.34)
△ Index net long % of OI	-10.8	-1.18
	(8.20)	(1.34)
Constant	80.5^{***}	15.1^{***}
	(17.5)	(3.11)
Structural break observed	May 2010	
Cumby-Huizinga test for autocorrelation	Significant at 5%	Significant at 1%
R-squared	0.39	0.48
N	20	51

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The regressions are conducted as per the equation (10). We conduct Supremum Wald tests to identify breaks in linear regressions. We use Newey and West (1987) heteroscedasticity and autocorrelation consistent (HAC) standard errors for these regressions. First-differenced variables are denoted by △. OI represents "open interest", or the number of outstanding futures contracts. VSR represents the variable storage rate.

Table 5: Equation (10) regression results for hard red winter (HRW) wheat (2006-2020)

	Before SSR	*With SSR*	*With VSR*
Variables	Basis	Basis	Basis
Wedge	1.63*	1.26***	0.71**
	(0.84)	(0.29)	(0.23)
△ Commercial net long % of OI	2.18	-2.84	-0.47
	(1.79)	(1.79)	(1.70)
△ Noncommercial net long % of OI	2.64	-2.64	-1.51
	(1.71)	(1.94)	(1.77)
△ Index net long % of OI	-0.49	-2.21	1.93
	(1.49)	(1.78)	(1.73)
Constant	41.2***	28.8***	6.55
	(7.98)	(6.23)	(5.84)
Structural break observed	March 2011 and December 2017		
Cumby-Huizinga test for autocorrelation	Significant at 1%	Significant at 1%	Significant at 10%
R-squared	0.27	0.23	0.54
N	24	34	13

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The regressions are conducted as per the equation (10). Simultaneous estimation of multiple breaks is conducted using Bai and Perron's (2003) algorithm. We use Newey and West (1987) heteroscedasticity and autocorrelation consistent (HAC) standard errors for these regressions. First-differenced variables are denoted by △. OI represents "open interest", or the number of outstanding futures contracts. SSR and VSR represent the seasonal storage rate and variable storage rate, respectively.

Table 6: Equation (11) Markov switching regression results for corn, soybeans, and wheat (2006-2020)

	Corn Basis	Soybeans Basis	SRW wheat Basis	HRW wheat Basis
Wedge	0.84***	1.06***	0.89***	0.66***
	(0.079)	(0.089)	(0.089)	(0.18)
State1				
△ Commercial net long % of OI	-0.76*	-0.67	-0.56	-0.68
	(0.44)	(0.62)	(1.40)	(0.81)
△ Noncommercial net long % of OI	-0.50	-0.82	-0.83	-0.89
	(0.40)	(0.66)	(1.38)	(0.87)
△ Index net long % of OI	-0.76	-1.01	-0.37	0.56
	(0.47)	(0.64)	(1.29)	(0.77)
Constant	7.83***	10.0***	10.2***	12.9***
	(0.77)	(0.99)	(1.81)	(2.16)
State2				
△ Commercial net long % of OI	-0.27	2.98*	-8.31	-0.026
	(1.21)	(1.62)	(10.6)	(1.58)
△ Noncommercial net long % of OI	-0.071	2.58	-9.84	0.44
	(1.18)	(1.63)	(11.0)	(1.66)
△ Index net long % of OI	-0.61	2.43	-5.05	-1.82
	(1.03)	(1.52)	(9.55)	(1.62)
Constant	19.1***	31.1***	78.5***	55.6***
	(1.81)	(2.69)	(10.1)	(4.79)

Table 6 continued

	Corn Basis	Soybeans Basis	SRW wheat Basis	HRW wheat Basis
State dependent variances				
σ_1	2.09	7.32	10.32	10.34
σ_2	12.36	13.27	49.90	20.20
Transition probabilities				
p11	0.75	0.96	0.96	0.95
p21	0.07	0.09	0.06	0.08
N	71	100	71	71

