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Price Discovery and the Basis Effects of Failures to Converge in Soft Red Winter Wheat Futures Markets

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Wheat futures contracts failed to converge to spot prices at delivery locations in 2008–2009. By analyzing basis at nondelivery locations surrounding this episode, we study the spatial pattern of failures to converge. We find that basis fell as distance from delivery location increased and remained tightly connected to basis at the delivery location during the nonconvergence episodes. This finding is uniform throughout the delivery zone. We conclude that nonconvergence did not affect the economic relationship between delivery and nondelivery locations' spot prices but only affected the connection between futures prices and spot prices.

Key words: cash price, convergence, delivery, grains

Introduction

Failures of convergence between delivery-month futures prices and spot prices in the late 2000s, primarily in wheat markets, have received considerable attention. Beyond academic studies, evidence of concern in regulatory circles is provided by Congress's authorization at the time of an ad hoc committee to investigate the phenomenon.[1] These episodes are just the most recent instance of recurrent concerns over the delivery specifications of futures contracts.

Williams (1995), for instance, discusses convergence issues in soft red winter wheat futures contracts in the 1980s arising from the then-growing discrepancy between futures contracts calling for delivery in Chicago and physical grain trade, which was moving away from Chicago. Continuing tension between the delivery specifications of contracts and the trade flows of the physical commodity have resulted in the several historical instances of convergence problems in wheat. It would not be unreasonable to expect them to recur.[2]

The convergence of futures and spot prices during the delivery period of a contract is fundamental to the efficient workings of futures markets. First, futures contracts fail in their primary function of providing hedging services if the price at which short-hedged producers, say, can sell their crop is not the same as the price at which they can buy back their short position. Second, the forecasting value of futures prices prior to delivery is based on market participants' expectations that the spot and futures prices will converge.

In reality, convergence typically is not exact due to transaction costs, market congestion, and imperfect information that limit arbitrage, and thus should be considered as occurring within a band determined by the cost of the delivery process (Irwin et al., 2011). But the fact that wheat futures

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[1] For an analysis of earlier episodes of nonconvergence, see Pirrong, Haddock, and Kormendi (1993).

[2] Delivery specifications for futures contracts reflect the dominant physical trading locations, but those locations change in importance as transportation networks evolve and as production and buying locations shift. Peck and Williams (1991) provide a review of markets from the 1960s through the 1980s.

contracts sometimes only came within a dollar per bushel of spot prices was and remains concerning as this price difference is well above the direct delivery cost estimate of 6–8¢/bu provided in Irwin et al. (2011).

We contribute to an understanding of the nonconvergence phenomenon by analyzing the effects of episodes of nonconvergence on spatial relationships in basis (i.e., cash price minus futures price) patterns, with attention paid to both markets designated for delivery on futures contracts and nondelivery markets. More specifically, we contribute to the literature by determining how the nonconvergence in a delivery market is transmitted to basis at nondelivery locations. Since only a small subset of markets comprises delivery points for futures contracts, most market participants are subject to basis conditions at nondelivery points. Based on the law of one price, basis levels in nondelivery markets should be influenced by lack of convergence at delivery points, but no empirical research has explored the issue.[3] There is a large empirical literature on the law of one price (e.g., Asche, Bremnes, and Wessells, 1999; Baffes, 1991; Goodwin, Grennes, and Wohlgenant, 1990; Goodwin and Piggott, 2001; McNew and Fackler, 1997; Olsen, Mjelde, and Bessler, 2015); our study here can be considered as addressing this price comovement issue, but during a particular time of disruption between cash and futures prices. Thus, our main goal is to determine whether the spot-futures price difference at the delivery point is spatially amplified or damped away from the delivery point if the prices at delivery markets fail to converge.

Our analysis exploits a unique and proprietary dataset from GeoGrain, Inc., comprising daily spot bid prices from over 100 wheat buyers in the Midwest and eastern parts of the United States from 2005 to 2013. This period comprises three subsamples: a period before issues of nonconvergence arose (2005–2008), a period during which nonconvergence was marked (2008 and 2009), and a period following the nonconvergence episode and after changes in delivery specifications of the contract were implemented by the Chicago Board of Trade (CBOT). Using a panel regression model, we measure the spatial basis surface (the spot-futures price differential keyed to location) and examine perturbations in that surface before, during, and after nonconvergence. We examine the extent to which convergence problems at delivery points led to weaker basis levels at nondelivery markets. Because nonconvergence problems have been most pronounced for winter wheat contracts, we restrict attention to soft red winter wheat.

Our results show that the basis at nondelivery locations became more strongly connected to basis at the delivery location during historical periods of nonconvergence. The increase in connection between outlying markets and the delivery location is statistically significant for more than one-quarter of the locations studied. In contrast, there is virtually no evidence of a weakening of connections during periods of nonconvergence. This suggests that spot prices are connected by transportation costs and local supply and demand conditions, and this relationship seems not to be significantly disrupted by the failure of futures prices to converge.

Previous Literature

The underlying reasons for the nonconvergence phenomenon has been studied in the literature by analyzing the characteristics of the futures contracts, such as delivery terms and storage costs, set by the CBOT. In a series of articles, Irwin et al. (2008, 2009, 2011) relate convergence failures in corn, soybean, and wheat markets to the slope of the delivery-time profile of futures prices. When the price spread between successive contracts rises close to the cost of storage, delivery-month convergence failures are more likely to occur. They argue that changes enacted in the CBOT corn and soybean contracts largely ameliorated the problem in those markets but that more fundamental changes in the delivery terms of wheat contracts still are required.

[3] As Irwin et al. (2008) argue, nonconvergence issues at delivery locations might not uniformly be transmitted to nondelivery locations due to differing transportation costs, local supply and demand conditions, and storage costs.

