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Crude Oil Prices, Interest Rates and the Dollar: Evidence from MF-DFA and MF-DCCA

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Outlines

- Introduction
- Literature Review
- Methodology
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- Results and Discussion
- Conclusion

Introduction

Background

- Crude oil
  - Leading indicator
  - Critical role in almost all production activities
  - Classical theory of microeconomics
    - Prices are determined by the demand and supply fundamental

Background (Con't)

- Interest rates
  - Negative relationship between real interest rates and oil prices (Akram, 2009).
  - Crude oil prices and interest rates influence each other (Wang and Hu, 2015).

Introduction

Background (Con't)

- Interest rates
  - Cheaper oil prices with low elasticity of demand ↑ money supply, ↓ interest rates.
  - Lower interest rates ↑ the present value of the expected future net storage costs, thereby ↑ current commodity prices.

Introduction

Background (Con't)

- Interest rates
  - ↑ in oil prices → crude oil supplies expensive, and further ↓ the demand for oil.
  - ↑ crude oil prices inspire people to demand for alternative energy, such as agricultural commodities to substitute bio-fuel for crude oil.

Introduction

Background

- **The Dollar**
  - Price per barrel of world crude oil is denominated in US dollars
  - As US dollars denominated commodity, crude oil price often losses its ground in home currencies of all other countries, especially for the oil rich nations where the US dollar is strong (Li et al., 2016).

Research Problems

- Higher oil price may induce global economic activities and higher inflation.
- If the inflation is caused by a shock (eg. oil price-increased), a contractionary monetary policy can deteriorate the long term output by increasing interest rate and decreasing investment.
- Thus, to what extent do commodity prices tend to overshoot in response to unanticipated changes in interest rates is still unexplored.

Research Gaps

Relationship between Oil Prices and Interest Rates

Positive

- Wang and Chuen (2013)

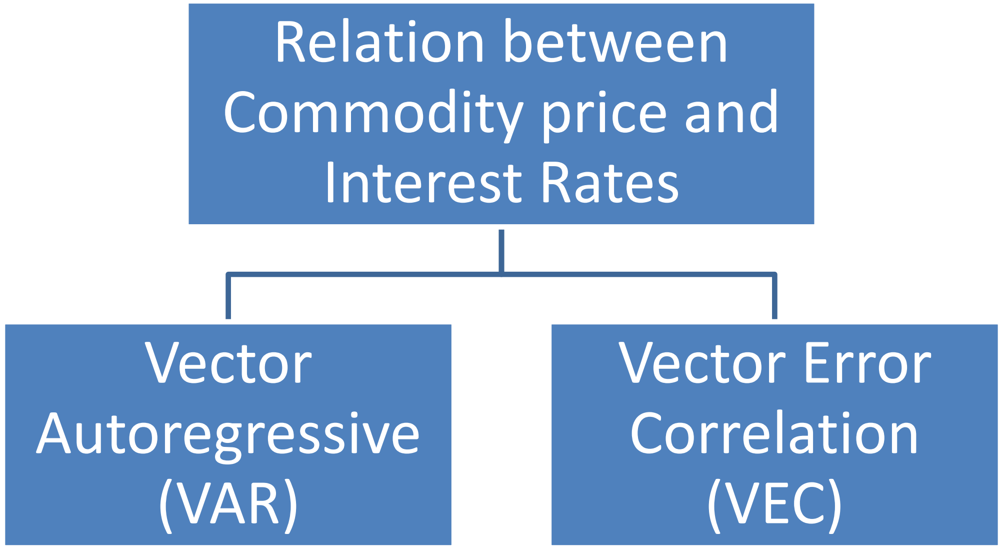
Negative

- Arora and Tanner (2013)
- Akram (2009)
- Frankel (2006)

No Linkages

- Alquist et al. (2011)
- Frankel and Rose (2009)

Research Gap (Con't)



- VAR and VEC assume linear joint dynamics (Wang and Hu, 2015).
- Arguments in the Econophysics studies denoted that linkages among economic variables are intrinsically nonlinear and change over time.
- it is thus inappropriate to capture the dynamics of economic variables using linear specifications.

Research Objectives

■ This study aims to

1. examine the existence of multifractality properties in the autocorrelation of crude oil prices, interest rates and the dollar using non-linear approach
2. examine the existence of multifractality properties in the cross-correlation of crude oil prices, interest rates and the dollar using non-linear approach

Research Questions

- Our **research questions** are:
  1. Is the autocorrelation of crude oil prices, interest rates and the dollar monofractal or multifractal?
  2. Is the cross-correlation between crude oil prices and interest rates monofractal or multifractal?
  3. Is the cross-correlation between crude oil prices and the dollar monofractal or multifractal?
  4. Is the cross-correlation between interest rates and the dollar monofractal or multifractal?
  - Using nonlinear approach
    - parsimony, interpretability, and predictability (Bates and Watts, 2007).

Significance of the Study

- Previous works focused on linear models, such as VAR or VEC methods.

- This study implements nonlinear approach that is parsimony, interpretability, and predictability (Bates and Watts, 2007).

- First study in econphysics literature that examines the autocorrelation and cross-cross correlation from a completely fresh perspective.
  - borrow the methods from statistical physics (econphysics) area

Methodology

Detrended Fluctuation Analysis (DFA)

- Proposed by Peng et al. (1994).
- To explore the long-range correlation embedded in the nonstationary financial time series.
- Out-perform rescale range analysis even over short size / short horizon time series.
- Two vital extensions: MF-DFA, MF-DCCA.

