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Estimating the Location of World Wheat Price Discovery

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Estimating the Location of World Wheat Price Discovery

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Abstract: The United States may be losing its leadership role in the world wheat market. Rising trading volume in foreign futures markets and shifting shares of world trade are suggested as evidence of this shift, but neither necessitates that futures markets in the United States are any less important for wheat price discovery. This paper applies market microstructure methods including the Yan and Zivot (2010) information leadership share to estimate the proportion of price discovery occurring in wheat futures markets in Chicago, Minneapolis, and Paris. We find that United States markets still dominate wheat price discovery, although the share of price discovery for the Paris market jumped noticeably in 2010 coinciding with major supply shocks in Russia and Ukraine.

Key words: wheat, price discovery, futures, market microstructure, information share .

JEL Classification Numbers: Q11, G13

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The United States (US) has been considered a world leader in the pricing, production, and trade of major grains. US wheat futures market prices are viewed as benchmarks, establishing the value of wheat for the entire world. Historically, the US led the world in the production and export of wheat. Today that leadership role is challenged by states in the former Soviet Union, the European Union, Canada, and Australia. USDA projections for global wheat markets as of October 2016 show the US as the third-leading producer of wheat (with 8.4% of forecasted global production in 2016/2017) behind the EU and Russia, and the second-leading exporter (providing 15.1% of traded wheat) behind Russia.

Two concurrent trends suggest that the prominence of the US in world wheat markets is not assured. First, the US share of world wheat trade has declined as production and exports of wheat from Kazakhstan, Russia, and Ukraine (KRU) increased. US export share has declined consistently since the early-1980s, when US wheat made up over 40% of the export market, on average; at that time, KRU exports were virtually nonexistent. KRU exports are projected to grow through at least 2024 Westcott and Hansen (2015). Second, US benchmark prices are being supplanted by new price benchmarks that more closely track supply and demand fundamentals in KRU. Indeed one French grain trader went as far as to suggest that "The market is not done in Chicago anymore. Prices of the European continent have taken the leadership of the world wheat market" (de la Hamaide, 2016).

Historically, futures exchanges located in the United States have been the world's deepest and most liquid agricultural commodity markets with frequent transactions occurring between a large number of buyers and sellers. This market liquidity is thought to provide more efficient and timely price discovery. Accordingly, traders of a given commodity tend to congregate at the most liquid exchange where trading is frequent and price discovery is best. In the case of wheat, futures trading is not concentrated on a single exchange.

Currently, active wheat futures contracts are traded on multiple exchanges: the Chicago Mercantile Exchange, which trades both Chicago Soft Red Winter Wheat futures and Kansas City Hard Red Winter Wheat futures, the Minneapolis Grain Exchange, and the Euronext exchange in Paris, also sometimes referred to by its former French acronym, MATIF[1]. As shown in figure 1, average monthly trading volume, or the number of contracts traded on each exchange, of Paris wheat futures contract is clearly growing in importance relative to the markets in Chicago, Kansas City, and Minneapolis. Anecdotal evidence suggests that the Paris wheat market is thought to provide better price discovery and risk management for farmers, traders, and end-users involved in the marketing of KRU-origin grain (de la Hamaide, 2016).

[1]For clarity, we refer to these markets by the city in which they were founded through the remainder of this article.

This paper examines the price discovery process among four major wheat futures markets in the context of the globally distributed set of shocks to supply and demand fundamentals for the underlying physical commodity. Using transaction price information from the most heavily traded futures markets, we identify the proportion of wheat price discovery occurring in each market. In doing so, we study whether new wheat price benchmarks are complements or substitutes for the leadership role traditionally played by US wheat futures markets and whether the increasing importance of production outside the US is associated with a diminished role for US markets in the price discovery process.

Our results have important implications for the US wheat industry, and are therefore of significant concern to producers, merchants, end-users, and policy makers. A shift in the location of price discovery may be related to declining export competitiveness of the US in world markets. For farmers, merchants, and consumers in the United States, the loss of price discovery at nearby futures exchanges means that prices in local markets - for example, the prices of wheat offered at a grain elevator in rural America (which are directly connected to futures prices via spatial and intertemporal arbitrage) - are affected to a greater degree by developments, like bumper crops, droughts, and floods in more distant markets.

If US supply and demand shocks dominate the world price of wheat (and domestic derivatives markets function well), the US would likewise dominate the price discovery relationship between US and international wheat futures. Expanding trade naturally reduces barriers to international price transmission; when foreign exporters make up a larger share of the export market, their fundamental shocks affect US participants more easily. The question of which exchange discovers these shocks first is affected by market structure and liquidity. Our research provides empirical evidence about the correlation between shifting trade patterns and the US role in price discovery.

To test the importance of the Paris wheat futures market relative to US markets, we apply market microstructure methods, specifically the Hasbrouck (1995) information share, Harris, McInish, and Wood (2002) component share, and Yan and Zivot (2010) information leadership share, to measures the proportion of a common fundamental value for the underlying commodity revealed in each market. These methods require high frequency intraday data on futures market transaction prices. While daily settlement prices as shown in figure 2 clearly suggest that a common factor is related to prices in each market, the time-scale of such data is not fine enough to reveal which market moves first in response to changes in this common factor, a widely used definition of price discovery in the literature.

