Dynamic price discovery in the European wheat market based on the concept of partial cointegration

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Understanding the pricing process in agricultural spot and futures markets is important for every market participant. In this article we analyse price discovery in the European wheat market based on the partial cointegration approach recently introduced by Clegg and Krauss (2017). Partial cointegration allows for not only transient but also persistent shocks to the long-run equilibrium relationship between two or more variables. By combining the concept of partial cointegration with state space modelling we are able to generate time-variant price discovery metrics that allow for shifts in the long-run relationship between futures and spot prices, for example due to changes in the quality composition of the wheat harvest from year to year, or due to changes in the specification of the futures contact. We find that price discovery is in general dominated by the futures market but that the spot market takes on greater significance for the pricing process during phases of higher price volatility. We also find evidence that the persistent shocks the long-run relationship between spot and futures prices estimated by the partial cointegration method are affected by the availability of high-quality wheat on the spot market.

Acknowledegment:

JEL Codes: Q11, Q14

#2083

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Keywords: price discovery, partial cointegration, state space, wheat, futures, spot

1 Introduction

International futures markets for agricultural soft commodities play an important role in decision making for many farmers as well as for firms upstream and downstream from farming. Futures markets are used as a risk management instrument to hedge prices for forward delivery (Acharya, Lochstoer and Ramadorai, 2013) and to forecast future spot prices (Chinn and Coibion, 2014). Hence, market participants are eager for information about the relationship between spot and futures prices and how these markets contribute to price discovery.

Lehmann (2002, p. 259) defines price discovery as “the efficient and timely incorporation of the information implicit in investor trading into market prices”. Most studies to date show that futures markets dominate the price discovery process for agricultural soft commodities. Garbade and Silber (1983) for example present evidence that wheat and corn futures markets in the United States (US) incorporate the majority of new information first and therefore dominate pricing in the respective spot markets. Schroeder and Goodwin (1991), Yang, Bessler and Leatham (2001), Kuiper, Pennings and Meulenberg (2002) and Peri, Baldi and Vandone (2013) confirm these findings for a variety of agricultural commodity markets inside and outside the US. These findings, which suggest that futures markets react more rapidly to react to new information than spot markets, are not surprising because futures markets are generally more liquid and have lower transaction costs (Working, 1962). Furthermore, futures markets attract a wider range of participants with possibly more varied sources of information than spot markets.

While futures markets' important contributions to price discovery on agricultural commodity markets are uncontested, some studies suggest that the strength of this contribution can be influenced by the volume of futures trade and by episodes of price volatility. Garbade and Silber (1983) study four US agricultural commodity markets and find that the three most liquid futures markets dominate their respective spot markets, but that the least liquid futures market does not. Other studies of agricultural commodities that find a positive relationship between the volume of futures trading and the futures market's contribution to price discovery include Brockman and Tse (1995), Mattos and Garcia (2004) and Ivanov (2011).

Besides liquidity, the influence of futures markets on price discovery might also be affected by episodes of market turmoil. For example, Peri, Baldi and Vandone (2013) present evidence that the importance of spot markets for price discovery on some US agricultural commodity markets increases during price bubbles. This is a politically sensitive topic, as futures markets have been blamed for triggering or at least amplifying price peaks. This issue regained prominence during the so-called food price crisis of 2007-08, and again between 2010 and 2013. Some observers, such as Worthy (2011), claimed that the increased activity of participants such as hedge and index funds on futures markets for agricultural commodities was generating unwarranted price peaks and volatility, prompting numerous empirical studies on the influence of speculation and other factors on price determination (Irwin and Sanders, 2011; Will *et al.*, 2013)

A recent study by Adämmer and Bohl (2015) makes an important contribution to the literature on the roles of spot and futures markets in agricultural price discovery. First, while the literature to date has focused exclusively on US agricultural commodity markets, Adämmer and Bohl (2015) study European markets for wheat, corn and canola. Second, they generate time-variant estimates of price discovery metrics using state space methods that allow them to explore whether the relative contributions of futures and spot markets to price discovery have changed over time. Their results indicate that the importance of futures markets for price discovery does depend on trading volumes, but only up to a certain level, beyond which other factors become more important than volume alone. In addition, they find that the dominance of futures markets in price discovery was higher during the 2007-08 price peak than when prices peaked once more after 2010, even though future trading volumes were much higher in the latter period. Adämmer and Bohl (2015) attribute this difference to the fact that "agricultural markets were hit by surprise" by the first price peak, which enhanced the role of futures markets in price discovery, whereas spot market participants were better informed and "anticipated" the subsequent peak, which reduced the dominance of futures markets in price discovery.