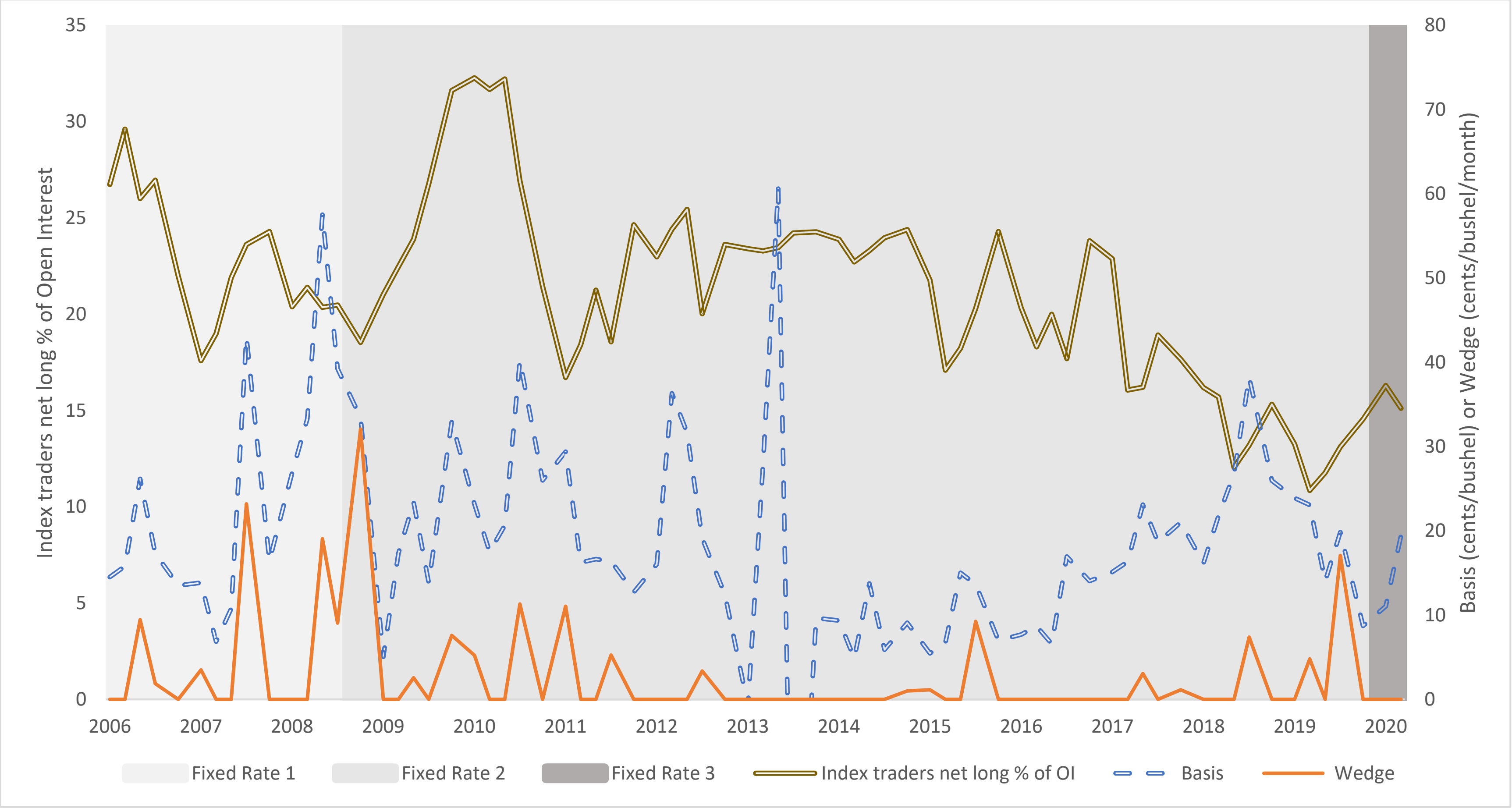
Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. First-differenced variables are denoted by $\triangle$. OI represents “open interest”, or the number of outstanding futures contracts.

Table 7: Duration of nonconvergence in corn, soybeans, SRW wheat, and HRW wheat markets

Commodity	Before/After Breakpoint	Expected Duration (contract deliveries)	95% Confidence Interval of Duration	
			Lower Bound	Upper Bound
Corn	No break	1.08	0.52	1.62
Soybeans (January 2009)	Before Fixed Rate 2	0.77	0.32	1.21
	After Fixed Rate 2	1.44	1.08	1.80
SRW wheat (Break: May 2010)	Before VSR	1.32	0.75	1.89
	With VSR	0.75	0.55	0.96
HRW wheat (Breaks: March 2011 & December 2017)	Before SSR	1.64	0.00	3.44
	With SSR	1.26	0.68	1.85
	With VSR	0.71	0.19	1.25