Garcia, Irwin, and Smith (2014) argue that the institutional structure of the delivery market was to blame for nonconvergence in corn, soybean, and wheat futures contracts. Using a rational expectations storage model, they show that the wedge between the marginal cost of storing the physical commodity and the cost of carrying the delivery instrument caused nonconvergence. Similarly, Adjemian et al. (2013) conclude that nonconvergence in corn, soybean, and wheat markets occurred because the exchange-set storage rate of the delivery instrument was too low relative to the true cost of storage.

Aulerich, Fishe, and Harris (2011), on the other hand, explain nonconvergence as emanating from an option value created by the CBOT's delivery system for grain. The authors show that as the relative volatility of cash and futures prices increases, this option value increases, creating a significant price divergence between cash and futures prices.

Prior literature on nonconvergence has focused on spot prices at delivery locations. We extend this analysis spatially by examining basis, the difference between a local market's price and the price of the nearby futures contract. Understanding basis is important from both risk management and price forecasting perspectives. Therefore, understanding the potential effects of nonconvergence on basis is important from those same perspectives. There is a large literature on the risk management and information benefits from using futures contracts.[4] The residual risk remaining after a futures hedge is basis risk, which cannot be hedged. There is also an extensive literature on the role of basis in hedging and forecasting local cash prices.[5] The implications of the hedging and forecasting literature is that stakeholders such as producers and other agribusiness firms—who buy, sell, and hedge away from futures delivery points—need to have a good understanding of basis and how it moves relative to basis at other locations, in particular, the delivery location. This motivates our specific focus on basis and geographic basis patterns.

A Theoretical Framework

Nonconvergence is about the temporal behavior of basis—a quantity that should converge to 0 at delivery time, at delivery locations, but at times has not. Because most grain is sold away from delivery locations, we find it natural to consider how basis behaves at nondelivery locations. Thus we study the connection between basis at nondelivery markets and basis at the delivery point, which is potentially different from the relationship between prices at the two locations. Benchmarking both prices against the nearby futures price introduces a third random variable into the empirical relationship; we consider the statistical implications of this fact below.[6]

We present a reduced-form theory of the relationship between basis at a delivery location (Toledo, Ohio, in our empirics) and basis in nondelivery locations (within a 100-mile radius of Toledo). We use the model to analyze how the relationship between the two bases can be expected to shift when futures prices and spot prices become less connected (nonconvergence). The model reveals that nonconvergence can make the connection between basis at the delivery location and a nondelivery location either stronger or weaker, thus motivating empirical measurement of this

[4] Examples include Zulauf and Irwin (1998); Schroeder et al. (1998); and Taylor, Dhuyvetter, and Kastens (2006). Many studies have shown that returns can be increased and price risk can be reduced if futures markets are used to hedge sales and purchases of commodities (e.g., Gorman et al., 1982; Hayenga et al., 1984; Brandt, 1985; Kenyon and Clay, 1987).

[5] See, for example, Hauser, Garcia, and Tumblin (1990); Naik and Leuthold (1991); Tomek (1997); and Taylor, Dhuyvetter, and Kastens (2006). In order to achieve a successful hedge, hedgers should be able to predict what the basis will be when the sale or purchase is made in the cash market and when the hedging position is closed in the futures market (e.g., Paroush and Wolf, 1989; Schroeder et al., 1998; Kastens, Jones, and Schroeder, 1998; Tonsor, Dhuyvetter, and Mintert, 2004).

[6] Hailu, Maynard, and Weersink (2015) provide motivation for a focus on basis. They demonstrate that basis (spot less futures price) at any location can be decomposed into a spatial component representing the price difference between that location and the delivery location and a temporal component representing the price difference between the delivery location and futures contract. The temporal component, which is weakly the sum of transportation cost between the local and delivery markets and the cost of carry, also represents the locked-in futures price a fully hedged producer receives at the time of contract maturity (Adjemian et al., 2016). Because basis is the random variable that a hedged seller is exposed to, we focus here and below on basis and not simply on the unhedged price.

relationship. Under reasonable and interpretable conditions, the model implies a strengthening of the basis-to-basis relationship during periods of nonconvergence, which is what we find in the empirical section that follows.

Basis at market i is defined as

$$b_{it} = P_{it} - P_{Ft}, \tag{1}$$

where P_{it} is the price at nondelivery market i on day t and P_{Ft} is the price of the nearby futures contract on that day. Similarly, basis at the delivery location (T for Toledo) is defined as

$$b_{Tt} = P_{Tt} - P_{Ft}. \tag{2}$$

The regression relationship between b_{it} and b_{Tt} reflects the trivariate distribution of three contemporaneous wheat prices: P_i, P_T, and P_F. The covariance matrix of the three underlying prices can be written as

$$\mathbf{\Sigma} = \begin{pmatrix} \sigma_i^2 & \sigma_{iT} & \sigma_{iF} \\ \cdot & \sigma_T^2 & \sigma_{TF} \\ \cdot & \cdot & \sigma_F^2 \end{pmatrix}. \tag{3}$$

Write the contemporaneous relationship between the two bases as a time series regression of basis at market i on basis at Toledo:

$$b_{it} = \alpha + \delta b_{Tt} + \varepsilon_{it}. \tag{4}$$

With the assumption of *i.i.d.* disturbances, the probability limit of the least squares estimator of δ can be written in terms of the elements of $\mathbf{\Sigma}$:

$$plim\ \hat{\delta} = \frac{Cov(b_i,\, b_T)}{Var(b_T)} = \frac{Cov(P_i - P_F,\, P_T - P_F)}{Var(P_T - P_F)} = \frac{\sigma_{iT} - \sigma_{iF} - \sigma_{TF} + \sigma_F^2}{\sigma_T^2 + \sigma_F^2 - 2\sigma_{TF}}. \tag{5}$$

Expression (5) depends on five of the six distinct elements of the trivariate covariance matrix.

