Analysis of the Relationship between Commodity Futures and Spot Prices

An Applied Time Series Analysis (Stationarity, Cointegration, Granger-Causality)

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January, 2012

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Introduction

Aims of this empirical analysis

- Examination of **stationarity** of daily commodity futures and spot prices
- Examination of **cointegration relationships** of daily commodity futures and spot prices
- Examination of **Granger-cause relationships** of daily commodity futures and spot prices

Introduction: Spot and Futures Prices

Spot Prices

The spot price of a commodity is the price that is quoted for immediate (spot) settlement (payment and delivery).

Futures Prices

The futures price of a commodity is the price that is quoted for a certain delivery time and a certain amount in the future.

Introduction: Spot Prices

SJ_GR850 ***Date change on Year***
St. Joseph, MO Wed Jan 04, 2012 USDA-MO Dept Ag Market News

Daily National Grain Market Summary

Grains closed slightly mixed after Tuesday's active trade. Corn closed mostly unchanged as it rallied late to close off its losses, as dry conditions in Argentina has curbed selling interest. Soybeans had slight gains as soybeans are also tied to the dry conditions in South America. Wheat had losses in Chicago and Minneapolis, with slight gains in K.C. Wheat closed slightly mixed. Corn traded steady to 3 cents higher. Soybeans closed 2-12 cents higher.

TRUCK BIDS:	DATE 01/04/12***	CHANGE 01/03/12***	YEAR AGO 01/05/11***
Wheat:			
Kansas City (HRW ORD)	6.89	up 1	7.98
Minneapolis (DNS)	8.94	dn 5 1/4	9.29
Portland (SWW)	6.05-6.25	dn 5	7.60-7.70
St. Louis (SRW)	6.63	dn 3	8.02
Corn, US No 2 Yellow:			
Kansas City	6.77	up 3	6.01-6.04
Minneapolis	No Bid	N/A	No Bid
So. Iowa	6.37 1/2-6.43 1/2	unch	5.93 1/4-5.97 1/4
Omaha	6.47-6.50	unch	5.91-5.95
Soybeans, US No 1 Yellow:			
Kansas City	12.20	up 12	13.55-13.59
Minneapolis	No Bid	N/A	No Bid
So. Iowa	11.99-12.02	up 2 1/2	13.57-13.71 1/2
Cent. Il Processor	12.20-12.25	up 12 1/2-2 1/2	13.71 1/2-13.86 1/2

Introduction: Futures Prices

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Corn Futures

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Quotes | Time & Sales | Volume | Settlements   **Trade Date: 1/5/2012**

Globex Futures | Open Outcry Futures   Market Data is delayed at least 10 minutes

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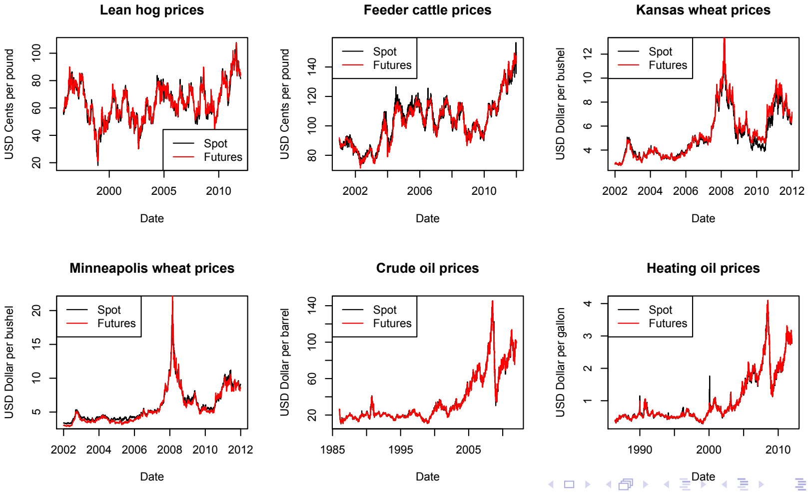
Month	Charts	Last	Change	Prior Settle	Open	High	Low	Volume	Hi / Lo Limit	Updated
Mar 2012 OPT		649'2	-9'2	658'4	658'0	659'6	645'6	84,871	698'4 618'4	10:29:46 AM CT 1/5/2012
May 2012 OPT		656'6	-10'0	666'6	666'2	668'0	653'4	34,141	706'6 626'6	10:29:47 AM CT 1/5/2012
Jul 2012 OPT		662'6	-10'2	673'0	671'6	674'0	659'2	27,427	713'0 633'0	10:29:44 AM CT 1/5/2012
Sep 2012 OPT		609'4	-8'2	617'6	616'4	617'4	606'0	1,409	657'6 577'6	10:29:47 AM CT 1/5/2012
Dec 2012 OPT		583'4	-6'2	589'6	589'0	589'6	580'4	10,375	629'6 549'6	10:29:46 AM CT 1/5/2012
Mar 2013 OPT		595'0	-6'6	601'6	600'0	601'4	594'0	206	641'6 561'6	10:25:24 AM CT 1/5/2012
May 2013 OPT		603'2	-6'0	609'2	608'4	608'4	603'0	16	649'2 569'2	9:46:53 AM CT 1/5/2012
Jul 2013 OPT		607'0	-6'6	613'6	609'4	609'4	606'6 a	42	653'6 573'6	10:24:56 AM CT 1/5/2012
Sep 2013 OPT		-	-	589'0	-	-	-	0	629'0 549'0	9:30:00 AM CT 1/5/2012