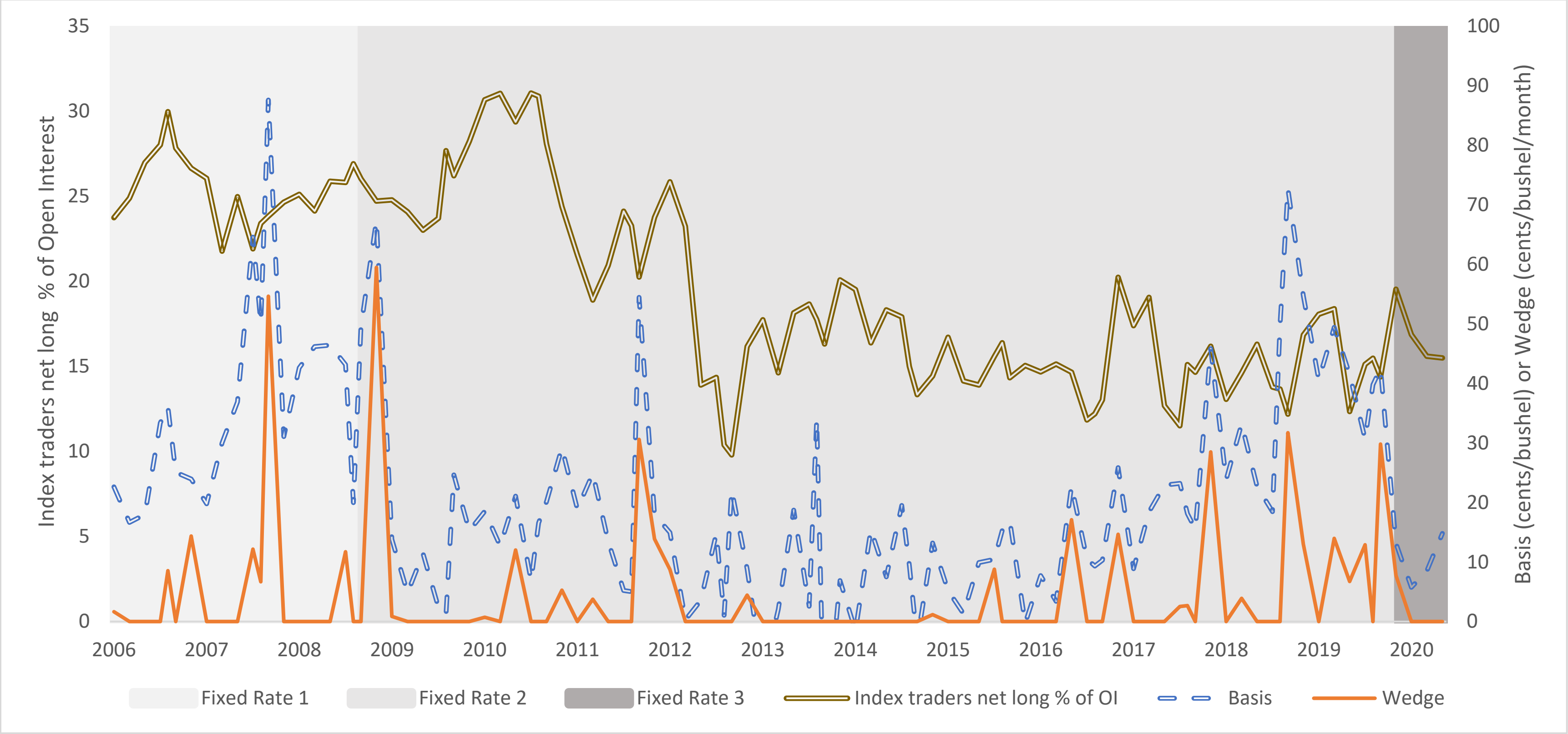
Note: Calculations of the duration of nonconvergence are based upon the constant coupon bond valuation equation (11). SRW wheat and HRW wheat stand for soft red winter wheat and hard red winter wheat, respectively. SSR and VSR represent the seasonal storage rate and variable storage rate, respectively. Structural break-dates are mentioned in parentheses.

Figure 1: The basis, the wedge, storage rate policies, and the index trader positions for corn (2006-2020)



