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Price discovery in the European wheat market

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Abstract

To know about the pricing process in agricultural spot and futures markets is important for every market participant. However, literature for the European market is rare. In this article we analyse price discovery in the European wheat market and focus especially on time periods with price turmoil. We find that price discovery is subject to structural changes over time and that the pattern of dominance in the pricing process alternates between the spot and futures market. Results suggest that neither price turmoil nor a change in the liquidity of the futures market is solely responsible for these structural changes.

Keywords: price discovery, price turmoil, wheat, commodity futures

1 Introduction

International futures markets for agricultural soft commodities play a considerable role in decision making for many farmers as well as suppliers. They are used as a risk management instrument to hedge prices for certain quantities for forward delivery (Acharya, Lochstoer and Ramadorai, 2013) as well as to forecast future spot prices (Chinn and Coibion, 2014). Due to this it is inescapable for market participants to be informed about the actual relation between spot and futures prices and to know in which of these markets price discovery takes place.

Earlier studies show that in general the futures market dominates the price discovery process for agricultural soft commodities. Garbade and Silber (1983) for example were the first to prove that wheat and corn futures markets in the United States (US) incorporate the majority of new information first and therefore dominate the pricing in the respective spot markets. Yang, Bessler and Leatham (2001) confirm their findings for the US wheat market. Brockman and Tse (1995) also support the role of futures markets for price discovery in Canadian grain and oilseeds prices.

But the futures market's dominant contribution to price discovery can be restricted by different aspects. Ivanov (2011) as well as Adämmer, Bohl and Gross (2016) show that the pricing guidance of futures markets depends on their liquidity. If the traded volume on a futures market is low, then its contribution to price discovery might be low as well. Besides liquidity the influence of futures contracts on price discovery might also be affected by episodes of market turmoil. Especially during the food price crises 2007/08 and later again between 2010 and 2013 prices surged and dropped rapidly. This triggered an ongoing debate about the reasons for such agricultural commodity price volatility. Although numerous factors have been widely discussed for different commodities in the literature, there is disagreement as to the relative influence of each of them. Fundamentals such as the population and food consumption growth in developing countries as well as the rising biofuel production in the US and the European Union (EU) have been thematised for example by Dewbre *et al.* (2008), Headey and Fan (2008) or Trostle (2008). Other controversially discussed causes for past price booms might have been the increasing financial market activity accompanied by speculation (Gilbert, 2010), declining stock to utilisation ratios (Piesse and Thirtle, 2009), weather shocks (Headey and Fan, 2008), changes in exchange rates (Adämmer and Bohl, 2015) or rising oil prices (Chen, Kuo and Chen, 2010). Whether or not this is true also hinges on the relationship between spot and futures prices.

Such phases of price volatility might have influenced the relation between spot and futures prices. Peri, Baldi and Vandone (2013) for example provide evidence that during price bubbles spot markets become more important for price discovery in the US market for some agricultural commodities. This is reasoned by the assumption that during drastic increases in commodity prices price discovery is less related to financial trading activity and more dependent on fundamental patterns. However, to date no studies have tested price discovery in the European spot and futures market for wheat and whether it is subject to structural changes especially during time windows with particular price surges and collapses.

In this paper we analyse whether the price discovery process occurs predominantly in the NYSE Euronext Paris wheat futures market or in the German spot market. We analyse the period from 2002 to 2016 and focus especially on time periods of high price volatility. The NYSE Euronext Paris is the EU's major futures exchange for agricultural soft commodities, and its milling wheat futures contract is widely considered to be a meaningful indicator for the pricing of milling wheat throughout the EU (Euronext, 2016). In addition, the German spot market is important because Germany is one of the largest wheat producers in the EU with a share of about 17 % in total EU wheat production of more than 150 million tonnes in 2015 (ADM Germany GmbH, 2016). Most studies of price discovery in agricultural spot and futures markets to date have focused on North America. To the best of our knowledge we are the first to test the price discovery function of a futures market in the European Union (EU) for a substantial European spot market. Thus, this article contributes to the literature since we analyse structural changes in the price discovery process during time periods with significant differences in the liquidity, volatility and price level for a substantial European wheat market.

To determine which one of these markets dominates price discovery, different metrics have been proposed in the literature. We make use of two popular price discovery metrics that are based on vector error correction models (VECM): the permanent-transitory method (PT) by Gonzalo and Granger (1995) and the information shares method (IS) by Hasbrouck (1995).