Measuring Price Discovery

Price discovery is one of the central economic functions of modern agricultural futures markets. US law governing derivatives trading codifies this purpose, stating that agricultural futures markets operate in the national interest to "provid(e) a means for managing and assuming price risks, discovering prices, or disseminating pricing information through trading in liquid, fair and financially secure trading facilities" (US Code Title 7, Ch. 1, Sec. 5). To fulfill this price discovery and dissemination purpose, markets must incorporate information about the value of the underlying commodity into prices in a timely manner. Information should be incorporated via bonafide transactions or standing bids and offers whose prices are known to all market participants.

Price discovery has been actively studied in the segment of the financial literature known as empirical market microstructure. Empirical price discovery measurement considers prices in markets for similar goods or related financial instruments. These markets hold in common the same fundamental forces that determine equilibrium prices, so that arbitrage prevents prices in one market from deviating from another by a large amount or for a long amount of time. This literature generally uses high-frequency intraday transactions data from multiple markets to estimate the relative proportion of price discovery that occurs in each market. Related markets in this literature include stocks cross-listed on multiple exchanges, futures and cash markets, options and futures markets, different contract maturities in a single futures market, electronic and open-outcry futures markets, and others. Putniņš (2013, p. 78) provides a comprehensive summary of price discovery analyses in the empirical market microstructure literature.

While commonly applied to financial markets, empirical market microstructure methods are relatively novel in the context of agriculture. Past applications include measurement of price discovery in electronic and open-outcry futures markets (Martinez et al., 2011; Shah and Brorsen, 2011) and estimation of bid-ask spreads and other measures of market quality and trading costs in livestock, grain, and cotton markets (Frank and Garcia, 2010; Shah, Brorsen, and Anderson, 2012; Janzen, Smith, and Carter, 2014). Market microstructure price discovery methods have also been applied to data measured in time intervals not commonly thought to be "micro" in the context of this literature. For example, Arnade and Hoffman (2015) estimate the relative proportion of price discovery in daily cash and futures market prices for soybeans and soybean meal.

Structural and Reduced-form Models of Price Discovery

Price discovery measures developed in the empirical market microstructure literature are based on an underlying structural model of the data generating process governing prices that is related to an estimable reduced-form vector error correction model (VECM). Using a VECM is intuitive in this case where prices for single commodity in multiple markets are thought to share a common long-run relationship represented by the error correction term in the VECM.

The structural model of the data generating process for prices in related markets begins with a single fundamental value or efficient price for the commodity. The fundamental value is conceptually the unobservable equilibrium price that reflects all available information about the supply and demand for the commodity at a given point in time. The fundamental value is assumed to follow a random walk,

$$m_t = m_{t-1} + u_t, \tag{1}$$

where u_t is an i.i.d. shock with mean zero and standard deviation σ_u. Since innovations in this random walk u_t are immediately and permanently impounded into observed prices, the random walk component represents the single underlying fundamental value that drives prices in all markets.

Prices in each of n markets follow the common fundamental value. Deviations in prices from the fundamental value are transient, so observed prices cointegrated. Denote the vector of prices observed at period t as $\mathbf{p_t}$. The price vector has a vector error correction representation, truncated at some lag K and expressed in first-differences as:

$$\Delta \mathbf{p_t} = \alpha(\beta \mathbf{p_t} - \mu) + \sum_{k=1}^{\infty} \Gamma_k \mathbf{p_t} + \mathbf{e_t}. \tag{2}$$

$\mathbf{p_t}$ is $I(1)$ or cointegrated of order one and, since there is a single fundamental value, there are $n-1$ cointegrating vectors β where $\beta_{\mathbf{i}}{}'\mathbf{p_t} = 0$. The known cointegrating vector ($[1\ -1]'$ in the most basic two price case and given for the $n > 2$ case in Yan and Zivot (2007)) assumes the difference between the first price $p_{1,t}$ and each subsequent price is $I(0)$.

μ are the expected differences or spreads between prices in the first market and each subsequent market. μ represents the known differences in prices between markets due to known differences in value based on location and quality attributes. $\mathbf{e_t}$ are the reduced form error terms with $E(\mathbf{e_t}) = 0$ and variance-covariance matrix $\mathbf{\Sigma_e}$. α are the error correction coefficients that represent the speed at which each market adjusts its price to maintain the long-run cointegrating relationship.

Based on the concept of a random-walk fundamental value and a VECM framework for prices in multiple markets, two measures of price discovery were independently developed to separate variation in observed prices into a permanent component associated with the fundamental value random walk and a transitory component related to frictions in the trading process. Potential sources for such noise are temporary imbalances in order flow, bid-ask bounce, and tick discreteness.

Hasbrouck (1995) developed one measure, known as the information share (IS) using the innovations from a reduced-form vector error correction model similar to equation 2. IS measures the proportion of the variance in the fundamental value explained by innovation in a particular series. The variance of the permanent component is $\psi' \mathbf{\Sigma_e} \psi$, where ψ is the cumulative impact of the reduced-form errors on prices. If the reduced-form errors are correlated, $\mathbf{\Sigma_e}$ is not diagonal and correlation between the reduced-form errors makes it more difficult to ascertain which market leads in terms of price discovery. In the extreme where the reduced-form errors are perfectly correlated, adjustment to changes in the fundamental value are identical across markets and neither market dominates price discovery.