Our objective in this paper is to extend Adämmer and Bohl (2015) work by incorporating the new concept of partial cointegration. Adämmer, Bohl and Ledebur (2016) introduce the use of state space techniques to generate time-variant estimates of the vector error correction model (VECM) that links two cointegrated prices. They then use these estimates to generate time-variant price discovery metrics. However, they maintain the classical model of cointegration according to which two or more prices are assumed to be linked by a time-invariant long-run equilibrium relationship, and all shocks that disturb this equilibrium relationship are considered to be transient. These might be reasonable assumptions when measuring price discovery for precisely defined and highly homogeneous financial assets with low trade costs. But agricultural commodities are generally less homogeneous and the basis between futures and spot prices is subject to shocks that can lead to persistent changes in the spot-future price relationship. For example, the relative availabilities of different qualities of wheat on spot markets change from year to year due to factors such as weather. This can lead to changes in quality premiums and thus affect the relationship between spot and futures prices. Occasional changes to the specification of a futures contract will have similar effects. Likewise, investments in infrastructure can lead to permanent shifts in the basis between a spot market and the delivery location specified in a futures contract.

The partial cointegration approach recently introduced by Clegg and Krauss (2017) allows for not only transient but also persistent shocks to the long-run equilibrium relationship between two or more variables. Hence, combining Adämmer and Bohl´s (2015) approach with partial cointegration allows us to generate time-variant price discovery metrics that are not based on the assumption of a time-invariant long-run relationship between futures and spot prices, but rather allow for shifts in this relationship that might result from factors such as quality, contract specification and infrastructure as outlined above.

We apply this combination of approaches to the European wheat market using the Euronext Paris wheat futures and a German spot market price. The Euronext Paris is the EU's major futures exchange for agricultural soft commodities. The German spot market is important because Germany is one of the largest wheat producers in the EU with a share of about 17 % of total EU wheat production (ADM Germany GmbH, 2016). We analyse the period from 2002 to 2016, which includes episodes of high and of low price volatility as well as changing volumes of futures trading. We use two popular price discovery metrics that are based on ECMs: the permanent-transitory measure (PT) proposed by Gonzalo and Granger (1995) and the information shares measure (IS) proposed by Hasbrouck (1995).

The rest of this paper is structured as follows: in sections 2 and 3 we describe the methods and the data that we use, respectively, and in section 4 we present and discuss our empirical results. Section 5 concludes and makes suggestions for future research.

2 Methodological approach

Our empirical analysis follows three steps. First, following Clegg and Krauss (2017) we test for partial cointegration between the spot and futures prices. Second, we estimate a standard VECM with partial cointegration and calculate PT and IS measures to determine which market dominates the price discovery process on average over the entire sample period. Third, following Adämmer and Bohl (2015) and Adämmer, Bohl and Ledebur (2016) we rewrite the partially cointegrated VECM in state space form and apply the Kalman filter. The result is a model that accounts for variation not only in the mechanism that corrects deviations from the long-run relationship between spot and futures prices, but also in the long-run relationship itself. Using the estimates of this model, we calculate time-variant PT and IS measures and study changes in price discovery on spot and futures markets for wheat in the EU over time. In the following we explain these steps in greater detail.

Partial cointegration

Partial cointegration (Clegg and Krauss, 2017) is a weaker form of cointegration and splits up the residual series into permanent and transient components. In our setting, a futures price series p_t^F and a spot price series p_t^S are partially cointegrated if the following model is satisfied:

$$
\begin{aligned}
p_t^F &= \beta_1 p_t^S + W_t && (1)\\
W_t &= M_t + R_t \\
M_t &= \rho M_{t-1} + \varepsilon_{M,t} && \text{with } \varepsilon_{M,t} \backsim N(0, \sigma_M^2)\\
R_t &= R_{t-1} + \varepsilon_{R,t} && \text{with } \varepsilon_{R,t} \backsim N(0, \sigma_M^2)
\end{aligned}
$$

where β_1 is the partially cointegrating vector, R_t is the permanent component of the residual series W_t, modelled as a random walk, and M_t is the transient component of the residual series, modelled as an autoregressive process of order 1 with coefficient ρ. The superscripts *F* and *S* refer to futures and spot markets, respectively, and *t* indexes time. The error terms $\varepsilon_{M,t}$ and $\varepsilon_{R,t}$ follow mutually independent, normally distributed white noise processes.

Clegg and Krauss (2017) prove that the system of equations in (1) is identified, i.e. that there is a unique set of parameters β_1, ρ, σ_M^2, and σ_R^2 corresponding to any realisation of that system. They also demonstrate that these parameters can be estimated by restating the model in state space and applying maximum likelihood to the associated Kalman filter.