The study is structured as follows: in section 2, we describe the data we use as well as our methodological approach. In section 3 we present and discuss our empirical results. Section 4 concludes and makes suggestions for future research.

2 Data and methodological approach

To evaluate the interaction between the spot and futures markets we use weekly logarithmised price data for wheat for the time period beginning at January 2002 till April 2016 that are obtained from Thomson Reuters Datastream. To reflect the German spot market we take the milling wheat prices fob Rostock, which is one of the biggest German ports where grain and oilseeds are tendered. For the corresponding futures market we use the milling wheat futures contract no. 2 which is traded at the NYSE Euronext Paris, Europe's major exchange where agricultural soft commodities are merchandised. But several comments about the futures prices are important. Since the nearby contracts are in general the most actively traded ones we only look at these, specifically the contract months January (2002-2015), March, May, July (2002-2005), August (2008-2012), September (2002-2007, 2015), November (2002-2014) and December (2015). Furthermore, the closer the contracts come to maturity the more they lose liquidity. Hence, we use price information from the first nearby contracts until the first day of the last trading month and then switch to the second nearby contract although the contracts do not expire until the 10th of the particular calendar month. However, since the futures contracts differ in their temporal distance from the expiry at any time t they do not correspond to the respective spot prices at time t adequately. Comparing both prices to one another

would lead to biased results since storage cost, that might cause differences in the basis between spot and futures prices, are not considered. To take account for this we adapt the idea of modified futures prices introduced by Garbade and Silber (1983) and Yang, Bessler and Leatham (2001) and calculate logarithmised cash equivalent futures prices

$$\ln(p_t^{CEF}) = \ln(p_T^F - r * [T - t]/360) \quad (1)$$

with p_t^{CEF} as the cash equivalent futures price at time t , p_T^F as the price of the futures contract at time t that expires at time T and r as the daily interest rates of the current 10 year federal bond of the German Bundesbank. In the following the cash equivalent futures price is referred to as the futures price.

Possible quality differences in wheat across the spot and futures markets also need to be considered. Although the Euronext futures contract is declared as a milling wheat contract there are no specifications regarding the protein content or Hagberg falling number for physical delivery for contracts with maturities up to May 2017. As a consequence it can be expected that the German milling wheat fob Rostock has a better quality. But despite these possible quality differences Ghoshray (2006) shows that different wheats with similar end use can be treated as perfect substitutes for one another or at least as substitutes to a certain degree.

The spot and futures prices are charted in figure 1. It appears that both prices co-move and exhibit common price spikes between mid-2003 and mid-2004, during 2007 and 2008 and later again between mid-2010 and 2013 (highlighted).

[Figure 1 about here]

Since both the PT and IS price discovery metrics are based on VECM estimation the price series are first tested for unit roots, using Augmented Dickey Fuller tests (ADF tests) (Dickey and Fuller, 1979). Johansen trace tests are adopted in the following to find out whether the time series are cointegrated and share a common long-term equilibrium relationship (Johansen and Juselius, 1990). The standard VECM that examines the long-run equilibrium as well as the short-run dynamics between the price series is estimated afterwards with the following equation

$$\Delta P_t = \alpha \beta' P_{t-1} + \sum_{i=1}^k A_i \Delta P_{t-i} + \varepsilon_t, \quad (2)$$

with Δ as a difference operator and with P_t and P_{t-1} as $n \times I$ vectors of n price series that are integrated of order one ($I(1)$). A_i as a $n \times n$ matrix represents the coefficients of the lagged variables and k determines the number of lags that are defined by the Akaike Information Criterion (AIC). Thereby $\sum_{i=1}^k A_i \Delta P_{t-i}$ denotes the short run dynamics of the system. $\beta' P_{t-1}$ represents the long-run equilibrium with β as a $n \times r$ matrix of the cointegration coefficients. r counts the number of cointegrating relations. α is a $n \times r$ matrix of error-correction coefficients that determine the speed of adjustment back to the long run equilibrium after exogenous price shocks. ε_t as a $n \times I$ vector displays the error terms as serially uncorrelated innovations with zero mean and the covariance matrix Ω .