When $\mathbf{\Sigma_e}$ is not diagonal, the IS measure cannot uniquely attribute covariance in the reduced form errors to each market, so Hasbrouck (1995) uses a Cholesky decomposition to orthogonalize the errors. If $\mathbf{F}$ is the Cholesky decomposition of $\mathbf{\Sigma}$ such that $\mathbf{FF}' = \mathbf{\Sigma}$, then the information shares are:

$$IS = \frac{(\psi' \mathbf{F})^2}{\psi' \mathbf{\Sigma} \psi}. \tag{3}$$

. Since the calculation of IS depends on the orthogonalization and thus the order of the variables in $\mathbf{p_t}$, he suggests considering all orderings of the variables in $\mathbf{p_t}$ and calculating upper and lower bounds for the share of information discovered in each market.

The other price discovery measure, known as the component share (CS), was derived from work byGonzalo and Granger (1995) on permanent-transitory decompositions in the context of cointegrated variables. While a number of scholars independently applied CS to measure price discovery, the literature often attributes it to Harris, McInish, and Wood (2002). The CS uses the error correction coefficients α to calculate the normalized weights of each price in the linear combination of prices that form the common fundamental value. Harris, McInish, and Wood (2002) show that the CS of the first market in $\mathbf{p_t}$ can be calculated as

$\alpha_2/(\alpha_2 - \alpha_1)$.

Both the IS and CS measures fail to identify price discovery in the case where changes in observed prices (and therefore the reduced-form errors and error correction terms) are highly correlated. This arises when prices are observed at low time frequency, so that intraday price data is nearly always necessary to apply these measures. This may explain why applications of market microstructure price discovery methods are rare in the agricultural economics. Agricultural futures markets were some of the last to move away from open-outcry trading where intraday price data is not readily made available.

Timeliness and Efficiency in Price Discovery Measurement

Both IS and CS are calculated from parameters estimated using a reduced-form VECM similar to equation 2. However, each measure requires a structural model to be related to the price discovery process inherent in the random-walk component given in equation 1. Lehmann (2002) noted that many applications often ignore, leave unspecified, or fail to test the assumptions of this structural model, which has confounded interpretation of IS and CS in the context of price discovery and generated some confusion about what these measures actually represent. The two measures are related since they are both derived from the estimation of the same VECM, however the nature of this relation is ignored in the literature.

Two recent papers by Yan and Zivot (2010) and Putniņš (2013) do much to alleviate this confusion by showing that Interpretation of IS and CS relies on structural relation between observed prices and the random walk. They explicitly connect the IS and CS measures to a common generalized model of the data generating process for prices in related markets.

Based on the definition of the price discovery in Lehmann (2002) as the "efficient and timely incorporation of the information into market prices," these papers model price discovery as related both to the speed at which information is revealed about the fundamental value (i.e. timeliness) and the avoidance of noise due to trading frictions (i.e. efficiency). Following the notation in Putniņš (2013), each price $p_{i,t}$ is assumed to follow the fundamental value with some lag δ_i and contain transitory noise $s_{i,t}$, so that the vector of prices can be expressed as

$$\mathbf{p_t} = m_{t-\delta_i} + \mathbf{s_t}, \tag{4}$$

where the transitory noise component is i.i.d normal with zero mean and variance $\sigma_{\mathbf{s}}$. If both the timeliness and efficiency components do not vary across markets then neither market plays a leading role in price discovery.

The existing literature has focused on timeliness in defining price discovery, beginning with Hasbrouck (1995) who sought to identify "'who moves first' in the process of price adjustment." In the context of equation 4, the market with a lower value for δ_i is the one where price discovery occurs. However, Yan and Zivot (2010) used a generalized structural VECM data generating process to demonstrate analytically that both IS and CS may confound timely incorporation of new information and relative avoidance of noise. They show that IS measures dynamic responses to both permanent shocks u_t and transitory shocks $s_{i,t}$, while CS measures only dynamic responses to the transitory component.

Yan and Zivot (2010) propose a useful expression based on IS and CS that nets out dynamic responses to transitory shocks in each price series. This expression, $|(IS_1/IS_2)(CS_2/CS_1)|$ where the subscripts 1 and 2 denote the share measures from the two markets under consideration, is shown to measure information leadership, or IL, of each market. In certain cases, CS may attribute a large share of price discovery to market 1 only because prices in that market exhibit low levels of transitory noise, even though prices in the market 2 are much quicker to incorporate new information. Though prices in market 1 are often 'stale', the CS measure treats the lack of noise as efficient price discovery. The Yan and Zivot (2010) IL measure avoids this problem. One limitation of Yan and Zivot (2010) was the assumption of a single transitory shock (which may have different relative effects on each price series).

Putniņš (2013) relaxes the assumption of a single transitory shock and uses simulation to show that Yan and Zivot (2010) result holds even if the elements of the transitory shock $\mathbf{s_t}$ differ. He confirmed that the IL measure still accurately measures the timeliness aspect of price discovery in this case. Putniņš (2013) also demonstrates how to express the IL measure as a percentage, similar to IS and CS, which he terms the information leadership share, or ILS.

Following Yan and Zivot (2010) and Putniņš (2013), we use the ILS as our preferred measure of price discovery while also reporting IS and CS. One complication in applying these price discovery measures is that the ILS measure can only be applied in the $n = 2$ case. Moreover, ILS relies on initial estimation of IS which is not exactly identified; only an upper and lower bound can be determined. Estimating IS in the $n > 2$ case also presents a problem of dimensionality. As the number prices grows, the number of price orderings in $\mathbf{p_t}$ grows exponentially and the upper and lower bounds on the IS may grow to the point where it is impossible to distinguish which market leads. Therefore, we restrict our empirical work to bivariate comparisons of price discovery though we have prices from four related markets.