Error correction model and price discovery measures

If p_t^F and p_t^S are found to be partially cointegrated we next estimate the following time-invariant VECM:

$$\begin{bmatrix}\Delta p_t^F\\ \Delta p_t^S\end{bmatrix} = \begin{bmatrix}\alpha^F\\ \alpha^S\end{bmatrix}\left(\begin{bmatrix}1 & -\beta_1\end{bmatrix}\begin{bmatrix}p_t^F\\ p_t^S\end{bmatrix} - R_t\right) + \sum_{i=1}^{k} \Theta_i \begin{bmatrix}\Delta p_{t-i}^F\\ \Delta p_{t-i}^S\end{bmatrix} + \begin{bmatrix}\nu_t^F\\ \nu_t^S\end{bmatrix}, \quad (2)$$

where, in addition to the notations defined above, Δ is the first difference operator, the Θ_i are *2 x 2* matrices of short-run coefficients, and the α are adjustment parameters that determine the speeds with which p^F and p^S adjust to correct transient deviations from their long-run equilibrium relationship. The ν_t are white noise error terms with variance-covariance matrix Ω, and *k* is the lag order of the short-run dynamics, which can be determined for example using the Akaike Information Criterion (AIC).

To quantify each market's relative contribution to price discovery we use two standard metrics of price discovery. The PT metrics proposed by (Gonzalo and Granger, 1995) measure how much each market contributes to the error correction of transient deviations from the long-run equilibrium relationship between two prices. In our setting the PT metrics for the futures and spot markets respectively are given by:

$$PT^F = \frac{\alpha^S}{\alpha^S - \alpha^F}, \qquad PT^S = 1 - PT^F = \frac{\alpha^F}{\alpha^F - \alpha^S}\ . \tag{3}$$

The denominators in equation (3) measure the combined adjustment of spot and futures prices to any deviation from their long-run equilibrium relationship, and PT^F (PT^S) is defined as the share of the spot (futures) market in this total adjustment. Hence, the values of PT are bound between zero and one, and the larger the burden of adjustment borne by one market, the larger the other market's PT metric. If, for example, $PT^F = 1$, then price discovery occurs entirely in the futures market, and the spot market only reacts; if $0.5 < PT_F < 1$, then both markets contribute to price discovery but the futures market contributes more.

The IS metrics proposed by Hasbrouck (1995) measure each price's contribution to the variance of the common trend shared by both prices. This common trend can be isolated by transforming the VECM in (2) into the integrated form of its vector moving average (VMA) representation in levels.[1] The variance of the common trend depends on the so-called long-run impact matrix of the VMA, ψ, and variance-covariance matrix of the VECM errors in (2), Ω. If the VECM errors are not correlated (i.e. Ω is diagonal), then calculation of the IS metrics is straightforward. Since in general Ω is not diagonal, Hasbrouck (1995) uses the Cholesky factorization $\Omega = CC'$, where C is a lower triangular matrix, to derive the following expressions for the IS metrics:

$$IS^F = \frac{([\psi C]^F)^2}{\psi\Omega\psi'}, \qquad IS^S = 1 - IS^F = \frac{([\psi C]^S)^2}{\psi\Omega\psi'} \tag{4}$$

where $[\psi M]^i$ is the element of the row matrix ψC corresponding to the *i*-th price, futures or spot as indicated. Baillie *et al.* (2002) show that the long-run impact matrix ψ can be derived from the estimation results of the VECM in (2), which simplifies the procedure.[2] Since the Cholesky factorization of the variance-covariance matrix Ω depends on the order of the prices in the VECM, the calculated IS metrics also depend on this order. In the literature it is common to calculate the information shares for both possible orders and report the mean of the

[1] Hasbrouck (1995), Baillie *et al.* (2002) and Adämmer et al. (2016) provide details on the derivation and calculation of the IS metrics.

[2] Although Baillie *et al.* (2002) derivation assumes that the cointegrating vector $[1, \beta_1] = [1, -1]$, Pavlova and Cramon-Taubadel (2016) show that the IS metrics can also be calculated for other cointegrating vectors.

resulting estimates (Flad and Jung, 2008; Fuangkasem, Chunhachinda and Nathaphan, 2014). The interpretation of the IS metrics, which are individually and in sum bound between zero and one, is analogous to that of the PT metrics.