To quantify each market's relative contribution to price discovery we use two different price discovery measures, PT and IS. While both decompose price changes into transitory and permanent components, they vary in how they determine these components. Under the assumption that prices for the same goods traded on different markets converge in the long term but may differ from each other in the short term, PT quantifies in how far each market's error correction terms contribute to this common long term trend (Gonzalo and Granger, 1995). To this end, so-called factor weights

that are orthogonal to the error correction process are measured. When linked to cointegrated prices, these factor weights form common trends. In the bivariate case the factor weights are given by

$$PT_1 = \frac{\alpha_2}{\alpha_2 - \alpha_1}, \quad PT_2 = 1 - PT_1 = \frac{\alpha_1}{\alpha_1 - \alpha_2} \quad (3)$$

Since the values of PT are bounded by $[0; 1]$ the interpretation is straightforward: If $PT_1 = 1$, then price discovery solely occurs in market 1 and if $PT_1 = 0$, then price discovery occurs only in market 2. If $PT_1 = PT_2 = 0.5$, then price discovery occurs equally in both markets. If $0.5 < PT_1 < 1$, then both markets contribute to price discovery but market 1 dominates the process.

The second price discovery metric IS calculates the variances of innovations to the common long term trend of two prices for the same good traded on different markets. The variance of the innovations caused by one market relative to the total innovation variance in the common trend is then defined as that one market's information share (Hasbrouck, 1995). For the case of positive correlated error terms across markets Cholesky factorization of the covariance matrix of the residuals of the VECM $\Omega = MM'$, where M is a lower triangular matrix, is used to eliminate contemporaneous correlation. The information shares of market i can then be computed as

$$IS_i = \frac{[(\psi M)_i]^2}{\psi \Omega \psi'}, \quad (4)$$

with $\psi \Omega \psi'$ as the total innovation variance and $(\psi M)_i$ as the i th element of the row of matrix ψM (Hasbrouck, 1995). The Cholesky factorization of the covariance matrix $\Omega = MM'$ depends on the order of prices in P_t . Thus, the results for the information shares can also depend on this order, leading to upper and lower bound estimates. In the literature to date it is common to calculate the information shares for both possible orders and report the mean of the resulting estimates (Baillie *et al.*, 2002; Flad and Jung, 2008; Fuangkasem, Chunchachinda and Nathaphan, 2014; Martinez *et al.*, 2011). Since $0 \leq IS_i \leq 1$ the interpretation of IS equals the interpretation of PT. In a bivariate case, the market with a higher IS dominates the price discovery process.

3 Results and discussion

First ADF tests are used 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 about here]

Table 2 reports the results of the Johansen trace test for cointegration and shows that the spot and futures prices are cointegrated and share a common long-run equilibrium.

[Table 2 about here]

We next estimate a standard VECM for the spot and futures prices and measure PT and IS. A constant term is included in the long-run equation of the VECM that is presented in table 3. In the long-run the logarithmised spot price equals 1.029 times the logarithmised futures price minus a constant value of 0.081. Both estimates are significant.

[Table 3 about here]

In table 4 the adjustment parameters (α) of the VECM¹, PT and IS are reported. Between 2002 and 2016 both markets react to equilibrium prices changes, but whereas the spot market adjusts by 7% per week the futures market adjusts by less than 5%. This leads to a PT of about 40% in the spot market and 60% in the futures market. Therefore price discovery takes place in both markets but is dominated by the futures market according to the PT metric. But the results change for IS. For both orders of spot and futures prices in the VECM the values of IS are higher in the spot market which indicates that price discovery predominantly takes place in the spot market with a mean IS of 66% for the spot market and a mean IS of 34% for the futures market.

[Table 4 about here]

3.1 Structural change

To analyse in a second step whether the estimated relation between spot and futures prices is subject to structural changes we apply Chow tests for every potential change point in the inner 75% of the dataset. It appears that the long-run relation is indeed characterised by structural changes with the first breakpoint in mid-2004 and a next one following in mid-2007. But instead of splitting the time series into only a few single time periods we allow for multiple structural changes over time and construct a window of $n=100$ observations and roll it over the entire sample. The first 100-observation window covers January 21, 2002 to December 15, 2003; the second window covers January 28, 2002 to December 22, 2003, and the last of 643 windows covers Mai 19, 2014 to April 18, 2016. For each time period VECM, PT and IS² are calculated separately. Figure 2 displays the values of PT and mean IS for the futures price series over time (left axis) as well as the sum of the traded futures contracts for the specific time periods (right axis). Since PT as well as IS each add up to one for both prices, only the results for one time series are reported for reasons of clarity. The time windows covering periods with higher prices and volatility as highlighted in figure 1 are marked. Although figure 2 only displays the mean IS (to avoid cluttering the graph), using the upper- or lower-bound-IS measure produces very similar results (available from the authors).