Data

We use high frequency transaction price data for the four major world wheat futures contracts to study price discovery and the reaction of prices to new information. Our motivation for using high-frequency price data is two-fold. First, existing research suggests futures prices rapidly incorporate new information into existing prices. For example, papers studying the corn (Lehecka, Wang, and Garcia, 2014) and wheat (Bunek and Janzen, 2015) futures markets show that United States Department of Agriculture (USDA) reports on crop conditions, planted acreage, inventories and other fundamental information generate significant price changes only in the first fifteen minutes following a report's release. In the context of our study, this implies that commonly-used daily futures price data aggregate over important price discovery dynamics.

Second, the literature on VECM-based price discovery measurement suggests that there is a technical trade-off between sampling frequency and the ability of these methods to identify which market moves first in response to new information. Hasbrouck (2007) and Yan and Zivot (2010) point out this tradeoff and propose sampling at very high frequency to reduce correlation among the reduced-form residuals e_t. Since these methods rely on innovations in one price revealing themselves prior to prices, strong contemporaneous correlation among the residuals suggests that the sampling frequency is too low.

There appears to be no test in the literature to identify the "correct" sampling frequency. Sampling intervals between observations are often dictated by data availability. Yan and Zivot (2010) review empirical applications of the Hasbrouck (1995) IS method and discuss how the optimality of sampling frequency is often judged by the spread between the upper and lower bounds placed on a market's IS. Previous studies find that sampling intervals from one second to five minutes can generate useful results in some contexts, while sampling at one minute intervals can generate poor results in other cases.

This paper considers transaction price data for the four major world wheat futures contracts, Chicago, Kansas City, Minneapolis, and Paris, purchased from CQG Inc. The data cover the period January 1, 2005 to December 31, 2015. Due to missing data for the November 2013 and November 2014 expirations for the Paris market, we truncate our sample period in May 2013. For our main results, we also exclude data from trading prior to January 2008. Before 2008, trading volume in Paris is low enough and price changes infrequent enough that we are unable to estimate the reduced-form VECM on many days in our sample.

Transaction prices in each market are time-stamped to the minute for this sample period. Since multiple transactions may occur inside a given minute, we first aggregate each price series to minute-level frequency by taking the last transaction price from each minute. When there are no transactions inside a given minute in one market, we replace these missing values with the most recent transaction price from that market. This leads to price series on some days in some markets with little variability and "stale" prices. This may lead to problems with the CS measure, where the avoidance of noise due to a lack of transactions can be misinterpreted by the model as price discovery.

The three US wheat futures contracts have common trading hours, which differ from trading hours in Paris. US exchanges varied their hours during our sample period whereas Paris hours are constant from 3:45am to 11:30am US Central Time. Figure 3 outlines the changes US trading hours. Generally US exchanges overlap with Paris between 3:45 and the close of the US overnight trading session and between the open of the US day trading session and the close of trading in Paris. The only exception is during a period in 2012 and 2013 where the US markets did not close between the overnight and day sessions. Note that this common trading window does changes by one hour for two weeks each fall and spring as each time zone implements daylight savings time on different dates.

On each trading day in this period, there are times when all markets trade and times when either US markets are closed and Paris trades or Paris is closed and US markets trade. This presents an interesting case for understanding price discovery. Price discovery cannot occur in a given market when it is closed. To assess the implications of market closures for price discovery, we calculate price discovery measures for the entire trading day, for times-of-day where some markets are closed, and for a short continuous daytime interval where all markets are open.

We match price data for the nearby contract for all US exchanges, rolling to the next-to-delivery contract on the first trading day of the delivery month. Matching nearby contract price data for US exchanges with Paris data is complicated by the alternative set of expirations listed by the Euronext/MATIF. During our sample period, the Paris exchange made changes to the expirations traded as shown in figure 4. US exchanges consistently listed March, May, July, September, and December expirations. Paris most commonly listed January, March, May, and November expirations.

We explored two potential rules for matching expirations between the US and Paris for a given trading day. First, we matched contracts based on the proximity of delivery period (delivery-matched). For example, we match the March and May contracts for both US and Paris markets when those contracts are nearest to delivery. On May 1, when the November Paris contract is nearest to delivery, we roll the US markets to the December contract, ignoring the July and September expirations since the delivery period for these contracts is further from the November Paris delivery period. The second matching rule is simply to use the nearest to delivery contract for each market for every date, regardless of the time to delivery (nearby-matched). We find the nearby-matched data generally superior to the delivery-matched data. There is often significantly lower trading volume in the first or second deferred contract, giving the impression that prices in that market are slow to adjust to new information when in actuality adjustment is simply occurring in the more actively traded expiration.

Having generated a dataset of minute-to-minute prices for the four markets, we perform conversions to Paris data to make it comparable to US data. We convert Paris prices which trade in Euros per metric ton to US dollars per bushel using daily exchange rate data from the St. Louis Federal Reserve Economic Database and a standard bushel weight for wheat of 60 pounds. This allows us to visually observe and compare differences in price across markets and determine the expected spread or relative value of wheat at each location. We also convert Paris trading volume, measured in the number of 50 metric ton contracts traded in a given period, to the number of 5000-bushel equivalent contracts.