To understand the role of futures prices in the link between b_{it} and b_{Tt}, it is helpful to consider the (unrealistic) special case where $\sigma_{iF} = \sigma_{TF} = 0$, a situation where both market i and the price at Toledo are uncorrelated with the futures price. In this case, expression (5) reduces to

$$plim\ \hat{\delta} = \frac{\sigma_{iT} + \sigma_F^2}{\sigma_T^2 + \sigma_F^2} = \frac{\beta_{iT}\sigma_T^2 + \theta\sigma_T^2}{\sigma_T^2 + \theta\sigma_T^2} = \frac{\beta_{iT} + \theta}{1 + \theta}, \tag{6}$$

where $\theta = \sigma_F^2/\sigma_T^2$, a variance ratio, and $\beta_{iT} = \sigma_{iT}/\sigma_T^2$ is the population regression coefficient in a regression of P_i on P_T. It can be seen from equation (6) that even when futures and spot prices are uncorrelated, the estimated relationship between b_i and b_T reflects more than just the relationship between P_i and P_T. In particular, the measurement of basis with respect to an uncorrelated P_F introduces noise that biases $\hat{\delta}$ upwards from β_{iT}. If $\theta = 0$ (the futures noise disappears), then the bias disappears and $plim\ \hat{\delta} = \beta_{iT}$. As θ becomes large (the noise comes to dominate), $plim\ \hat{\delta} = 1$ and b_{it} and b_{Tt} tend to move one for one.

Consider, then, expression (5) in the more realistic case of strong correlation between both spot prices and futures prices, but both correlations becoming weaker during nonconvergence episodes due to failures of the futures prices to converge to spot prices at delivery. First, reparameterize $\mathbf{\Sigma}$ to allow σ_{iF} and σ_{TF} to change concurrently:

$$\sigma_{iF} = \omega\sigma_{TF}. \tag{7}$$

The parameterization in equation (7) places no restriction on the covariance structure, as the parameter σ_{iF} has been replaced with the parameter ω. Any value of σ_{iF} can be achieved by varying

ω, but—holding ω fixed—varying σ_{TF} will then change the covariance of both cash prices with the futures price.

The reparameterized, but as yet unrestricted, version of expression (5) can be written as

$$plim\ \hat{\delta} = \frac{\sigma_{iT} - \sigma_{iF} - \sigma_{TF} + \sigma_F^2}{\sigma_T^2 + \sigma_F^2 - 2\sigma_{TF}} = \frac{\sigma_{iT} - (1+\omega)\sigma_{TF} + \sigma_F^2}{\sigma_T^2 + \sigma_F^2 - 2\sigma_{TF}}. \tag{8}$$

Expression (8) allows us to ask how a reduction in the covariance between futures prices and both cash prices will affect the relationship between basis at market i and basis at market T. That is, if both cash prices simultaneously become less correlated with the futures price, what can be expected to happen to the relationship between bases at the two locations?

Expression (8) gives the probability limit of the basis-on-basis estimator as it depends on the parameters of the covariance matrix $\mathbf{\Sigma}$:

$$plim\ \hat{\delta} = f(\sigma_{iT},\ \sigma_{TF},\ \omega,\ \sigma_T^2,\ \sigma_F^2), \tag{9}$$

where ω is defined in equation (7).

Calculating the derivative of $plim\ \hat{\delta}$ from expression (8) with respect to σ_{TF} results in

$$\frac{\partial f}{\partial \sigma_{TF}} = \frac{(1-\omega)\sigma_F^2 - (1+\omega)\sigma_T^2 + 2\sigma_{iT}}{D^2}, \tag{10}$$

where D is the denominator of expression (8).

In general, equation (10) cannot be signed for arbitrary covariance parameters; a simultaneous weakening of the correlation between futures and both cash prices can either weaken or strengthen the relationship between b_{it} and b_{Tt}. However, if $\omega = \sigma_{iF}/\sigma_{TF} = 1$ and if $\beta_{iT} < 1$, then equation (10) is negative. The condition $\beta_{iT} < 1$ indicates that an increase in the market T price implies a smaller change in the market i price. If this holds, then for $\omega = 1$ (and in fact for all values of ω greater than a number less than 1), the derivative of the probability limit in expression (5) with respect to σ_{TF} is negative; the spatial basis relationship (δ in equation 4) weakens with higher degrees of correlation between cash and futures and strengthens with lower degrees of correlation. To preview our empirical results, we find a tighter connection between b_i and b_T during the nonconvergent episodes when spot prices were less connected to futures prices.

Data

GeoGrain, Inc., collects grain bid prices from over 3,500 grain buyers in the United States every trading day. Prices are collected on corn, soybeans, five classes of wheat, and minor grain and oilseed crops. Along with spot bids for immediate delivery, forward prices are collected for delivery up to a year in advance. The price gathered from grain buyers is referred to as a "posted bid price," a common metric used in the industry. It is reported by the grain buyer after the futures market has closed at the end of the day and represents the price they are willing to pay for grain delivered that meets normal grading standards. No premiums or discounts for quality or moisture are reported in the prices.

The data used in this study comprise a subset of data from GeoGrain, Inc., for soft red winter wheat (SRW) in the eastern United States, the variety of wheat that is deliverable against the CBOT wheat contract. The markets represent a wide array of merchants and users, including millers, export terminals, local co-ops, and delivery terminals for the underlying CBOT wheat futures contract. Each market is geocoded for the delivery location of the grain, providing an exact reference for calculating distance to the delivery location. Figure 1 displays all the buying points from which GeoGrain, Inc., reports bids for SRW—the area of buying locations corresponds to the part of the country that grows SRW. Notice a dense cluster of buying points near Toledo, Ohio, and a more diffuse cluster of buying points in Illinois, spread between the delivery points of Chicago and St. Louis.

Figure 1. GeoGrain, Inc., Buying Points for Soft Red Winter Wheat

Data from the cash grain markets are matched to daily settlement prices of CBOT SRW futures contracts. There are five delivery months in each year: March, May, July, September, and December. We collect data over the lives of all contracts from March 2005 through May 2013. Two futures contracts (December 2011 and March 2012) are missing cash price data, yielding daily data on 40 different wheat contracts and contemporaneous cash prices.