[Figure 2 about here]

The results indicate that the price discovery process in the European wheat market is subject to structural changes between 2002 and 2016 since the results of both applied metrics PT and IS lead to changing roles of the spot and futures markets over time. The results for PT suggest that price discovery in futures and spot markets goes through six main phases. In the first phase covering the time windows with right way adjustment rates starting until August 2004 price discovery is clearly dominated by the futures market because of its $PT > 0.5$. In the second phase including all time windows starting between August 2004 and June 2005 price discovery is still dominated by the futures market, but this dominance is less pronounced. In all time periods starting between June 2005 and October 2006 as the third phase as well as starting between August 2008 and February 2010 as the fifth phase the spot market is the leader in the price discovery process with PT of above 50%. In the fourth phase covering all time windows starting between October 2006 and August 2008 the dominant position switches back to the futures market. In the remaining time windows starting between February 2010 and May 2014 (sixth phase) the futures market generally dominates the price discovery process again with only a few single exceptions in the last windows.

¹ Detailed results of the short-run equation of the VECM are available upon request.

² Detailed results are available upon request.

The results for the IS measure are similar and also indicate that price discovery goes through six phases. However, in the second and in the fourth phase price discovery is more evenly distributed compared to the results for the PT measure. But the futures market still dominates in the majority of the time windows in both phases. In the third and in the fifth phase the dominance of the spot market is a bit more distinct compared to the results of the PT metric. In the last time windows starting in mid-2010 onwards as the sixth phase the spot market dominates approximately in the first and in the last third of the time windows whereas the futures market dominates in the middle of the sixth phase. These results differ the most from the results of PT that point to an explicit leading role of the futures market in the whole phase.

Different results in the last phase might result from the methodological variations between the two metrics. PT and IS are both well established in the literature, especially in fields of financial assets, and have their merits depending on the exact definition 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 calculates the amount of information generated by one market. Therefore possible changes in different parameters of the VECM might affect the results of both metrics in different ways. Between 2010 and 2016 we can say that in terms of error correction the futures market dominates the price discovery process because the spot markets adjust to price changes quicker than the futures market. But when looking at IS the amount of variation in the prices is explained by the change in the spot market stronger than by the change in the futures market in the majority of the time windows.

A possible explanation for the differences between PT and IS could result from changes in the long-run relation between the spot and futures prices that is displayed in figure 3. It can be observed that the slope parameter only varies slightly over time in contrast to the constant. The two highlighted areas on the right side of figure 3 in which the constant increases remarkably match to the parts of phase six in which the pattern of dominance differs between PT and IS. These substantial high values of the constant parameter might be one explanation for the differences between PT and IS in the last phase. The highlighted area on the left side of figure 3 in which the constant is again higher matches to the first part of the second phase in which the spot market dominates when looking at IS but the futures market dominates when calculating PT.

[Figure 3 about here]

Reasons for these changes in the VECM in the sixth phase might be related to the increased volatility in both prices from mid-2010 onwards that is observable in figure 1. Moreover the contract specifications of the wheat futures contract at the NYSE Euronext Paris changed over time. Between 2002 and 2012 either the contract months September or August were tradable as ex-harvest contracts. But these summer contracts were extremely illiquid compared to the remaining tradable contract months. Since these contract months dropped out in most parts of the sixth phase results might differ because the spot prices were then compared to futures prices of different contract months with different expiry dates.

3.2 Liquidity of the futures market

Furthermore the amount of traded wheat futures contracts at the NYSE Euronext Paris considerably increased during the last years starting with about 0.04 million contracts in 2002 up to more than 4 million contracts in 2015. This results in a nearly constantly increasing sum of traded contracts in

the respective time windows as shown in figure 2. To test whether the liquidity of the futures contract influences the price discovery process quadratic regression functions are estimated. The results are presented in table 5.