Description of Data

Commodity	Exchange	Time Period	Data Points
Lean hog	CBOT	1995-11-02 to 2011-12-30	4065
Feeder cattle	CBOT	2001-01-02 to 2011-12-30	2763
Kansas wheat	KCBOT	2002-01-02 to 2011-12-30	2468
Minneapolis wheat	MGE	2002-01-02 to 2011-12-30	2465
Crude oil	NYME	1986-01-02 to 2011-12-30	6514
Heating oil	NYME	1986-06-02 to 2011-12-30	6406

- Futures prices are obtained from the particular exchange (data of the next-to-delivery contract month, respectively).
- Spot prices are obtained from USDA (grains), CME (meats), and U.S. EIA (energy) reports, respectively.

Description of Data



Tests on Stationarity

ADF Test

$$\Delta X_t = a + bt + \phi X_{t-1} + \sum_{j=1}^{p-1} \alpha_j \Delta X_{t-j} + u_t$$

$H_0 : \phi = 0 <=>$ unit root in the characteristic polynomial $=>$ nonstationarity
$H_1 : \phi < 0 <=>$ **no** unit root in the characteristic polynomial $=>$ (trend) stationarity.
The lag order p is determined by minimizing AIC for autoregressions with a constant and a linear trend. X_t are logarithms of the nominal price series.

Tests on Stationarity

ADF test results

Commodity	Series	ADF	ADF-I(1)	Lags	Implication
Lean hog	Spot	-3.87**	-23.87***	3	I(0)
	Futures	-3.69**	-61.19***	1	I(0)
Feeder cattle	Spot	-1.90	-17.38***	10	I(1)
	Futures	-2.23	-47.43***	1	I(1)
Kansas wheat	Spot	-2.33	-50.68***	0	I(1)
	Futures	-2.21	-48.56***	0	I(1)
Minneapolis wheat	Spot	-1.94	-48.87***	0	I(1)
	Futures	-2.01	-48.13***	0	I(1)
Crude oil	Spot	-3.29*	-39.20***	5	I(1)
	Futures	-3.42**	-81.41***	0	I(0)
Heating oil	Spot	-2.76	-43.18***	4	I(1)
	Futures	-2.70	-80.18***	0	I(1)

Note: Single (*), double (**), and triple asterisks (***) denote significance at the 10%, 5%, and 1% levels, respectively.

Tests on Cointegration

Johansen Procedure (Multivariate DF Model)

If the re-written vector representation

$$\Delta X_t = \mu + \Pi X_{t-1} + \Psi_1 \Delta X_{t-1} + \Psi_2 \Delta X_{t-2} + ... + \Psi_{p-1} \Delta X_{t-p+1} + u_t$$

with $X = (X_1, ..., X_n)'$ is cointegrated, then Π is singular and can be represented as

$$\Pi = \alpha\beta',$$

with $(n \times r)$-matrices α, β of rank r. The r columns of β are cointegrating vectors that describe equilibrium relations. The coefficients in α are called loading coefficients and describe how the variables react to deviations from equilibrium.

Tests on Cointegration

The Johansen procedure step by step:

1. All variables X_j, $j = 1, ..., n$ should be either I(1) or I(0).
2. Determine the VAR lag order p by multivariate information criteria.
3. Determine the cointegrating rank r by sequences of hypothesis tests: estimate β.
4. Estimate the full EC-VAR model given p and r to estimate α and Ψ_j.