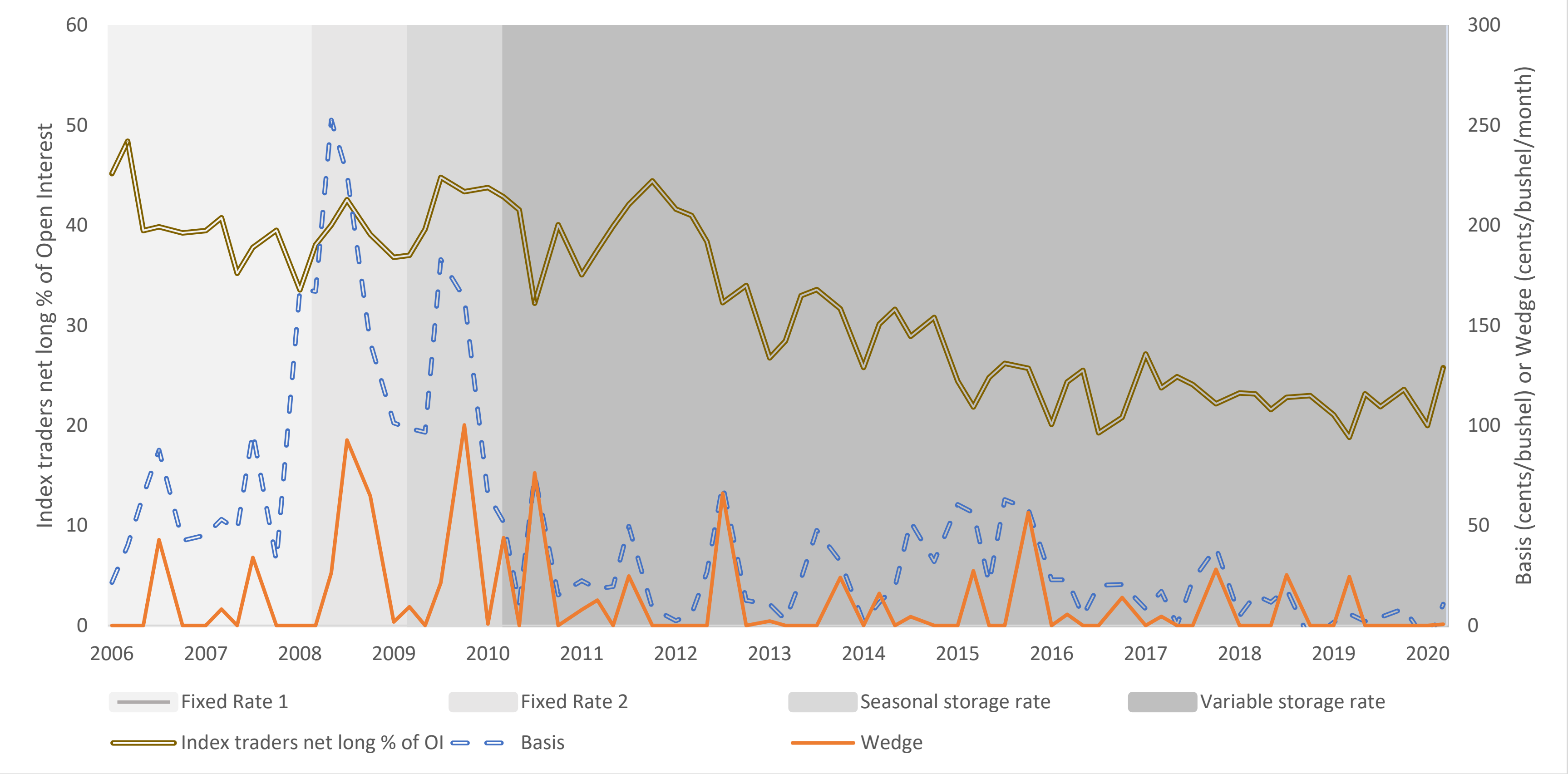
Note: The market is shown to transition from one fixed storage rate regime to another in the background. Basis is calculated as futures minus cash prices at cheapest-to-deliver locations. Wedge represents the difference between the market price of storage and the storage fee set by CME. The index trader positions are calculated in terms of their net long positions as percentage of total open interest (OI).

Figure 2: The basis, the wedge, storage rate policies, and the index trader positions for soybeans (2006-2020)