Estimation and Results

For each day in our sample period, January 1, 2008 to April 30, 2013, we estimate a VECM for log prices in one US wheat futures market and the Paris market. We select the lag length for this VECM using the Akaike Information Criteria (AIC) determined each day. On average, the AIC selects a VECM with between four and five lags. Following the literature, the VECM includes no trends. We specify a constant in the error correction term to account for the average price difference or basis between the two markets on a given trading day. This is similar to Mizrach and Neely (2008) who use IS and CS to study price discovery for US treasury securities of varying maturities. Changes in basis are generally smaller than changes in price levels within a given trading day.

We calculate the IS, CS, and ILS daily for US and Paris markets, adapting the procedures laid out in code provided with Hasbrouck (2002). We exclude from our analysis trading days where we cannot reliably calculate these measures due to an absence of trades. We exclude days where the number of trades in either market is extremely low (less than five) and days where the difference in the high and low trading price is extremely small (less than one cent per bushel). This excludes many limit move days in US markets where markets do not trade because prices have changed the maximum amount allowed relative to the previous day's settlement price. Days where differences in trading calendars across markets lead to one market trading while the other does not - for example, on US holidays such as President's Day or Thanksgiving not observed in France - are not in our results as 100% of price discovery occurs in the open market by definition.

For our main results, we estimate price discovery measures using the Chicago market as the US market. Chicago has higher trading volume and potentially a greater role in price discovery relative to other US markets. We use transaction prices from the intraday period between 3:45am and 1:15pm US Central Time. This includes both the open and close of trading in the Paris market and the open and close of the day trading session in US markets. We select this period because of the well-known U-shaped pattern in intraday futures trading volume. Higher trading volume and market liquidity are thought to be concentrated around the open and close of trading. Since these are likely correlated with price discovery, we want to include periods where price discovery in either market is likely to occur and not exclude such periods for one market more than another.

Summary statistics for all price discovery measures for the Chicago market are given in table 1. Since the shares measures sum to one by definition, the mean daily share in Paris is one minus the mean daily share in Chicago and the standard deviation of shares in each market is identical. These summary statistics are derived from calculated shares for 862 trading days from January 2008 to April 2013. This number is less than the total number of trading days over this period, since we exclude some trading days from our sample as discussed above and because we exclude days where the estimated coefficients on the error correction term in the VECM generate a CS outside the bounds of zero and one. These are likely days where the structural model underlying the IS and CS measures does not hold as suggested in Lehmann (2002).

These statistics show that while both markets play an active role in wheat price discovery, the Chicago market is dominant. We report the error correction coefficients for the Chicago price equation, α_c, and the Paris price equation, α_p. These coefficients are generally of opposite sign and roughly the same magnitude which suggests both markets adjust with similar speed to the long-run (intraday) relationship represented by the error correction term. α_c is larger in absolute magnitude, but these coefficients cannot tell us which market generates more timely price discovery since they confound permanent and transitory changes in price.

Table 1 summarizes each of the price discovery shares discussed above. Both the IS and ILS measures show that Chicago wheat futures are responsible for roughly 80% of price discovery during this period. The CS measure is considerably lower, suggesting that Chicago accounts for only 45% of price discovery. This appears to be a case of the "avoidance of noise" problem with the CS identified by citetYan:2010a and Putniņš (2013). Because there is more trading in Chicago, prices tend to fluctuate more from minute-to-minute. The Paris market is often inactive and prices there are "stale" but not noisy. This biases CS to toward relatively equal shares of price discovery across each market.

We consider changes in relative price discovery across time. Figure 5 plots the average IS, CS, and ILS measures for the Chicago market over our sample period. We do not plot measures for the Paris market since these are simply one minus the numbers shown. For the IS measure, both the upper and lower bound and the midpoint are represented. Again, Chicago wheat futures dominate wheat price discovery throughout our sample period.

There is a visually distinct change in the proportion of price discovery in Chicago before and after mid-2010. Both the IS and ILS are lower after mid-2010 and the bounds on the IS measure are wider. T-tests of differences in means for IS, CS, and ILS before and after July 1, 2010 show significant changes in price discovery at the 1% significance level. For example, the mean daily ILS is 0.89 before July 1, 2010 and 0.76 after. The standard deviation of daily ILS is 0.24 before July 1, 2010 and 0.33 after. Therefore, we conclude that price discovery has become more diffuse and more variable between markets.

This significant change in the nature of wheat price discovery is suggestive evidence of KRU supply shocks influencing global price discovery. In 2010, the KRU region experienced extreme drought and exacerbated the effects of this drought by enacting export bans on wheat beginning in August 2010 (Wegren, 2011). Our results suggest the Paris market may more closely track supply and demand conditions in Europe and KRU. Large shocks to global wheat supply and demand originating in this region are correlated with a larger share of price discovery in the Paris market.

Results for different times of day

As a robustness check, we truncate the number of observations considered each day to assess whether price discovery varies by market throughout the trading day. We consider five intraday periods: the full day used in our main results above, only the US overnight session including the market open in Paris, the full Paris trading session excluding the close of trade in US markets, only the US day trading session, and only the period where both markets trade during the US day session including the US market open.