The widely noted failures to converge in wheat futures contracts are illustrated in figure 2. The average values of basis are plotted over the last 20 days of trading for each of the 40 contracts and for each of three CBOT delivery locations in Toledo, Chicago, and St. Louis. Each point plotted measures the extent to which the spot price at a delivery location deviated from the futures price in the 20 days prior to delivery—a time when fundamental notions of market efficiency predict that futures prices should be converging to spot prices. The convergence behavior across contracts was broadly similar across the three delivery locations, and spot prices were significantly below futures prices at the time of expiration for several contracts during 2008 and 2009.

Figure 2 identifies three periods: before nonconvergence, nonconvergence, and after nonconvergence. This demarcation requires judgement because basis near contract expiration is never exactly 0 and varies continuously. We maintain the separation into three regimes in part from the evidence in figure 2 and, in part, from the received literature. The CME Group has reported that the nonconvergence issue in wheat markets started after the expiration of the March 2008 contract and ended before the expiration of the March 2010 contract (Seamon, 2010). We consider years 2005–2007 and the first (March delivery) contract in 2008 to be before nonconvergence. The remaining four contracts in 2008 and all five contracts in 2009 we take to be in the nonconvergence period. All observed contracts in 2010–2013 we take to be after nonconvergence. Our categorization leans in the direction of labeling nonconvergent contracts as convergent.[7] By possibly mixing nonconvergent contracts into the periods before and after nonconvergence, we bias our results in favor of finding no significant differences across periods.

We report 20-day averages in figure 2 to smooth across daily changes. However, note that the earlier parts of the 20-day windows do not occur during delivery periods and so large absolute basis

[7] Note that Hoffman and Aulerich (2013) define a generally acceptable basis level during delivery period as ±10¢/bu.

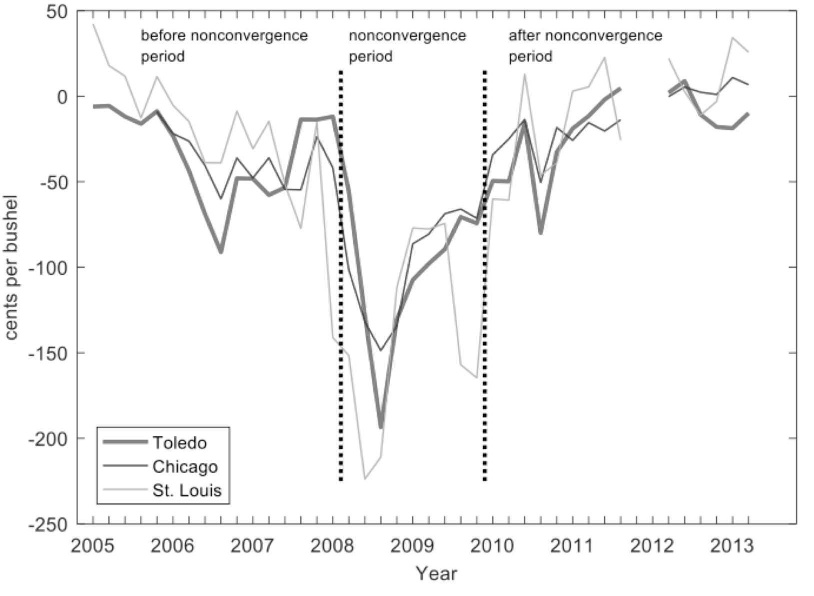

Figure 2. Wheat Basis at Delivery Locations

Notes: Average over the 20 days prior to contract expiration.

in those days does not necessarily indicate a failure to converge. Before nonconvergence, absolute basis in Toledo was typically less than 50¢/bu in the 20 days prior to expiration, with spot price below futures. Failures to converge were large and persistent starting with the May 2008 contract, reaching a peak of $2.00, again spot below futures, in the September 2008 contract. As seen in figure 2, the behavior of basis and convergence for the three delivery locations is similar. In what follows, we focus on basis relationships relative to the Toledo delivery location. Toledo's economic significance as a wheat delivery location is due to the port of Toledo on Lake Erie, which connects to export routes through the Saint Lawrence Seaway.

In order to focus on a delivery-relevant area, we identify all markets within 100 miles of Toledo. Further, we only analyze locations (markets) that have sufficient observations in both convergent and nonconvergent periods to make meaningful comparisons. A thorough visual review of the data resulted in the removal of a number of observations and several markets due to apparent price reporting anomalies. We are left with a total of 141,411 observations on 106 markets; their locations can be seen in figure 3.[8]

Empirics

Our empirical method is to analyze panel regression models fit to daily data on basis[9] from the 106 buying locations over the 40 observed wheat futures contracts during 2005–2013. The daily observations from each market come from the days on which the contract in question is the near-delivery contract. Typically a given contract is the nearest to delivery for approximately 60 trading days.[10] The first model incorporates fixed effects (FE) for market and futures contract. We call it an

[8] The percentages of market-specific observations over total observations range from 0.24% to 1.25%. In addition, among the 106 markets the minimum (maximum) percentages of observations before, during, and after nonconvergence are 4.58% (72.84%), 0.94% (84.10%), and 2.39% (68.07%).

[9] Basis series are tested for stationarity using Fisher-type panel unit root tests suitable for unbalanced panel data. Results from both the Augmented Dickey–Fuller and Phillips–Perron tests strongly reject the existence of a unit root in all series.

[10] The price data on a given futures contract start after the near-delivery contract expires so that there are no overlapping contracts on a given day. This eliminates possible contemporaneous correlation among futures prices.