Tests on Cointegration

Cointegration test results

Commodity	$r \leq 1$	$r = 0$	Lags	Implication
Lean hog	11.79***	109.56***	12	system is stationary
Feeder cattle	2.00	27.31***	23	cointegration $r = 1$
Kansas wheat	2.60	12.36	2	no cointegration
Minneapolis wheat	2.65	19.11**	12	cointegration $r = 1$
Crude oil	0.88	105.90***	22	cointegration $r = 1$
Heating oil	0.98	82.54***	22	cointegration $r = 1$

Note: Single (*), double (**), and triple asterisks (***) denote significance at the 10%, 5%, and 1% levels, respectively. The standard model with a constant is used. The VAR lag order is determined by minimizing multivariate AIC. X_t are logarithms of nominal price series.

Cointegration Relationships

For example **feeder cattle** spot and futures prices cointegrate (the rank $r{=}1$) and the system can be written as

$$\begin{bmatrix} \Delta \text{Spot}_t \\ \Delta \text{Futures}_t \end{bmatrix} = \begin{bmatrix} 0.0103 \\ -0.0018 \end{bmatrix} + \underbrace{\begin{bmatrix} \mathbf{-0.0906} \\ \mathbf{0.0174} \end{bmatrix}}_{\alpha} \underbrace{[\mathbf{1}, \mathbf{-0.98}]}_{\beta'} \begin{bmatrix} \text{Spot}_{t-1} \\ \text{Futures}_{t-1} \end{bmatrix}$$
$$+ \begin{bmatrix} \Psi_{11} & \Psi_{12} \\ \Psi_{12} & \Psi_{22} \end{bmatrix} \begin{bmatrix} \Delta \text{Spot}_{t-1} \\ \Delta \text{Futures}_{t-1} \end{bmatrix} + \ldots + \begin{bmatrix} u_{1,t} \\ u_{2,t} \end{bmatrix}.$$

Tests on Granger-Causality

In the case of two time series, X_1 and X_2, X_1 Granger-cause X_2 if X_2 can be better predicted using the histories of both X_1 and X_2 than it can by using the histories of X_2 alone.

Granger-Causality Test

$X_{2,t}$ is not Granger-causal for $X_{1,t}$ iif the bivariate VAR(p) process of the form

$$\begin{bmatrix} X_{1,t} \\ X_{2,t} \end{bmatrix} = \sum_{i=1}^{p} \begin{bmatrix} \gamma_{11,i} & \gamma_{12,i} \\ \gamma_{12,i} & \gamma_{22,i} \end{bmatrix} \begin{bmatrix} X_{1,t-i} \\ X_{2,t-i} \end{bmatrix} + \begin{bmatrix} u_{1,t} \\ u_{2,t} \end{bmatrix},$$

has $\gamma_{12,i} = 0$, for all $i = 1, 2, ..., p$.

Tests on Granger-Causality

Notes on Granger-causality tests:

- It requires checking whether specific coefficients are zero, therefore standard tests for zero restrictions are applied (χ^2- or F-test based on the Wald principle).

- They have nonstandard asymptotic properties if the VAR contains I(m) variables with $m > 0$ (or possible cointegration).
- This can be overcome in fitting VAR processes whose order exceeds the true order.
- A lag augmented model with m additional lags can be used in the test.
- The hypothesis of zero coefficients has to be tested on only the first p coefficients.

See Toda and Yamamoto (1995) for more details.

Tests on Granger-Causality

Granger causality test results

Commodity	Spot $\nrightarrow$ Futures	Futures $\nrightarrow$ Spot
	p-values	
Lean hog	0.01***	0.00***
Feeder cattle	0.00***	0.00***
Kansas wheat	0.73	0.00***
Minneapolis wheat	0.00***	0.00***
Crude oil	0.00***	0.00***
Heating oil	0.00***	0.00***

Note: Single (*), double (**), and triple asterisks (***) denote significance at the 10%, 5%, and 1% levels, respectively. A VAR model with a constant is used. The same lag orders as in cointegration tests are used. m (the maximum order of integration of both time series) additional lags are included. Logarithms of nominal price series are used.

Tests on Granger-Causality

Implications of Granger-causality test results:

- Granger-causality between commodity spot and futures prices appears generally to be bi-directional. Futures prices cause spot prices and vice versa.
- This suggests that no profitable arbitrage exists, new information appears to be reflected by spot and futures prices simultaneously.

Summary and Conclusion

Test Results

- Stationarity: Unit roots tests suggest that daily commodity spot and futures prices appear generally to be **non-stationary**.
- Cointegration: Tests on cointegration suggest that daily commodity spot and futures prices appear generally to be **cointegrated**.
- Granger-causality: Tests on Granger-causality suggest generally **bi-directional causality** between daily commodity spot and futures prices.

References

- Lütkepohl, H. and Krätzig, M. (eds.) (2004). Applied Time Series Econometrics. Cambridge University Press, Cambridge, UK.
- Toda, H. Y. and Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. Journal of Econometrics, 66, 225–250.