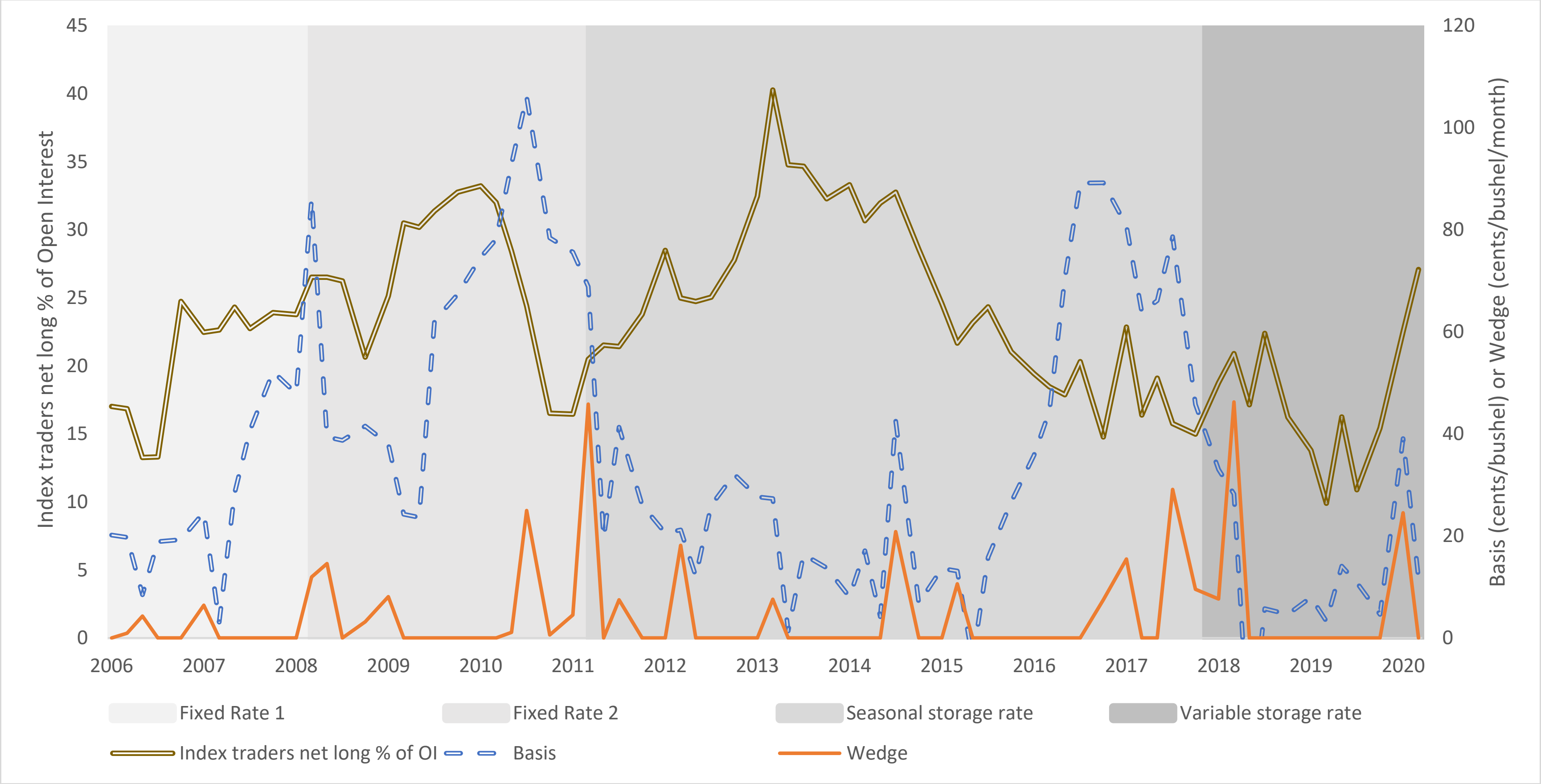
Note: The market is shown to transition from one fixed storage rate regime to another in the background. Basis is calculated as futures minus cash prices at cheapest-to-deliver locations. Wedge represents the difference between the market price of storage and the storage fee set by CME. The index trader positions are calculated in terms of their net long positions as percentage of total open interest (OI).

Figure 3: The basis, the wedge, storage rate policies, and the index trader positions for SRW wheat (2006-2020)



Note: The soft red winter (SRW) wheat market is shown to transition from fixed storage rate regimes to seasonal storage rate (SSR), and finally to variable storage rate (VSR) in the background. Basis is calculated as futures minus cash prices at cheapest-to-deliver locations. Wedge represents the difference between the market price of storage and the storage fee set by CME. The index trader positions are calculated in terms of their net long positions as percentage of total open interest (OI).

Figure 4: The basis, the wedge, storage rate policies, and the index trader positions for HRW wheat (2006-2020)



Note: The hard red winter (HRW) wheat market is shown to transition from fixed storage rate regimes to seasonal storage rate (SSR), and finally to variable storage rate (VSR) in the background. Basis is calculated as futures minus cash prices at cheapest-to-deliver locations. Wedge represents the difference between the market price of storage and the storage fee set by CME. The index trader positions are calculated in terms of their net long positions as percentage of total open interest (OI).