[Table 5 about here]

The results of the regression estimations suggest that an increasing trading volume in the futures market leads to a slightly stronger influence of the futures market on the price discovery process when looking at the PT model. Simultaneously the influence of the spot market decreases with an increase in the number of traded futures contracts. Having in mind that the maximum amount of traded contracts in the 643 time windows is about 8 million contracts we see that the level of the coefficients is extremely low. Hence, the influence of the liquidity of the futures market on the price discovery process is extremely weak and neglectable. In addition the results are not significant. Considering the IS model the interpretation of the results is equivalent because of the low estimated values. Using changes in the trading volume between two sequential time windows instead of the absolute values does not lead to a different interpretation. Taking account of these results the futures market's contribution to price discovery does not seem to depend on its liquidity as distinct as pointed out in earlier studies by Ivanov (2011) or Adämmer, Bohl and Gross (2016) for example.

3.3 Time periods with price turmoil

Focusing on the time periods with price spikes highlighted in figure 1 and figure 2 the results are inconsistent. For the time windows covering the first period of higher prices from mid-2003 until mid-2004 both metrics cannot be calculated due to the incorrect signs of the adjustment parameters with the exception of two windows in which the futures market clearly dominates. When looking at the the time slots covering the food price crises starting in mid-2007 up to the end of 2008 with rapidly rising and dropping commodity prices the futures market dominates price discovery when measuring PT as well as IS although the process is much more evenly distributed for IS. But when looking at the time windows covering the third period of price turmoil between mid-2010 and mid-2013 the results are inconclusive for both metrics. The futures market clearly dominates when calculating PT whereas the spot market incorporates new information first when calculating IS.

Therefore our results do not match earlier results by Peri, Baldi and Vandone (2013) who point out that in times of price bubbles the importance of spot markets for price discovery increases.

4 Conclusions

To know about the actual relation 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. To date most studies of price discovery in agricultural commodity markets have focused on regions in North America. In contrast we analyse the price discovery process in a substantial European spot and futures market for milling wheat considering multiple possible structural changes. Based on VECM estimations we make use of two popular price discovery metrics, that are both well established in the literature: the PT model proposed by Gonzalo and Granger (1995) and the IS method introduced by Hasbrouck (1995). We construct time windows and roll them weekly to be able to see what new values entering the window have led to a change in the results. This differs from earlier studies that measure price discovery only for a few single static time periods.

The futures market's dominant contribution to price discovery for agricultural commodities is widely discussed in the literature but only supported partially by our results for the European wheat market. We find that between 2002 and 2016 the pricing process in the European wheat market was neither clearly dominated by the spot market nor by the futures market but that both markets contribute to price discovery. These findings are not completely in line with many earlier studies that refer to a major role of futures prices in the process of price discovery due to greater liquidity or transparency in the futures market over the physical spot markets. Furthermore our results indicate that price discovery was subject to structural changes over time.

These structural changes occur in the results of both applied metrics. Our outcomes suggest that price discovery goes through six phases but that differences between the phases are not only explainable by price turmoil or a change in the liquidity of the traded futures contract as supposed by earlier studies. Although the amount of traded futures contracts nearly constantly increased during the last years a direct influence on the pricing process is neither graphically observable nor approved by regression analyses.

During the food price crisis in 2007/2008 both metrics point to a dominant position of the futures market in the price discovery process whereas the results are inconclusive for the period of price spikes and crashes between 2010 and 2013. All in all we do not find consistent outcomes regarding the price discovery process in the European wheat market during time windows with price turmoil. But we assume that differences between PT and IS might be related to an increasing volatility in the wheat prices from 2010 onwards.

Since we only focus on the European wheat market our study offers potential for future research. Further studies could focus on additional agricultural commodities like corn or oilseeds and might also compare the results with the price discovery process of non-storable goods. In addition the reasons for structural changes in price discovery in spot and futures markets have to be looked upon more in detail.

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Table 1: Results of the ADF tests

Price		Lags ^{a)}	Test-statistic ^{b)}
Spot	levels	3	-1.9096
Futures		4	-2.2677
Spot	1 st difference	2	-11.5952
Futures		3	-11.4642

^{a)} Number of lags chosen by AIC

^{b)} Critical values for test statistics: -3.44 (1%), -2.87 (5%), -2.57 (10%)

Table 2: Results of the Johansen trace test for cointegration

Lags ^{a)}	Rank	Test-statistic ^{b), c)}
6	0	40.23
	1	4.56

^{a)} Number of lags chosen by AIC

^{b)} Critical values for trace-test-statistic for rank 0: 24.60 (1%), 19.96 (5%), 17.85 (10%)