State space approach

The steps described so far produce time-invariant estimates of the PT and IS metrics based on the partially cointegrated system in (1) and the corresponding VECM in (2). To generate time-variant estimates of the PT and IS metrics, we write (2) in state space form with the observation equation (5a) and state equation (5b):

$$P_t = Z_t \xi_t + \epsilon_t \qquad \text{with } \epsilon_t \sim N(0, V) \tag{5a}$$

$$\xi_t = I \xi_{t-1} + \upsilon_t \qquad \text{with } \upsilon_t \sim N(0, W). \tag{5b}$$

In equation (5a) $P_t = \begin{bmatrix} \Delta p_t^F \\ \Delta p_t^S \end{bmatrix}$ is the left-hand-side vector of price changes in the VECM, Z_t arrays the right-hand-side variables of VECM equations in block diagonal form, and ξ_t, which stacks the coefficients of the VECM equations, is the vector of state variables. In equation (5b), I is an identity matrix of dimension *2*(2k+1)*, which corresponds to the column dimension of Z_t and the row dimension of ξ_t, where *k* is the lag order of the short-run dynamics in the VECM. ϵ_t and υ_t are serially uncorrelated white noise error terms with zero mean and diagonal covariance matrices *V* and *W*. Application of the Kalman filter produces optimal estimates of the state variables in ξ_t at each time t. These state variables include the adjustment parameters α^F and α^S, which we use to calculate time-variant estimates of the PT price discovery metric.

3 Data

To analyse price discovery on spot and futures markets for wheat in the EU we use logarithms of weekly wheat prices from January 2002 until April 2016 obtained from Thomson Reuters Datastream. As an indicator of the German spot market price (p_t^S) we use milling wheat prices fob Rostock on the Baltic Sea, which is one of the biggest German ports where grain and oilseeds are tendered. For the corresponding futures market price (p_t^F) we use the milling wheat futures contract no. 2 which is traded at the Euronext Paris, Europe's major exchange for agricultural soft commodities. Accounting for changes in the expiry dates of the Euronext Paris wheat contract over the sample period, we consider the contract months January (2002-

2015), March and May (2002-2016), July (2002-2005), August (2008-2012), September (2002-2007, 2015), November (2002-2014) and December (2015). Furthermore, as it is common in the literature (Yang, Bessler and Leatham, 2001; Liu and An, 2011; Gilbert, 2010), on the first day of its maturity month we roll over from the first nearby contract to the second nearby contract. The Euronext wheat contracts expire on the 10th of the month, but rolling over somewhat earlier ensures that we work with the most liquid contracts. Finally, following Garbade and Silber (1983) and Yang, Bessler and Leatham (2001) we calculate cash-equivalent futures prices to correct for changes in the correspondence between a spot market price and a futures market price as the time remaining until futures contract's expiry date passes. Hence, we calculate cash-equivalent futures prices:

$$\ln(p_t^{CEF}) = \ln(p_{T|t}^F - r * [T - t]/360) \quad (6)$$

where p_t^{CEF} is the cash equivalent futures price at time *t*, $p_{T|t}^F$ is the price of the futures contract at time *t* that expires at time *T*, and *r* is the daily interest rate of the current 10 year federal bond of the German Bundesbank. In the following, we refer to the cash-equivalent futures price as 'the futures price'.

The resulting spot and futures prices are presented in figure 1 (left axis). It appears that both prices co-move and exhibit common price increases in 2003/04, 2007/08 and again from mid-2010 through 2013. Figure 1 also presents the volatility of the futures prices (right axis), which increased between August 2003 and July 2004, between May 2007 and April 2008, and later again between August 2010 and May 2013.