Appendix

Table A1: Phillips-Perron and Zivot-Andrews test results for the trader positions used in our regressions (2006-2020)

Commodity	Variables	p-value for Phillips-Perron (1988) unit root test	Minimum t-statistic for Zivot-Andrews (1992) unit root test
Corn	Basis	0.00	-8.38
	Wedge	0.00	-9.36
	Commercial (% of OI)	0.00	-4.45
	Noncommercial (% of OI)	0.00	-3.63
	Index (% of OI)	0.02	-4.24
	Commercial net long (% of OI)	0.00	-4.08
	Noncommercial net long (% of OI)	0.00	-4.67
	Index net long (% of OI)	0.11	-4.32
Soybeans	Basis	0.00	-4.57
	Wedge	0.00	10.59
	Commercial (% of OI)	0.01	-6.02
	Noncommercial (% of OI)	0.00	-4.021
	Index (% of OI)	0.09	-4.31
	Commercial net long (% of OI)	0.01	-6.14
	Noncommercial net long (% of OI)	0.00	-5.60
	Index net long (% of OI)	0.22	-5.90

Table A1 continued

Commodity	Variables	p-value for Phillips-Perron (1988) unit root test	Minimum t-statistic for Zivot-Andrews (1992) unit root test
SRW wheat	Basis	0.06	-5.16
	Wedge	0.00	-9.52
	Commercial (% of OI)	0.03	-3.34
	Noncommercial (% of OI)	0.17	-5.80
	Index (% of OI)	0.30	-3.85
	Commercial net long (% of OI)	0.05	-6.23
	Noncommercial net long (% of OI)	0.00	-6.42
	Index net long (% of OI)	0.33	-5.46

Table 1 continued

Commodity	Variables	p-value for Phillips-Perron (1988) unit root test	Minimum t-statistic for Zivot-Andrews (1992) unit root test
HRW wheat	Basis	0.04	-2.82
	Wedge	0.00	-3.85
	Commercial (% of OI)	0.00	-5.69
	Noncommercial (% of OI)	0.11	-3.48
	Index (% of OI)	0.10	-4.43
	Commercial net long (% of OI)	0.00	-5.34
	Noncommercial net long (% of OI)	0.01	-5.06
	Index net long (% of OI)	0.09	-3.90

Note: We use the Phillips-Perron (1988) test to determine if a variable has a unit root (without a structural break), and the Zivot-Andrews (1992) test to verify if a variable has unit root while permitting a single unknown structural break. The null hypothesis for the Phillips-Perron tests, that the series has a unit root, is rejected at p-values lower than 10%. The null-hypothesis for the Zivot-Andrews test, that the series has a unit root, is rejected when the critical values of -5.34 (at 1% level), -4.80 (at 5% level), and -4.58 (at 10% level) are greater than the minimum t-statistic in absolute value. SRW wheat and HRW wheat represent soft red winter wheat and hard red winter wheat, respectively.

Table A2: Phillips-Perron and Zivot-Andrews test results for the trader positions used in van Huellen (2018) regressions

Commodity	Variables	p-value for Phillips-Perron (1988) unit root test	Minimum t-statistic for Zivot-Andrews (1992) unit root test
SRW wheat	Commercial (% of OI)	0.06	-4.62
	Index (% of OI)	0.89	-3.13
	Commercial net long (% of OI)	0.01	-6.47
	Index net long (% of OI)	0.70	-3.96
Corn	Commercial (% of OI)	0.01	-5.12
	Index (% of OI)	0.18	-4.59
	Commercial net long (% of OI)	0.09	-4.63
	Index net long (% of OI)	0.08	-4.09
Soybeans	Commercial (% of OI)	0.01	-4.14
	Index (% of OI)	0.44	-4.63
	Commercial net long (% of OI)	0.05	-4.23
	Index net long (% of OI)	0.32	-4.65

Note: Phillips-Perron (1988) test is used to check if a variable has a unit root (without a structural break), and the Zivot-Andrews (1992) test to verify if a variable has unit root while permitting a single unknown structural break. The null hypothesis for the Phillips-Perron tests, that the series has a unit root, is rejected at p-values lower than 10%. The null-hypothesis for the Zivot-Andrews test i.e., unit root with structural break, is rejected when the critical values of -5.34 (at 1% level), -4.80 (at 5% level), and -4.58 (at 10% level) are greater than the minimum t-statistic value. SRW wheat represents soft red winter wheat.

Table A3: Equation (10) regression results for corn with trader weights (2006-2020)

Variables	*Corn* Basis
Wedge	1.08***
	(0.28)
△ Commercial % of OI	-0.11
	(0.25)
△ Noncommercial % of OI	-0.29
	(0.35)
△ Index % of OI	-0.26
	(0.35)
Constant	15.9***
	(1.61)
Structural break observed	No
Cumby-Huizinga test for autocorrelation	Not significant
R-squared	0.23
N	71

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
The regressions are conducted as per the equation (10). We conduct Supremum Wald tests to identify breaks in linear regressions. We use Newey and West (1987) heteroscedasticity and autocorrelation consistent (HAC) standard errors for these regressions. First-differenced variables are denoted by △. OI represents “open interest”, or the number of outstanding futures contracts..