^{c)} Critical values for trace-test-statistic for rank 1: 12.97 (1%), 9.24 (5%), 7.52 (10%)

Table 3: Results of the long-run equation of the VECM

Dependent variable	Independent variable	Estimate	Std. error	t-value	p-value
Spot	Futures	1.029	0.007	153.800	<0.001
	constant	-0.081	0.033	-2.392	0.017

Table 4: Results of the price discovery metrics

Price	α ^{a)}	PT	IS		mean
			1 st bound ^{b)}	2 nd bound ^{c)}	
Spot	-0.070 (0.0226)	0.399	0.594	0.725	0.660
Futures	0.046 (0.0294)	0.601	0.406	0.275	0.340

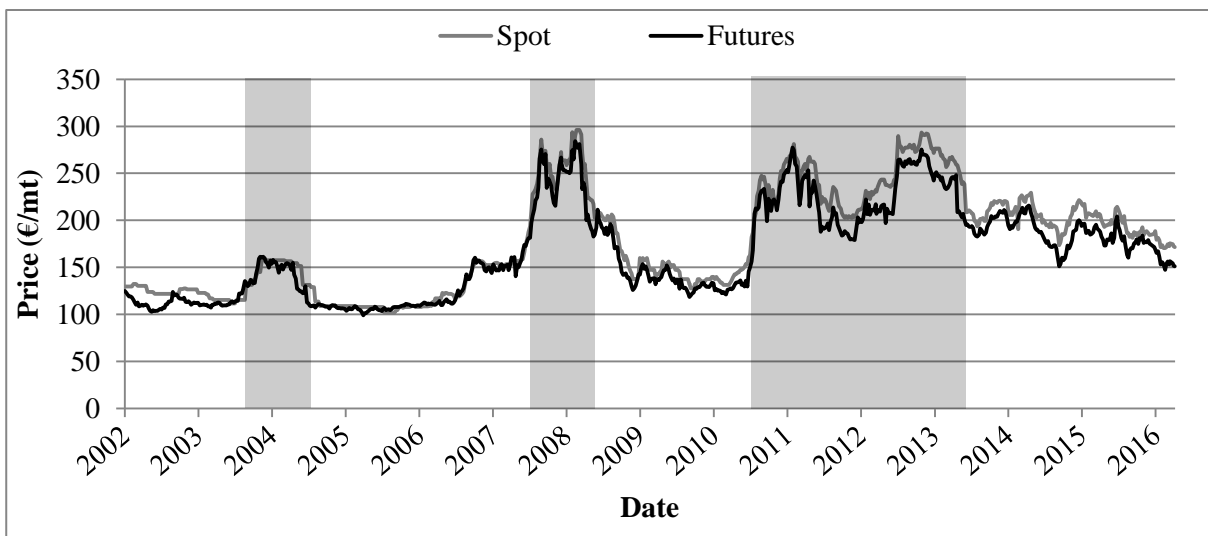
^{a)} p-values in brackets

^{b)} Order of prices: 1) spot, 2) futures

^{c)} Order of prices: 1) futures, 2) spot

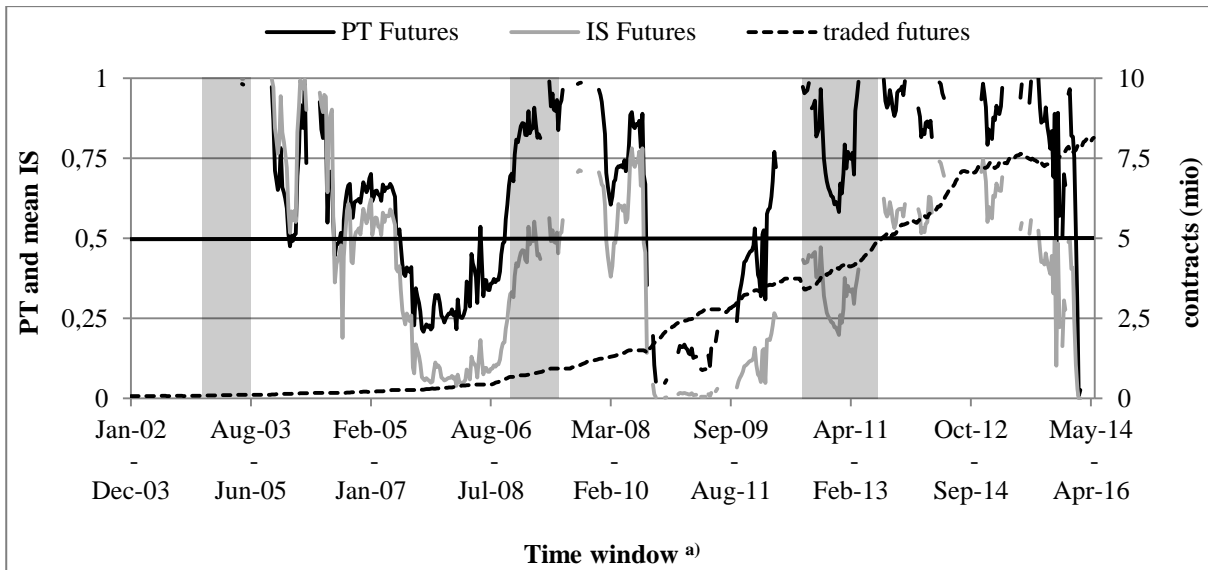
Table 5: Results of the regression estimations