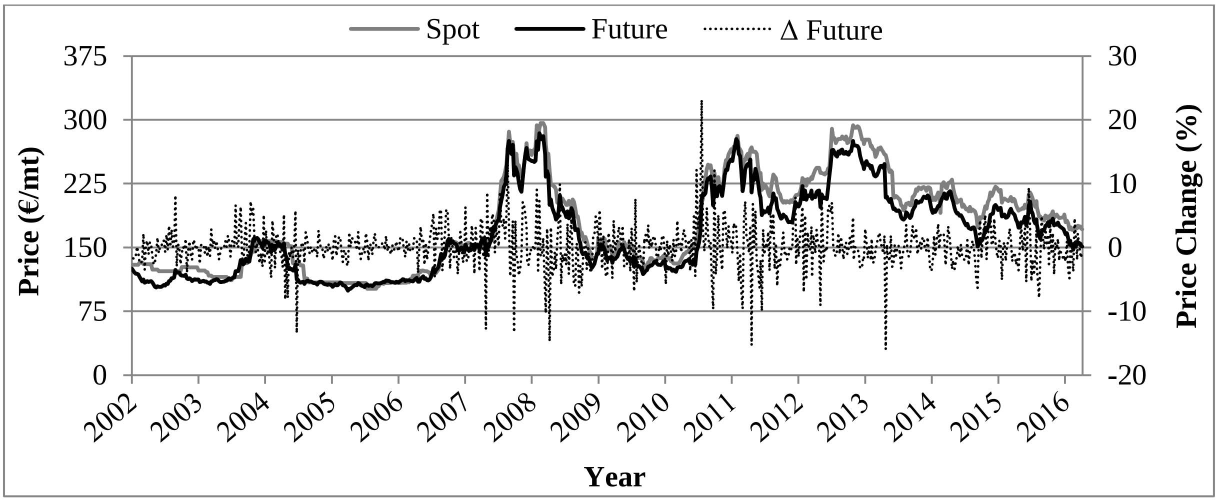


Figure 1: European spot and futures prices for wheat between 2002 and 2016

The specification of the Euronext wheat futures contract has changed over the period we study. Two locations are specified for physical delivery, Rouen and Dunkirk, both in northern France. The driving distances from Rostock to these two locations are roughly 1100 and 900 km, respectively. Prior to the 2014/15 season, only a minimum specific weight (76kg/hl) and maximum permissible moisture (15%), broken grains (4%) and impurities (2%) were specified to calculate discounts for differences between standard and delivered quality. Beginning in 2014/15, a minimum protein content (10.5%) and a minimum Hagberg falling number (220) were added to these requirements. These quality parameters are typical for French export wheat, much of which is destined to North and East African or Middle East markets; milling wheat that is traded in Germany typically contains roughly 1% more protein. Adämmer, Bohl and Ledebur (2014) state that due to these quality differences, hedging German milling wheat with the Euronext wheat futures contract amounts to cross-hedging.

Due to problems with the quality of the French harvest in 2014, Hagberg falling numbers as low as 170 were tolerated in 2014/15, and this tolerance was continued in 2015/16 and 2016/17.[3] While the quality of the 2014 harvest was low in France, the volume was very high. Exports developed slowly and silos, including at the two delivery locations, filled rapidly. This prompted the delivery silos to suspend wheat reception in late 2014, a step which was repeated in 2015 (Prehn, Steinhübel and Glauben, 2016).

Changes in the specification of a futures contract and the suspension of delivery will trigger persistent shifts in the relationship between spot and futures prices. This is one reason we propose to use partial instead of classical cointegration methods to measures price discovery in our setting. However, there are other reasons. First, the difference between the quality specified in the Euronext wheat contract and the typical qualities available in northeastern Germany and traded in Rostock can be expected to fluctuate from year to year, for example due to variations in crop and harvest weather. Available qualities on French markets can also change from year to year, as described above. Such changes can lead to persistent shifts in the basis between the spot price in Rostock and the Euronext futures price. These shifts can especially be expected when we shift from the May to the next nearby contract (September, November

[3] See Prehn, Steinhübel and Glauben (2016) for details. For information on the current specification of the Euronext wheat contract, see https://derivatives.euronext.com/en/products/commodities-futures/EBM-DPAR/contract-specification.

or December, depending on the year in our sample period), because the May contract refers to the 'old' harvest, while the next nearby contract refers to the upcoming 'new' harvest, which will display different qualities and be marketed under new set of supply and demand conditions. Second, some shifts in the basis might also result from changes in transportation infrastructure between Rostock and the delivery locations; Rostock is located in what was the German Democratic Republic and in the years since German reunification large investments to improve east-west transport links have taken place. For these reasons we propose that the relationship between the Rostock spot price and the Euronext futures price for wheat is better characterized by partial rather than time-invariant linear cointegration.

4 Results and discussion

We first use the Augmented-Dickey-Fuller-Test (ADF tests) (Dickey and Fuller, 1979) to test the price series for unit roots (table 1). Applying the tests over the entire time period the futures prices as well as the spot prices are integrated of order one (I[1]) since the time series are non-stationary in levels but stationary in their first differences.

Table 1: Results of the ADF tests

Price	**Lags** [a)]	**Test-statistic** [b)]
$\ln(p_t^S)$ - spot	3	-1.91
$\ln(p_t^F)$ - futures	4	-2.27
$\Delta\ln(p_t^S)$ - spot	2	-11.60
$\Delta\ln(p_t^F)$ - futures	3	-11.46

[a)] Number of lags chosen by AIC
[b)] Critical values for test statistics: -3.44 (1%), -2.87 (5%), -2.57 (10%)

Next we apply the likelihood ratio test routine proposed by Clegg and Krauss (2017) to determine whether the spot and futures prices are partially cointegrated. The null hypothesis of no partial cointegration consists of two conditions that are tested separately: i) the residual series follow a pure random walk (no cointegration), or ii) the residual series follow a pure *AR(1)* process (time-invariant linear cointegration). In addition, the union of these hypotheses is also tested. The null hypothesis of no partial cointegration is rejected if both of these conditions are rejected individually. Table 2 reports the results of the likelihood ratio test routine which suggest that the spot and futures prices are partially cointegrated.