Table 2 presents summary statistics for the ILS calculated for each intraday period. Comparing mean ILS across times-of-day shows that Paris captures a larger share of price discovery in the overnight period for US markets. Chicago has an ILS of just 0.24 in this period. As more of the US day session is included in the sample, the ILS in Chicago is greater.

Results for different US markets

As additional robustness check, we consider whether there are significant differences in the estimated share of US price discovery if we use prices from the smaller Kansas City and Minneapolis markets. We use the full day period as in table 1. Recall that wheat futures trading volume in Paris is similar in magnitude to Kansas City and greater than Minneapolis, so we might expect relative price discovery in these markets to be lower than Chicago.

Table 3 compares ILS relative to Paris for the Chicago, Minneapolis, and Kansas City markets. We find estimated price discovery shares are remarkable similar across US exchanges. On average, the price discovery share of the US market relative to Paris is approximately 80%.

Conclusions

In this paper, we use high frequency price data from multiple markets to draw inference about structural changes in world wheat markets that would be impossible using production and trade data only available at an annual or monthly frequency. We find that the observed increase in trading volume for the Paris wheat futures contract and the shift in world wheat trade away from the United State has occurred contemporaneously with an increase in the proportion of wheat price discovery occurring at the Paris exchange relative to the benchmark Chicago futures market. The most dramatic change in price discovery occurred in the summer of 2010 coinciding with a large supply shock from KRU. These results are robust to the consideration of alternative trading periods and alternative US futures markets.