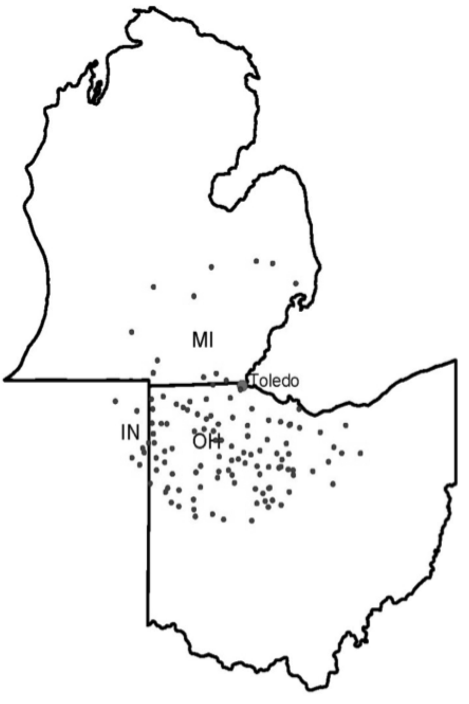

Figure 3. Buying Points within 100 Miles of Toledo

additive FE model:

$$(11)\quad \begin{aligned} b_{ikt} &= \alpha_i + \varphi_k + \delta_{0i} b_{kt}^{Toledo} + \psi_{1i} b_{kt}^{Toledo} D_k^{nonconv} + \psi_{2i} b_{kt}^{Toledo} D_k^{after\ nonconv} + \varepsilon_{ikt}, \\ i &= 1, \ldots, 106 \text{ (markets)}, \\ k &= 1, \ldots, 40 \text{ (all contracts from March 2005–May 2013} \\ &\quad \text{except December 2011 and March 2012)}, \\ t &= 1, \ldots, \sim 60 \text{ (days up until contract expiration)}, \end{aligned}$$

where b_{ikt} is the basis in market i for contract k on day t. The dependent variable, basis, is calculated as $b_{ikt} = P_{ikt} - F_{kt}$, where P_{ikt} is the local price at market i on the tth day of the kth futures contract and F_{kt} is the nearby futures price on that day. On the right side, b_{kt}^{Toledo} is the same basis calculation at Toledo. The variable $D_k^{nonconv}$ is a dummy variable indicating nonconvergent contracts, and $D_k^{after\ nonconv}$ is the dummy variable indicating after-nonconvergence contracts. The omitted category comprises before-nonconvergence contracts from March 2005 to March 2008.

The model allows for both market-specific (α_i) and contract-specific (φ_k) fixed effects and also allows for the relationship between market i's basis and basis at the Toledo futures delivery point to vary by market (δ_{0i}). Further, the market-specific comovement coefficient is allowed to change across convergence regime boundaries (ψ_{1i} and ψ_{2i}). It is these changes in comovements that are of primary interest in the present paper. The model is estimated by ordinary least squares and robust standard errors are clustered at the market-contract level to account for possible spatial autocorrelations across markets on a given trading day and for heteroskedasticity across observations on a given market. The distribution of the estimated parameters is reported in table 1.[11]

[11] The complete set of estimation results is available from the authors upon request.

Table 1. Comovements with Toledo Delivery Location in an Additive FE Model

	Fixed Effects (¢/bu): α_i (1)	Comovement Before Nonconvergence: δ_{0i} (2)	Comovement During Nonconvergence: δ_{1i} (3)	Comovement After Nonconvergence: δ_{2i} (4)	Change in Comovement (Before to During): $\delta_{1i} - \delta_{0i}$ (5)	Change in Comovement (During to After): $\delta_{2i} - \delta_{1i}$ (6)	Change in Comovement (Before to After): $\delta_{2i} - \delta_{0i}$ (7)
n	106	106	106	106	106	106	106
Mean	−12.34	0.57	0.82	0.66	0.25	−0.16	0.09
Min	−41.88	−0.41	0.50	0.06	−0.52	−0.63	−0.53
Max	17.23	1.38	0.99	1.07	1.28	0.20	1.48
10th percentile	−24.36	0.47	0.78	0.51	0.13	−0.31	−0.12
90th percentile	−2.73	0.70	0.88	0.83	0.37	0.00	0.26
Counts:							
Significantly $> 0^*$		99 (93%)	106 (100%)	104 (98%)	23 (22%)	0 (0%)	8 (8%)
Significantly > 0 and $< 1^*$		98 (92%)	106 (100%)	103 (97%)			
Number > 0		104 (98%)	106 (100%)	106 (100%)	104 (98%)	12 (11%)	72 (68%)
Significantly $< 0^*$		1 (1%)	0 (0%)	0 (0%)	1 (1%)	35 (33%)	2 (2%)

Notes: Summary statistics from a linear regression using daily data from 106 markets, 40 contracts over 2005–2013 (N = 141,411). Before nonconvergence contracts are all of 2005–2007 plus March 2008 (16 contracts). Nonconvergence contracts are May 2008 to end of 2009 (9 contracts). After nonconvergence contracts are all of 2010–2012 plus March and May 2013, excluding December 2011 and March 2012 for data availability reasons (15 contracts). Single asterisk (*) indicates statistical significance measured at the 5% level with one-tailed tests.

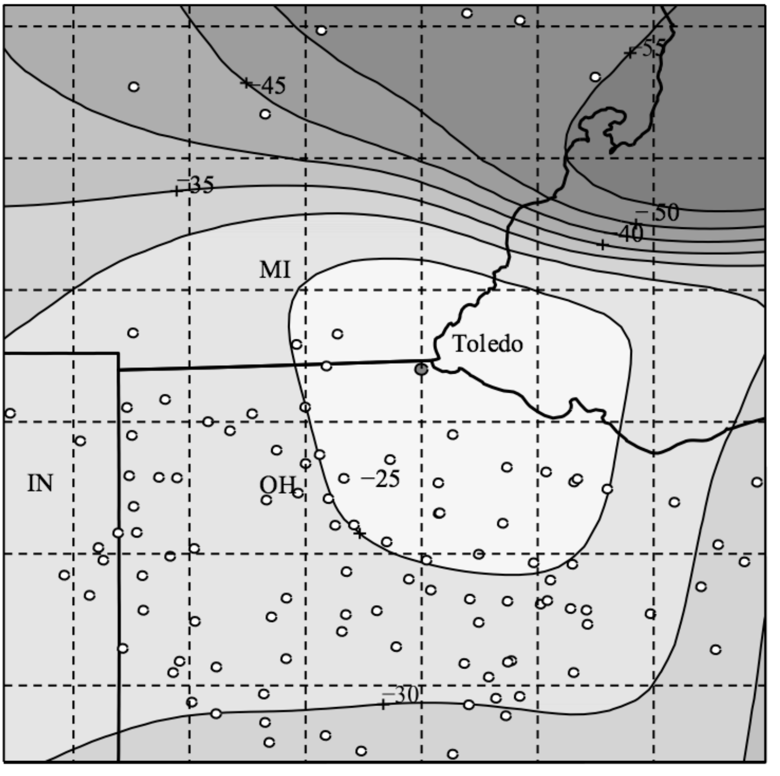

Figure 4. Predicted Basis by Market Location

Notes: Calculated for Toledo basis = 20¢ and with smoother std. dev. = 20 miles.