Table 2: Results of the likelihood ratio test for partial cointegration between spot and futures prices

Hypothesis	Test-statistic	p-value
Random walk	-40.16	0.01
AR(1)	-4.50	0.01
Combined		0.01

The values of the test statistic follow a χ^2 distribution with degrees of freedom equal to the difference in dimensionality between the null hypothesis and the alternative hypothesis ((Clegg, 2015).

We next estimate an ECM and account for partial cointegration to differentiate between permanent and transient price shocks. The estimated partially cointegrated long-run relationship between spot and futures price is presented in table 3. The spot price equals 1.029 times the futures price minus a constant value of 0.081. The results of the partially cointegrated model indicate that the mean-reverting or transient component accounts for 88% of the total variance in the deviations from this long-run relationship, while the permanent component accounts for 12%.

Table 3: The estimated partially cointegrated long-run relationship between spot and futures prices

Dependent variable	Independent variable	Estimate	Std. error	t-value	p-value
$\ln(p_t^S)$ - spot	$\ln(p_t^F)$ - futures	1.029	0.007	153.800	<0.001
	Constant	-0.081	0.034	-2.392	0.017

Based on the results of the partially cointegrated model, we estimate the VECM in equation (3) and calculate average PT and IS metrics for the entire sample period (Table 4).

Table 4: Results of the price discovery metrics

Price	α [a)]	PT	IS		
			1st bound [b)]	2nd bound [c)]	mean
Spot	-0.388 (0.001)	0.163	0.370	0.436	0.403
Futures	0.076 (0.615)	0.837	0.630	0.564	0.597

[a)] p-values in brackets
[b)] Order of prices: 1) spot, 2) futures
[c)] Order of prices: 1) futures, 2) spot

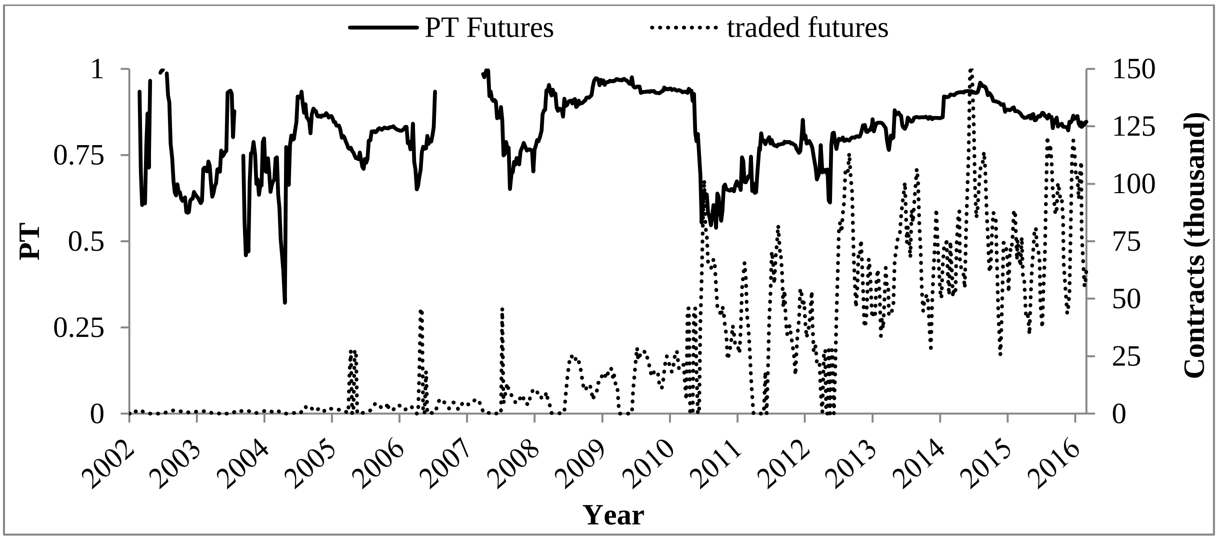
Between 2002 and 2016 both spot and future prices adjust to correct transient deviations from their long-run equilibrium relationship, but whereas the futures price adjusts by less than 8%

per week the spot market adjusts by nearly 39%. This leads to a PT of about 16% in the spot market and about 84% in the futures market. Therefor price discovery takes place in both markets but is clearly dominated by the futures market according to the PT metrics. The IS metrics point to qualitatively similar but less extreme results, with a mean IS of 63% for the futures market and a mean IS of 37% for the spot market.