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Figures

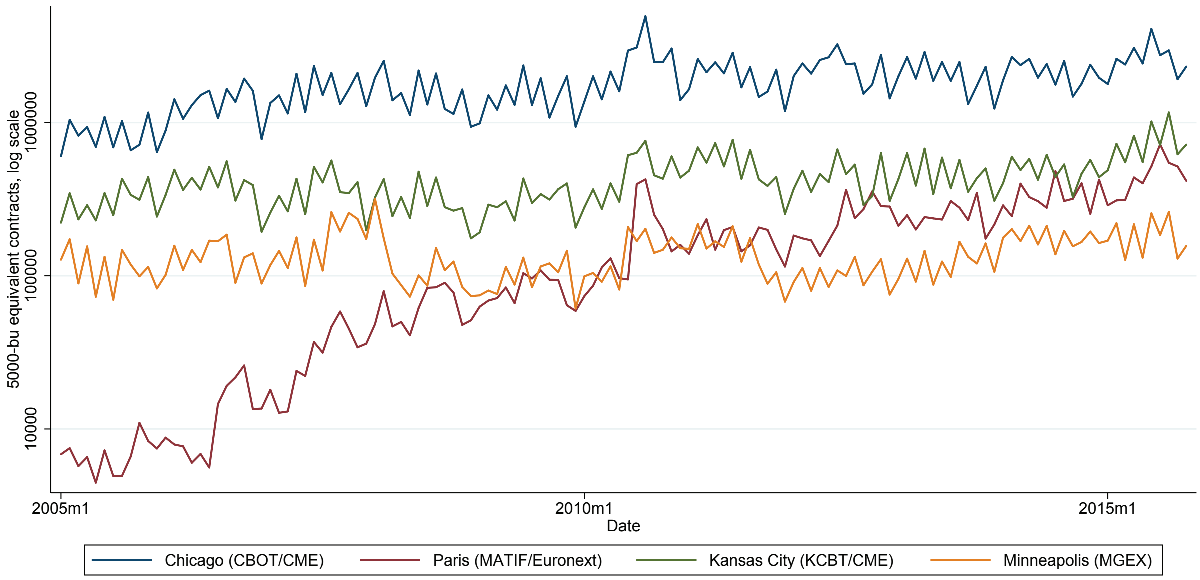

Figure 1: Monthly trading volume for wheat futures contracts, 2005-2015

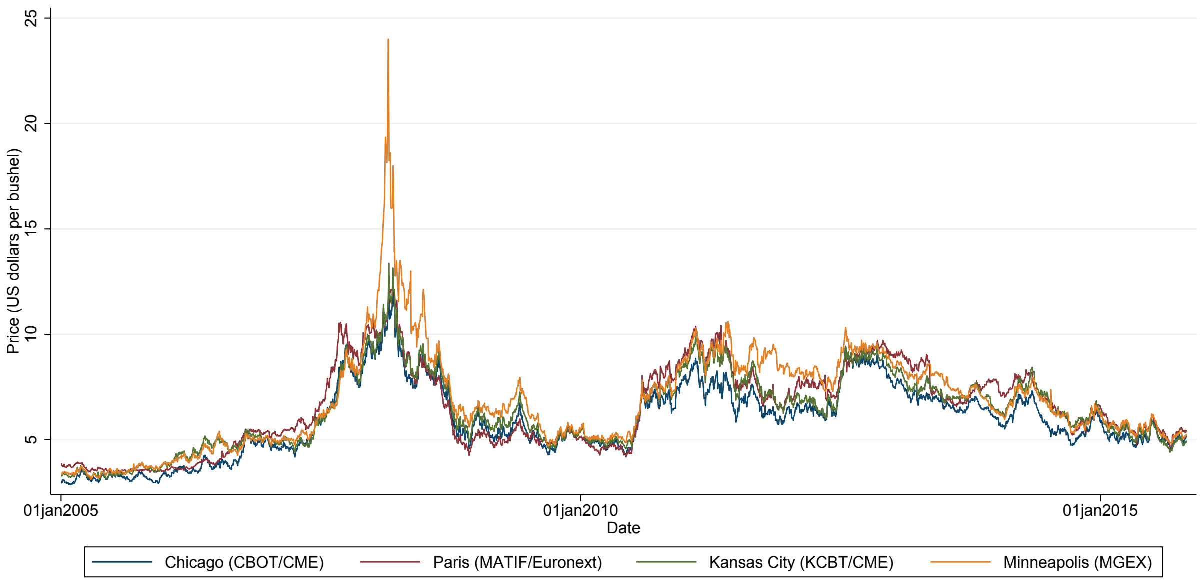

Figure 2: Daily settlement prices for nearby wheat futures contracts, 2005-2015

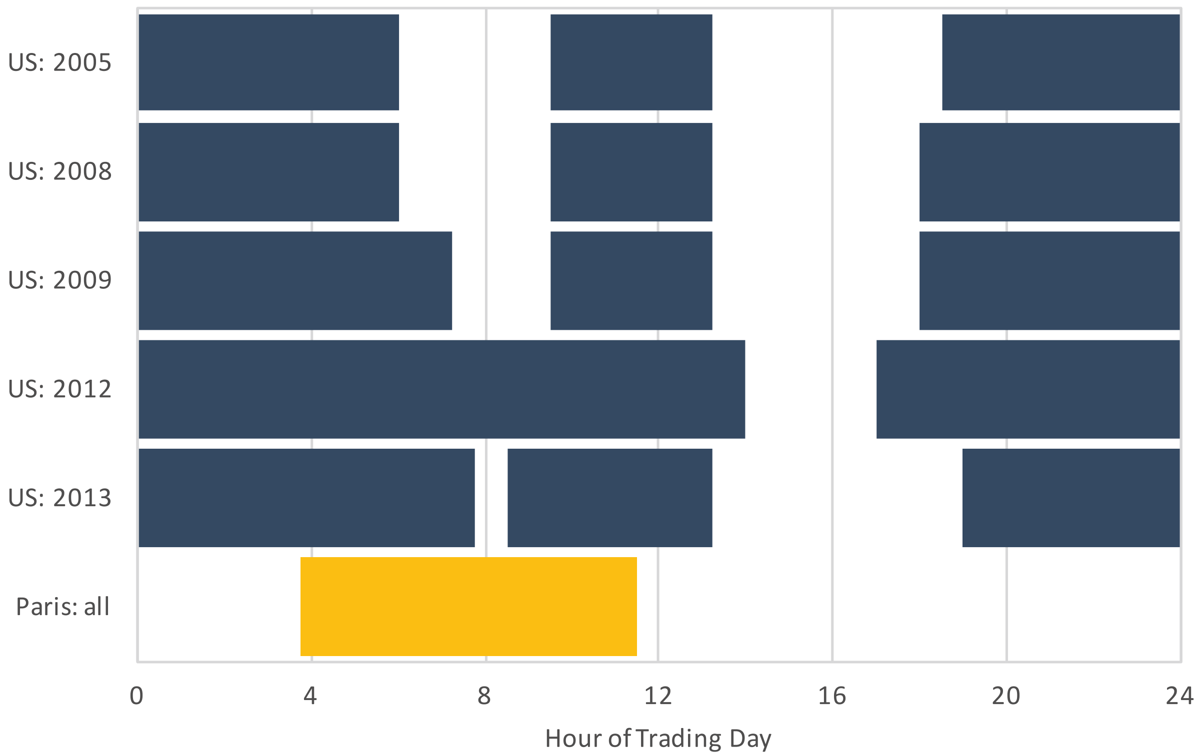

Figure 3: Trading hours for US and Paris wheat futures in US Central Time, 2005-2013

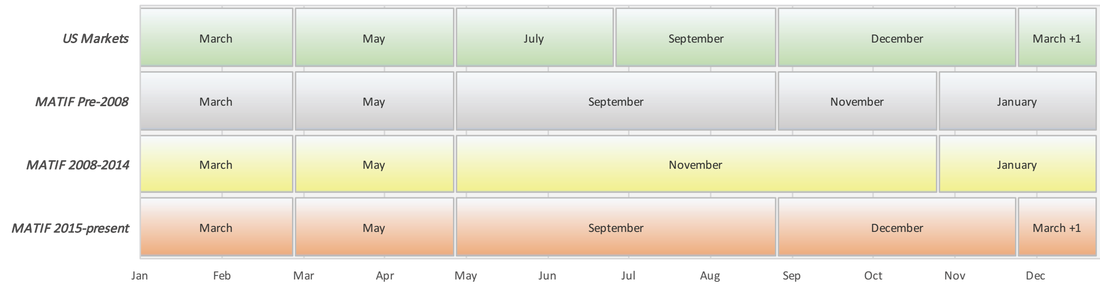

Figure 4: Nearest-to-delivery contract expirations for US and Paris wheat futures markets, 2005-2015