Predicted Basis

The estimated model provides a prediction of basis at each market given a value of basis at Toledo. The primary source of variation in basis is the variation in market fixed effects, which are described in column 1 of table 1. The values of the fixed effects are not meaningful in themselves, but their range expresses the range of expected basis across the sample, conditional on Toledo basis. Their range reflects a spread of predicted basis across markets of 59¢/bu. For comparison, the average SRW spot price over the sample is 551¢/bu. The 10th–90th percentile range of fixed effects accounts for a range of over 22¢/bu.

The fixed effects for the 106 markets are smoothed over space with a bivariate normal kernel smoother, and the contours of the smoothed surface are displayed in figure 4.[12] A clear peak for predicted basis is found over Toledo with basis declining asymmetrically as distance to the delivery location increases. Economic theory suggests that the price of grain (hence, basis) should decline as one moves farther away from a delivery location due to the costs of transportation. This is exactly what the results from the additive FE model show.[13]

[12] The kernel smoother constructs a three-dimensional surface of expected basis from the three-dimensional geographic scatter of the 106 predicted basis points. The height of the surface at each latitude–longitude pair is the weighted average of all 106 points, where the weights derive from a bivariate normal probability density function centered at the point in question. The weights are normalized to sum to 1. The probability density function sets the variance parameters to be equal to one another in the latitude and longitude dimension and sets the covariance parameter to 0. Thus, the kernel has circular iso-density contours. The results we report are robust to different choices of bandwidth; in the figures that appear in the paper, the standard deviation of the kernel is set to 20 miles.

[13] We also analyzed directly the contemporaneous price differences between Toledo and nondelivery locations in a FE model that allows the price difference to vary by market and, for a given market, across convergence regimes. The estimated model is

$$P_{it} - P_T^{Toledo} = \alpha_i + \psi_{1i} D_t^{nonconv} + \psi_{2i} D_t^{after\ nonconv} + \varepsilon_{it},$$

Basis Comovement with Toledo Basis

Table 1 also reports summary statistics and measures of statistical significance for the estimates of the market-specific comovement effects in the three regimes: δ_{0i}, $\delta_{1i} \equiv \delta_{0i} + \psi_{1i}$, and $\delta_{2i} \equiv \delta_{0i} + \psi_{2i}$. Consider first the estimates of δ_{0i}, comovement before nonconvergence. Their mean across the 106 markets is 0.57, reflecting a somewhat damped response on average to basis changes at Toledo: a 1¢ basis change at Toledo is associated with a 0.57¢ change in basis, on average, in nondelivery markets. The estimates cluster fairly closely together, with a 10th–90th percentile range of 0.47–0.70. The large majority of the estimates (93%, or 99 out of 106) are statistically significantly positive (at the 5% level with one-tailed tests), and the great majority (92%) are statistically significantly greater than 0 and less than 1.

Column 3 of table 1 reports the estimates of δ_{1i}, basis comovement during nonconvergence. The distribution of comovement parameters shifts sharply and significantly to the right compared to the earlier, convergent period. The mean comovement parameter changes from 0.57 before nonconvergence to 0.82 during nonconvergence: nondelivery buying points are more closely tied to the Toledo delivery point during nonconvergence than previously. The 10th–90th percentile range spans 0.78–0.88, with no overlap between that range and its before-nonconvergence counterpart. Further, during nonconvergence, 100% of the estimates are statistically significantly positive and significantly less than 1.

Figure 5 displays the full distribution of the δ parameters—a graphical representation of the estimates summarized in table 1. The densities show the clear shift to the right during nonconvergence from before (δ_o) to during (δ_1) and also the shift back afterward (δ_2), when nonconvergence has ended. Figure 5, however, does not settle the issue of statistical significance. The test results in table 1 show that the market-by-market movements between convergence regimes are indeed statistically significant shifts. Column 5 reports the summary of market-by-market hypothesis tests. Across the 106 markets, 23 reject the null hypothesis that the comovements are the same in the two periods in favor of an alternative hypothesis that comovement is greater during nonconvergence. Thus, in 22% of the markets, comovement during nonconvergence is deemed greater than the comovement before nonconvergence. In 83 markets, comovements during nonconvergence are less than comovements before nonconvergence.

Finally, consider how the estimated comovement parameters change again from the nonconvergence period to the period after nonconvergence. Column 4 of table 1 reports that the mean coefficient becomes closer to its before nonconvergence level; the mean is 0.66 after nonconvergence compared to 0.57 before nonconvergence. The 10th–90th percentile ranges are also similar before and after nonconvergence. Further, the statistical tests provide some support that, market by market, the comovement coefficients decline between the nonconvergence period and afterward. In 33% of the markets, a null of constant parameters is rejected in favor of the alternative that the parameters declined; in none of the markets is there a statistically significant increase in comovement between nonconvergence and afterward.