The PT and IS metrics are both well established in the literature, especially in fields of financial assets, but they refer to differing concepts of price discovery. As Jong (2002) and Baillie *et al.* (2002) point out, PT considers price discovery only as an error correction process by weighting the adjustment parameters of the VECM. In contrast, IS also factors in the variation in prices by including the covariance matrix of the residuals in addition to the adjustment parameters and thus measuring the amount of information generated by one market. While the IS metrics therefore provide a more comprehensive measure of price discovery, a disadvantage is that they are sensitive to the ordering of the prices used in the analysis. However, in our application, the difference between 1st and 2nd bound estimates is small (see Table 4). Overall we conclude that on the European wheat market the futures market dominates the price discovery process, but the PT metrics may overestimate this dominance to some extent.

Time-varying estimates

To look at the price discovery process over time we rewrite equation (3) in state space format and estimate time-varying PT values. Figure 2 displays the PT values for the futures prices (left axis) as well as a four week moving average of the volume of traded futures contracts (right axis). Since the PT metrics for two markets add up to one in the bivariate case, only the PT metric for the futures price series is presented.



The volume of traded futures contracts is displayed as a four week moving average.

The adjustment parameters in equation (3) are expected to be positive for the futures prices and negative for the spot prices. We do not calculate PT for observations that do not fulfil this requirement.

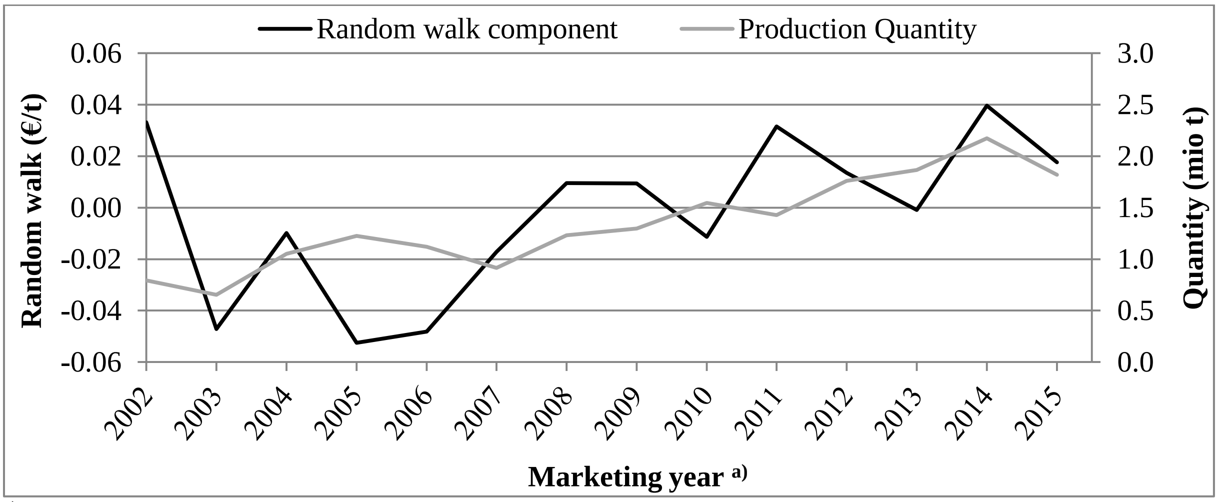
Figure 2: Time-varying PT and trading volume

The results in Figure 2 confirm that the price discovery process is clearly dominated by the futures market; the corresponding PT values exceed 50% over almost the entire sample period. However, the results in Figure 2 also reveal that the dominance of the futures market changes over time. Between mid-2003 and mid-2004 prices increased and became more volatile (compare also Figure 1). During this time the dominance of the futures market in price discovery decreased. Similarly, during the so-called food price crisis in 2007/08 prices and price volatility again surged, and the dominance of the futures market in price discovery fell as well. Finally, find that the dominance of the futures market fell again and especially sharply after the onset of the episode of high and volatile prices that began in 2010. Overall, our results suggest that while the futures market clearly dominates price discovery on European wheat markets, the importance of the spot market increases during time periods of market turmoil. This is of particular interest in the discussion about the regulation of futures markets. Partly due to the past food price crises the EU agreed on position management power and position limits in the commodities regulatory framework ‘Markets in Financial Instruments Directive II’ (MiFID II) to enhance transparency and to combat market abuse (The European Parliament and the Council of the European Union, 2014). However, our results suggest that the importance of futures markets for price discovery is actually less pronounced when concerns over its influence are highest.