Dependent variable	Independent variables	Estimate	Std. error	t-value	p-value
PT ^{Futures}	(mio contracts) ²	0.003	0.002	1.208	0.228
	mio contracts	0.016	0.018	0.849	0.397
	constant	0.559	0.022	25.561	<0.001
IS ^{Futures}	(mio contracts) ²	-0.013	0.003	-5.199	<0.001
	mio contracts	0.091	0.019	4.870	<0.001
	constant	0.547	0.022	24.871	<0.001



Source: Thomson Reuters Datastream

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

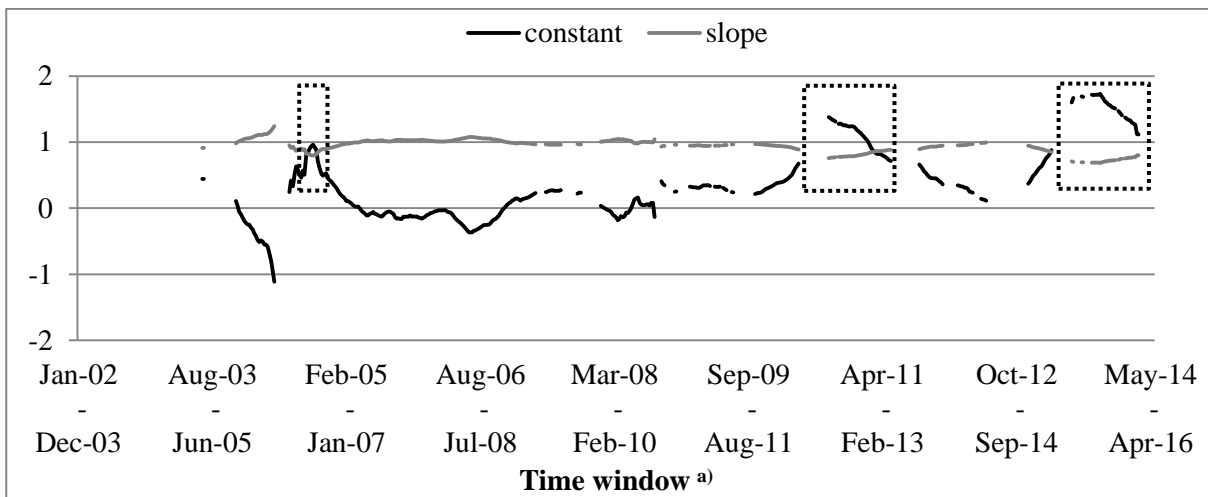


Time windows with price spikes in the inner 75% of their dataset are highlighted.

a) Each time window covers $n=100$ weekly observations

b) Since the adjustment parameters are expected to be positive for the futures prices and negative for the spot prices wrong way adjustment rates are excluded and we do not calculate PT and IS for those periods so that 400 time windows remain.

Figure 2: Results of PT and mean IS^{b)} for futures prices over time



The spot price in natural logarithms is defined as the dependent variable and the futures price in natural logarithms is defined as the independent variable.

The parameters of the long-run relation between spot and futures prices are only displayed for the 400 time windows with right way adjustment rates for which PT and IS are calculated.

a) Each time window covers $n=100$ weekly observations

Figure 3: Changes in the long-run relation of spot and futures prices over time