The shift back in the δ_{2i} distribution can plainly be seen in figure 5. Consistent with the numerical evidence from table 1, the distribution of comovement parameters shifts clearly and dramatically to

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where subscript i denotes market and t denotes trading day. The dummy variables on the right side denote the nonconvergence and after nonconvergence periods. We refer to the left side variable as direct basis, as it makes no reference to futures price. The model calculates the average value of direct basis for each market and in each regime. Estimation versions of the model show that the averages of direct basis across markets are broadly similar during the three periods: -15.9¢ before nonconvergence, -13.7¢ during nonconvergence, and -17.2¢ after nonconvergence. In terms of variation, there were modest changes across regimes in the spread of direct basis across markets. Before nonconvergence, the spread between the 10th and 90th percentiles of the direct basis distribution was 20.2¢. During nonconvergence the spread was 23.4¢, and after nonconvergence it was 15.1¢. To summarize, the gap between the price at Toledo and prices at nondelivery locations narrowed modestly during nonconvergence (average direct basis was the smallest in absolute value across the three regimes); the distribution of direct basis across markets is modestly wider during the nonconvergence regime. Neither effect seems large in economic terms.

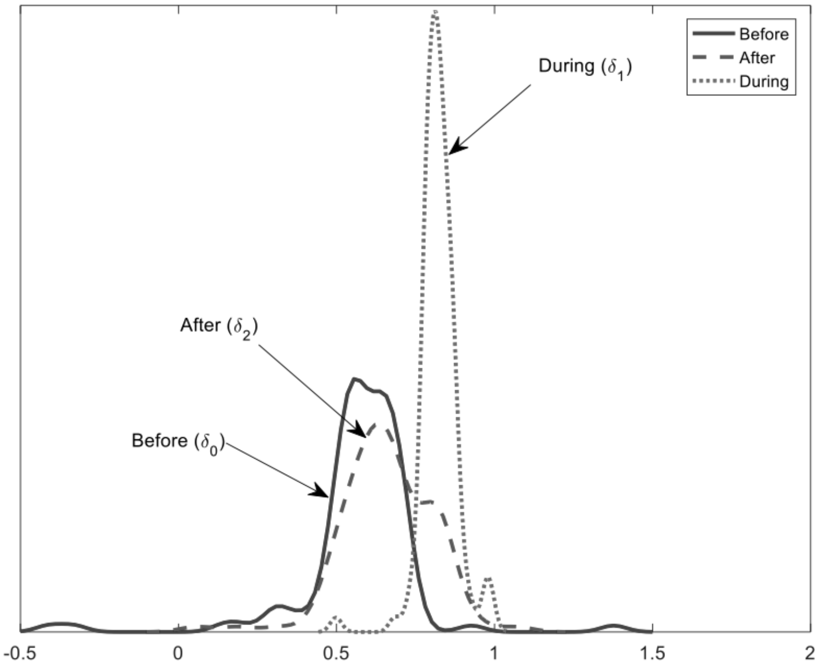

Figure 5. Delivery Comovements Distributions: Before, During, and After Nonconvergence—Additive FE Model

the left in the later period, during which convergence performance at the delivery market was fairly good.

Column 7 of table 1 reports statistical tests of the constancy of comovement parameters between the periods before and after nonconvergence. While there are mostly statistically insignificant changes in comovement coefficients between these periods, the statistically significant changes are divided between those that increased (8% of markets) and those that decreased (2% of markets).

Basis Comovement: Multiplicative FE Estimates

The additive FE model just discussed allows intercepts and slope parameters to vary across the 106 markets (while allowing slopes to vary in market-specific ways across convergence regimes). The only parameters assumed constant across markets are the contract fixed effects (φ_k): an assertion that basis can systematically change across the 40 contracts, but that the parameter changes are the same among the 106 markets. We examine the robustness of our results to a much more generously parameterized model, one with market fixed effects, contract fixed effects, and fixed effects for all interactions between markets and contracts. Thus, while the additive FE model estimates 106 (markets) + 40 (contracts) = 146 intercept shift parameters, the multiplicative FE model estimates $106 \times 40 = 4,240$ intercept shift parameters.

We estimate the multiplicative FE model to test the robustness of our results to a relaxing of what could be a restrictive assumption. Each market in the multiplicative FE model has its own intercept (α_i) and slopes (δ_{0i}, ψ_{1i}, ψ_{2i}) as in the additive FE model but also has its own set of 40 contract fixed effects (φ_{ik}). Thus, the multiplicative FE model can be expressed as equation (11) with φ_k replaced with contract fixed effects, φ_{ik}. Each of these time series regressions is more profligate in its use of market-specific shift parameters. Further, possible spatial correlation and heteroskedasticity are accommodated by the use of clustered robust standard errors at the market-contract level, allowing

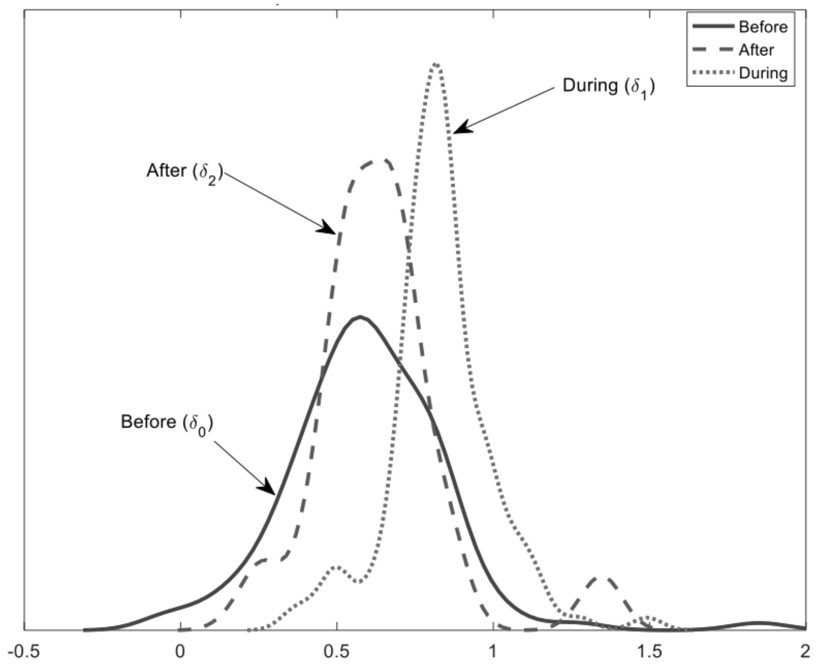

Figure 6. Delivery Comovements Distributions: Before, During, and After Nonconvergence—Multiplicative FE Model

observations on different markets to be correlated within a contract (i.e., the cluster). The estimates from the multiplicative FE model are reported in table 2 and displayed in figure 6.