Our results share some similarities with those presented by Adämmer and Bohl (2015), but also differ in some important respects. First, unlike Adämmer and Bohl (2015) we find that the importance of spot markets did increase in 2007/08, albeit not as strongly as in 2010. Second, we do not find that the contribution of the futures market to price discovery continued to fall through 2011 and 2012 after its sharp decline in 2010. Instead, according to our estimates, the PT metric for the futures market increased steadily from its 2010 low up to mid-2014. Hence, we cannot confirm Adämmer and Bohl's (2015) conclusion that the contribution of spot markets to price discovery was higher during the episode of high and volatile prices that began in 2010 because spot markets anticipated this episode, while they had been surprised by the earlier episode in 2007/08.

There are several possible explanations for these differences between our results and those reported by Adämmer and Bohl (2015). First, we use a spot price for Rostock, while Adämmer and Bohl (2015) use a spot price for Hamburg. Second, our sample period begins and ends roughly two years later than theirs. Finally, and perhaps most importantly, our results are based on the concept of partial as opposed to classical cointegration. Hence, our estimates do not assume that the long-run relationship between spot and futures prices is time invariant and that all deviations from the long-run relationship are transient. Instead, according to our estimates, roughly 12% of the variance in these deviations is due to shocks that lead to permanent shifts in the long-run relationship, which we interpret as shifts in the basis between spot and future prices.

The evolution of this permanent component is displayed in Figure 3. The values of this component can be interpreted as shifts in the constant term of the long-run equilibrium relationship described in Table 3, i.e. as shifts in the basis between the Rostock spot and the Euronext futures prices. Many factors can influence this basis over time, including the local availability of quality wheat on the spot market in Rostock to affect the spread time series. Figure 4 presents information on the quantity of milling wheat harvested in northeastern Germany, and the average value of the estimated permanent component in the corresponding marketing years.



[a] Marketing year 2002 includes all observations between July 2002 and June 2003.
Source: Own estimation and own calculations based on harvest quality information from Lindhauer et al. (various issues).

Figure 3: Random walk component and production of quality wheat in northeastern Germany

Since the traded volume between 2002 and 2004 was extremely low (figure 2) the results for these years must be treated with caution. But from 2005 onwards we can often observe that the permanent component increases from one year to the next, if the quantity of quality wheat has fallen over the same period, and vice versa. For example, the increased quantity of milling wheat harvested in northeastern Germany in 2005 compared with the previous years corresponds to a downward shift of the permanent component. The increase in the permanent component in 2006 and 2007 corresponds to reductions in the quantity of high-quality wheat produced in northeastern Germany. This pattern is broken in 2008, which may be due to changes in freight cost; in 2008 the Baltic Dry Index as an indicator of freight rates of various raw materials such as grains notably increased (The Baltic Exchange, 2018), which might have further enlarged the basis between Rostock and France. Between 2009 and 2010 the random walk slightly decreased as milling wheat production increased. The stronger random walk in 2011 again corresponds to a lower production quantity, and is followed by a decrease in the random walk and higher production quantities in the ensuing years. This pattern is broken once again in 2014, which may be due to the futures contract specification changes and market developments discussed earlier. As a result of the low quality of the French wheat harvest in 2014, the futures contract in France was effectively a milling wheat rather than a milling wheat contract. Therefore the spread between the futures and spot prices was especially high in this year. In ongoing work we are exploring other explanations for the shifts in the basis that are indicated by our partial cointegration estimates.

5 Conclusions

Understanding the relationship between spot and futures markets for agricultural soft commodities is important for every market participant to make estimations about future price trends and trading activities. Using the PT (Gonzalo and Granger, 1995) and the IS (Hasbrouck, 1995) metrics we analyse the price discovery process on European spot and futures market for milling wheat. We follow the recently introduced concept of partial cointegration (Clegg and Krauss, 2017), ,which enables us to distinguish between transient and permanent shocks to the long-run equilibrium relationship between spot and future prices. Combining the idea of partial cointegration with state space modelling allows us to produce time-varying estimates of the price discovery metrics.

For the price discovery process in the European wheat market our results lead to a clear dominance of the futures market between 2002 and 2016. These findings are in line with many earlier studies that refer to a major role of futures prices in the process of price discovery due to its greater liquidity and transparency compared with spot markets. But our results also indicate that price discovery is subject to structural changes over time. We find that the importance of the spot market increases during episodes of high and volatile prices. Preliminary evidence suggests that permanent shifts in the long-run relationship between spot and futures prices may be related to changes in the availability of quality wheat on the spot market. Specifically, the average quality of wheat harvested in northeastern Germany appears to affect the basis between the spot and futures prices.

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