Table A4: Equation (10) regression results for soybeans with trader weights (2006-2020)

Variables	*Before break* Basis	*After break* Basis
Wedge	0.97^{***}	1.41^{***}
	(0.091)	(0.19)
△ Commercial % of OI	-1.10^{***}	-0.48^{*}
	(0.33)	(0.29)
△ Noncommercial % of OI	0.057	0.034
	(0.49)	(0.33)
△ Index % of OI	-0.31	-0.13
	(1.12)	(0.41)
Constant	31.7^{***}	12.3^{***}
	(3.74)	(1.49)
Structural break observed	January 2009	
Cumby-Huizinga test for autocorrelation	Significant at 5%	Significant at 5%
R-squared	0.64	0.46
N	20	80

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The regressions are conducted as per the equation (10). We conduct Supremum Wald tests to identify breaks in linear regressions. We use Newey and West (1987) heteroscedasticity and autocorrelation consistent (HAC) standard errors for these regressions. First-differenced variables are denoted by △. OI represents “open interest”, or the number of outstanding futures contracts.

Table A5: Equation (10) regression results for soft red winter wheat (SRW) wheat with trader weights (2006-2020)

Variables	*Before break* Basis	*After break* Basis
Wedge	1.34^{***}	0.75^{***}
	(0.42)	(0.083)
△ Commercial % of OI	-2.02	0.46
	(2.56)	(0.50)
△ Noncommercial % of OI	-0.15	0.53
	(5.12)	(0.39)
△ Index % of OI	4.26	-0.69
	(3.70)	(0.58)
Constant	78.9^{***}	15.1^{***}
	(18.1)	(3.02)
Structural break observed	May 2010	
Cumby-Huizinga test for autocorrelation	Significant at 5%	Significant at 1%
R-squared	0.41	0.48
N	20	51

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The regressions are conducted as per the equation (10). We conduct Supremum Wald tests to identify breaks in linear regressions. We use Newey and West (1987) heteroscedasticity and autocorrelation consistent (HAC) standard errors for these regressions. First-differenced variables are denoted by △. OI represents "open interest", or the number of outstanding futures contracts. VSR represents the variable storage rate.

Table A6: Equation (10) regression results for hard red winter wheat (HRW) wheat with trader weights (2006-2020)

Variables	*Before SSR* Basis	*With SSR* Basis	*With VSR* Basis
Wedge	1.83^{**}	1.00^{***}	1.10
	(0.81)	(0.31)	(0.61)
△ Commercial % of OI	-0.26	-0.98	-0.61
	(0.60)	(0.75)	(0.96)
△ Noncommercial % of OI	0.41	-1.23^{*}	-0.29
	(0.77)	(0.68)	(0.99)
△ Index % of OI	-1.36	-0.59	-1.33
	(1.87)	(1.18)	(1.61)
Constant	39.8^{***}	30.9^{***}	10.3^{*}
	(8.53)	(6.20)	(5.24)
Structural break observed	December 2010 and September 2017		
Cumby-Huizinga test for autocorrelation	Significant at 1%	Significant at 1%	Significant at 5%
R-squared	0.20	0.16	0.48
N	24	34	13

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The regressions are conducted as per the equation (10). Simultaneous estimation of multiple breaks is conducted using Bai and Perron's (2003) algorithm. We use Newey and West (1987) heteroscedasticity and autocorrelation consistent (HAC) standard errors for these regressions. First-differenced variables are denoted by △. OI represents "open interest", or the number of outstanding futures contracts. SSR and VSR represent the seasonal storage rate and variable storage rate, respectively.

Table A7: Equation (11) Markov switching regression results for corn, soybeans, and wheat (2006-2020)

	Corn Basis	Soybeans Basis	SRW wheat Basis	HRW wheat Basis
Wedge	1.08^{***}	1.08^{***}	0.86^{***}	0.62^{***}
	(0.24)	(0.10)	(0.084)	(0.19)
State1				
△ Commercial % of OI	0.067	-0.33	0.64	-0.50^{*}
	(0.20)	(0.23)	(0.42)	(0.30)
△ Noncommercial % of OI	0.097	0.068	0.59^{*}	-0.46
	(0.27)	(0.32)	(0.31)	(0.32)
△ Index % of OI	-0.38	-0.13	-0.30	-0.20
	(0.35)	(0.40)	(0.42)	(0.50)
Constant	14.0^{***}	10.2^{***}	10.3^{***}	14.1^{***}
	(1.21)	(1.14)	(1.74)	(2.13)
State2				
△ Commercial % of OI	-0.0028	-0.73	-1.99	-0.00061
	(1.14)	(0.47)	(2.39)	(0.52)
△ Noncommercial % of OI	-1.52	0.19	-1.07	-0.13
	(1.71)	(0.60)	(3.24)	(0.52)
△ Index % of OI	0.18	-0.94	4.86^{*}	-1.25
	(2.19)	(0.81)	(2.82)	(1.50)
Constant	21.4^{***}	32.0^{***}	78.6^{***}	57.7^{***}
	(5.38)	(2.38)	(9.68)	(5.03)