In short, the increase in comovement from before to during nonconvergence (from δ_0 to δ_1) is visually evident in the distribution in figure 6. So, too, is the shift back (from δ_1 to δ_2). But the estimated shifts are less pronounced than those from the additive FE model.

Table 2 demonstrates the size and statistical significance of the δ parameter shifts seen in figure 6. The mean of the δ_{0i} (before) parameters is 0.59. The mean of the δ_{1i} (during) parameters is a substantially larger 0.80. Market by market, 19% of the δ_{1i} estimates are statistically significantly greater than their δ_{0i} counterparts, and only 3% are significantly less.

The left shift from the δ_{1i} (during) distribution to the δ_{2i} (after) distribution is evident but less dramatic in the multiplicative FE model. In 22% of the markets, the δ_{2i} estimate is significantly less than the δ_{1i} estimate; in only 5%, the δ_{2i} estimate is significantly greater than the δ_{1i} estimate. Overall, the comovement parameters decline from an average of 0.80 during nonconvergence to an average of 0.67 after nonconvergence.

To broadly summarize and compare the two FE approaches, the temporal sequence of across-market average of comovement parameters in the additive model is 0.57 (before), 0.82 (during), and 0.66 (after). The corresponding sequence in the multiplicative model is 0.59 (before), 0.80 (during), and 0.67 (after)—virtually the same.

Conclusion and Discussion

Motivated by the importance of basis in hedging decisions and forecasting local prices, our study analyzes the potential impact of nonconvergence experienced in futures markets on the spatial relationships in basis patterns. Specifically, we analyze the basis-to-basis relationship for soft red winter wheat for markets surrounding futures contracts' delivery location, Toledo.

Table 2. Comovements with Toledo Delivery Location in a Multiplicative FE Model

	Fixed Effects (¢/bu): $\beta_{ik} \equiv \alpha_i + \phi_{ik}$ (1)	Comovement Before Nonconvergence: δ_{0i} (2)	Comovement During Nonconvergence: δ_{1i} (3)	Comovement After Nonconvergence: δ_{2i} (4)	Change in Comovement (Before to During): $\delta_{1i} - \delta_{0i}$ (5)	Change in Comovement (During to After): $\delta_{2i} - \delta_{1i}$ (6)	Change in Comovement (Before to After): $\delta_{2i} - \delta_{0i}$ (7)
n	3,643	106	106	106	106	106	106
Mean	−30.15	0.59	0.80	0.67	0.21	−0.14	0.07
Min	−275.44	−0.04	0.38	0.15	−1.40	−1.06	−1.05
Max	84.41	1.85	1.47	1.39	0.77	0.57	0.78
10th percentile	−62.96	0.32	0.61	0.49	−0.07	−0.41	−0.23
90th percentile	−3.93	0.84	0.97	0.86	0.53	0.15	0.39
Counts:							
Significantly $> 0^*$		94 (89%)	106 (100%)	103 (97%)	20 (19%)	5 (5%)	10 (9%)
Significantly > 0 and $< 1^*$		91 (86%)	96 (91%)	99 (93%)			
Number > 0		104 (98%)	106 (100%)	106 (100%)	91 (86%)	26 (25%)	69 (65%)
Significantly $< 0^*$		0 (0%)	0 (0%)	0 (0%)	3 (3%)	23 (22%)	4 (4%)

Notes: Summary statistics from a linear regression using daily data from 106 markets, 40 contracts over 2005–2013 (N = 141,411). Before nonconvergence contracts are all of 2005–2007 plus March 2008 (16 contracts). Nonconvergence contracts are May 2008 to end of 2009 (9 contracts). After nonconvergence contracts are all of 2010–2012 plus March and May 2013, excluding December 2011 and March 2012 for data availability reasons (15 contracts). Single asterisk (*) indicates statistical significance measured at the 5% level with one-tailed tests.

Economic theory indicates that spot prices of soft red winter wheat are connected by transportation costs and local supplies and demands. Our results suggest that these relationships are modestly weakened by the failures to converge in the wheat futures market. But the connections between basis in about one-quarter of the nondelivery locations and basis at the delivery node became statistically stronger during a historical period of nonconvergence, a result that can be explained by the weaker relationship between futures and all cash prices during nonconvergence. Basis in nondelivery locations was less closely connected to basis at Toledo before and after nonconvergence.

Note that there are two ways to state this result. The first is that failures to converge are propagated spatially throughout the grain marketing system—at least for the Toledo delivery basin and for a nontrivial portion of the markets studied. Weak basis at the delivery location translates into weak basis far away. The second is that the fact that futures prices do not converge at expiration to spot price at a delivery point has to do with the specification of the futures contract (which is the argument advanced in various forms in Irwin et al. 2008; 2009; 2011 and Garcia, Irwin, and Smith 2014) and not with factors fundamental to the prices of wheat.

Producers located near and away from the delivery point might have thought that they were fully hedged, but it turned out that they were not due to nonconvergence at Toledo. Further, our results demonstrate that the signal from the delivery location as to the unhedgeable component of risk—basis—is as informative or more informative during periods of nonconvergence as it is before and after.

We have taken a fairly nonparametric approach to the economic relationship between spot prices in nondelivery locations and the spot price at a delivery location. A fruitful area for further research would be incorporating more economic structure and taking explicit empirical account of transportation costs and local supply and demand conditions. Such an approach could yield further insight into the basis relationship between delivery and nondelivery locations.

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