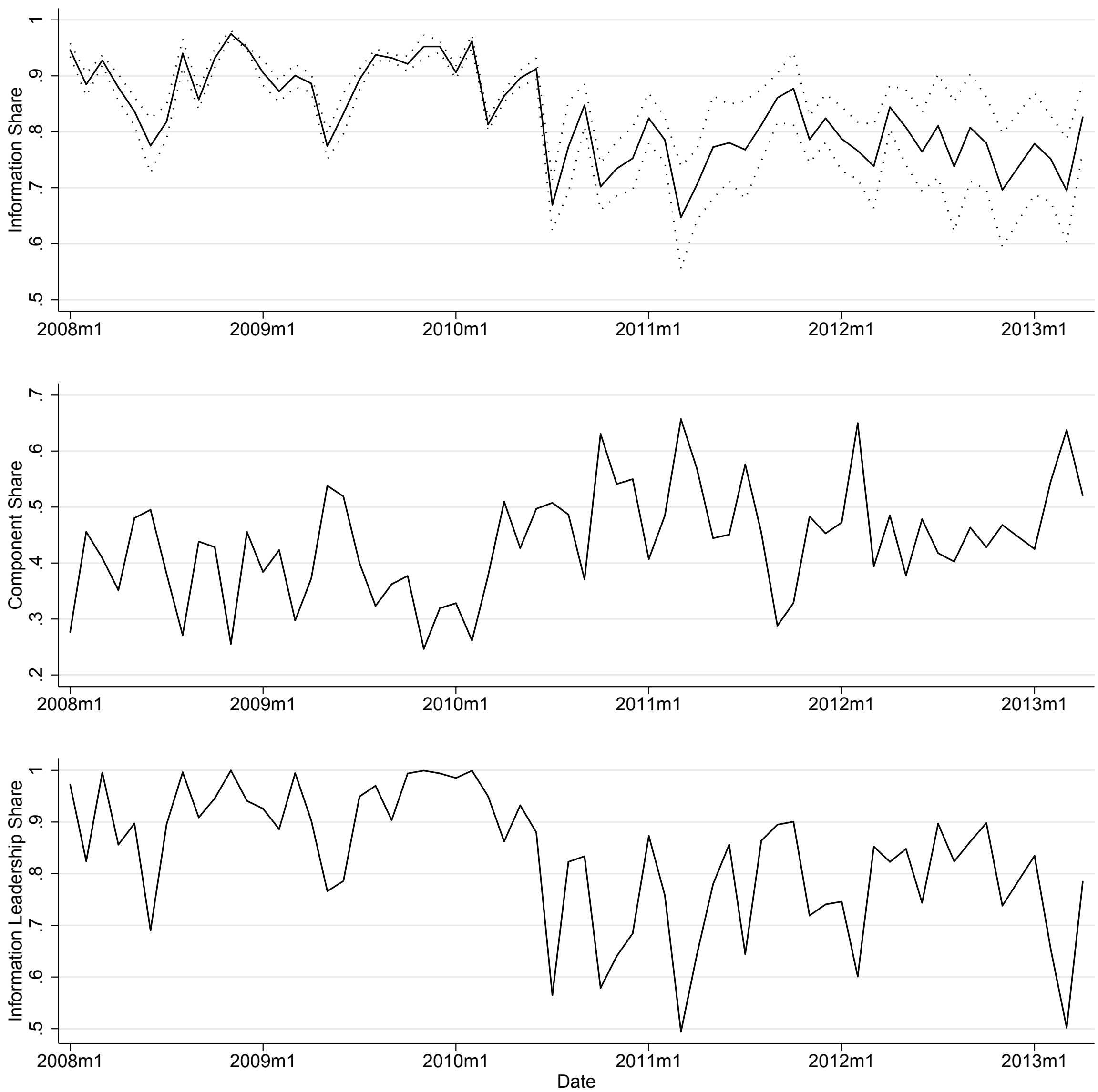

Figure 5: Monthly average price discovery measures for the Chicago wheat futures market, 2008-2013

Tables

Table 1: Summary statistics for daily price discovery measures for the Chicago wheat futures market, 2008-2013

Statistic	Mean	Std. Dev.	Min	Max
α_c	-0.0120	0.0118	-0.0722	0.0121
α_p	0.0100	0.0103	-0.0032	0.0616
IS_{upper}	0.8700	0.1331	0.2739	1.0000
IS_{lower}	0.7851	0.1760	0.2397	0.9999
IS_{mid}	0.8275	0.1504	0.2738	0.9999
CS	0.4475	0.2526	0.0015	0.9999
ILS	0.8220	0.2973	0.0001	1.0000

Table 2: Summary statistics for daily information leadership shares (ILS) for the Chicago wheat futures market by time of trading day in US Central Time, 2008-2013

Time Period	Minutes in Period	Mean	Std. Dev.	Min	Max
Full day (3:45am - 1:15pm)	565	0.8220	0.2973	0.0001	1.0000
Overnight session (3:45am - 7:15am)	210	0.2420	0.3410	0.0000	1.0000
Full Paris session (3:45am - 11:30am)	465	0.6703	0.3670	0.0000	1.0000
US day session (9:30am - 1:15pm)	225	0.8946	0.2286	0.0001	1.0000
Overlapping day session (9:30am - 11:30am)	120	0.7927	0.2982	0.0000	1.0000

Table 3: Summary statistics for daily information leadership shares (ILS) for alternative US wheat futures markets relative to the Paris market, 2008-2013

Market	Mean	Std. Dev.	Min	Max
Chicago	0.8220	0.2973	0.0001	1.0000
Minneapolis	0.8247	0.3002	0.0000	1.0000
Kansas City	0.7953	0.3151	0.0000	1.0000