Table A7 continued

	Corn Basis	Soybeans Basis	SRW wheat Basis	HRW wheat Basis
State dependent variances				
σ_1	6.01	8.56	9.99	10.91
σ_2	19.41	10.51	48.14	20.75
Transition probabilities				
p11	0.92	0.97	0.96	0.95
p21	0.24	0.06	0.06	0.09
N	71	100	71	71

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. First-differenced variables are denoted by $\triangle$. OI represents "open interest", or the number of outstanding futures contracts.

Table A8: Replication of van Huellen's (2018) original results (all series are in logarithms)

	Wheat		Corn		Soybeans	
	Basis	Basis	Basis	Basis	Basis	Basis
Storage premium	0.06*** (0.01)	0.05*** (0.01)	0.18*** (0.04)	0.12*** (0.04)	0.17*** (0.04)	0.18*** (0.04)
Inventory	1.13*** (0.33)	1.38*** (0.38)	-0.27*** (0.08)	-0.28*** (0.09)	-0.30*** (0.09)	-0.28*** (0.08)
Inventory-square	-0.11*** (0.03)	-0.13*** (0.04)	0.02*** (0.00)	0.02*** (0.01)	0.01*** (0.00)	0.011*** (0.00)
Stocks-to-use (total disappearance over ending stocks)	-0.01 (0.02)	-0.01 (0.02)	0.01** (0.01)	0.01** (0.01)	0.02*** (0.01)	0.01** (0.01)
Commercial % of OI	0.09* (0.05)		0.004 (0.02)		0.05* (0.02)	
Index % of OI	-0.18*** (0.06)		-0.04*** (0.01)		0.005 (0.009)	
Commercial net long % of OI		0.007 (0.02)		0.003 (0.00)		0.003 (0.00)
Index net long % of OI		-0.12* (0.06)		-0.03*** (0.01)		-0.01 (0.01)
constant	-2.67*** (0.81)	-3.32*** (0.97)	2.14*** (0.30)	1.85*** (0.31)	3.08*** (0.65)	2.98*** (0.63)
R-squared	0.54	0.42	0.57	0.57	0.51	0.50
N	48	48	48	48	68	68

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A9: Replication of van Huellen's (2018) results using first-differenced trader positions (all series are in logarithms)

	Wheat		Corn		Soybeans	
	Basis	Basis	Basis	Basis	Basis	Basis
Storage premium	0.05^{***}	0.05^{***}	0.10^{**}	0.11^{**}	0.17^{***}	0.20^{***}
	(0.01)	(0.01)	(0.04)	(0.04)	(0.04)	(0.04)
Inventory	1.56^{***}	1.57^{***}	-0.31^{***}	-0.30^{***}	-0.30^{***}	-0.26^{***}
	(0.42)	(0.41)	(0.08)	(0.08)	(0.09)	(0.09)
Inventory-square	-0.15^{***}	-0.15^{***}	0.02^{***}	0.02^{***}	0.011^{***}	0.010^{***}
	(0.04)	(0.04)	(0.01)	(0.01)	(0.00)	(0.00)
Stocks-to-use (total disappearance over ending stocks)	0.01	0.01	0.01^{**}	0.01^{**}	0.01^{***}	0.01^{**}
	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.04)
△ Commercial % of OI	0.01		-0.02		0.06^{**}	
	(0.06)		(0.02)		(0.02)	
△ Index % of OI	-0.10		-0.01		-0.003	
	(0.10)		(0.02)		(0.01)	
△ Commercial net long % of OI		-0.004		-0.003		0.003
		(0.01)		(0.00)		(0.00)
△ Index net long % of OI		-0.06		-0.01		0.01
		(0.07)		(0.01)		(0.01)
constant	-3.72^{***}	-3.75^{***}	1.86^{***}	1.84^{***}	3.00^{***}	2.96^{***}
	(1.01)	(1.02)	(0.33)	(0.30)	(0.59)	(0.62)
R-squared	0.33	0.33	0.49	0.49	0.53	0.49
N	47	47	47	47	67	67

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.