Methodology

Multifractality

- First introduced in the context of turbulence
  - There after applied to Finance area due to the heavy tail and long-range dependence features (Green et al., 2014)
- Types of Multifractality
  - Multifractality due to a broad probability density functions for the values of time series
  - Multifractality due to different long-range (time-) correlation of small and large fluctuations

Methodology

Multifractality Detrended Fluctuation Analysis (MF-DFA)

- Proposed by Kantelhardt et al. (2002)
- To examine the presence of multifractality in the autocorrelation of financial time series.
  - E.g., Wang and Hu (2015), Lye and Hooy (2012), Wang et al. (2011)

Methodology

Multifractality Detrended Cross-Correlation (MF-DCCA)

- Proposed by Podobnik and Stanley (2008)
- To examine the presence of multifractality in the cross-correlation of financial time series
- E.g., Li et al. (2016), Liu (2014), Guo et al. (2012)

Methodology

Multifractality Detrended Cross-Correlation (MF-DCCA)

- Step 1

$\{x(i),\ i = 1,2 \ldots, N\}$ → $X(i) = \sum_{t=1}^{i}(x(i) - \bar{x})$

$\{y(i), i = 1,2 \ldots, N\}$ → $Y(i) = \sum_{t=1}^{i}(y(i) - \bar{y})$

Where $i = 1,2, \ldots, N$

$\bar{x}$ and $\bar{y}$ represent the average of time series, $x(i)$ and $y(i)$

Methodology

Multifractality Detrended Cross-Correlation (MF-DCCA)

- Step 2
  - Divide both the series, $X(i)$ and $Y(i)$ into $N_s = N/s$ non-overlapping segments of equal length, *s*.
  - The same process is repeated from the opposite end of each series.
  - $2N_s$ non-overlapping segments are obtained

Methodology

Multifractality Detrended Cross-Correlation (MF-DCCA)

- Step 3
  - The local trends, $x^{v}(i)$ and $y^{v}(i)$ for each of the segments (*v=1,2,…..,N*) are estimated by least squares fits of each series

$$F^2(s,v) = \frac{1}{s}\sum_{i=1}^{t}\left|X\big((v-1)s+i\big) - X^{v}(i)\right| \bullet \left|Y\big((v-1)s+i\big)Y^{v}(i)\right|$$

where *v=1,2,…..,N*

Methodology

Multifractality Detrended Cross-Correlation (MF-DCCA)

- Step 3 (Cont…)

$$F^2(s,v) = \frac{1}{s}\sum_{i=1}^{t}|X(N-(v-N_s)s+i)-X^v(i)| \bullet |Y(N(v-N_s)s+i)Y^v(i)|$$

where $v = N_s, N_s+1, \ldots, 2N_s$

– The trends, $x^v(i)$ and $y^v(i)$ can be computed from linear, quadratic or higher order polynomials fits

Methodology

Multifractality Detrended Cross-Correlation (MF-DCCA)

- Step 4
  - In order to obtain *q*th-order fluctuation functions, average over all segment is required

$$F_q(s) = \left[\frac{1}{2N_s}\sum_{v=1}^{2N_s}[F^2(s,v)]^{q/2}\right]^{1/q}$$

Multifractality Detrended Cross-Correlation (MF-DCCA)

- Step 4 (Con't…)
  - In particular, when *q*=0, Equation in step 4 can be re-defined as

$$F_0(s) = exp\left[\frac{1}{4N_s}\sum_{v=1}^{2N_s}\ln[F^2(s,v)]\right]$$

  - In this step, MF-DFA is the standard of the DFA when *q*=2

Multifractality Detrended Cross-Correlation (MF-DCCA)

- Step 5
  - If two series are long-range cross-correlated, will increase $F_q(s)$ ues of s, and a power-law expression can be expressed as

$$F_q(s) \sim s^{H_{xy}(q)}$$

Multifractality Detrended Cross-Correlation (MF-DCCA)

- Step 5
  - Equation in Step 5 can be represented in log form as below

$$\log F_q(s) = H_{xy}(q)\log(s) + \log A$$

  - The scaling exponent, $H_{xy}(q)$ is the generalized cross-correlation exponent that describe the power-law relationship

Methodology

Multifractality Detrended Cross-Correlation (MF-DCCA)

- Step 5 (Con't….)
  - If time series $x(i)$ and $y(i)$ are identical, MF-DCCA is equal to MF-DFA, and MF-DCCA = DCCA when *q*=2
  - Thus, the cross-correlation exponent, $H_{xy}(q)$ is equivalent to the generalized Hurst exponent $H_{xy}(1)$

Methodology

Multifractality Detrended Cross-Correlation (MF-DCCA)

- Step 5 (Con't….)

$H_{xy}(q) > 0.5$ → Persistent (Positive)

$H_{xy}(q) < 0.5$ → Anti-Persistent (Negative)

$H_{xy}(q) = 0.5$ → Not cross-correlated

Multifractality Detrended Cross-Correlation (MF-DCCA)

- Step 5 (Con't….)
  - Multifractal formalism recommends the Renyi Exponent to characterize the multifractal nature

$$\tau_{xy}(q) = qH_{xy}(q) - 1$$

  - If $\tau_{xy}(q)$ is linear of the q, the cross-correlation is monofractal, and otherwise.

Methodology

The Strength of Multifractality

- The difference between the largest values of Hq and the smallest values of Hq

- Autocorrelation or cross-correlation is said to be multifractal if exponents, H varies for different values of fluctuation order, q.

Methodology

■ Variables:

1. Crude oil prices (Brent, WTI, Dubai); [Datastream]
2. US federal funds rate (proxy for Interest rates); [Federal Reserve]
3. Real broad effective exchange rate (proxy for US dollar) [Datastream]

■ Frequency: Daily

■ Study period: 05 Jan 1995 – 31 Dec 2015 (availability of REER data: Jan 1995)

Methodology

Data

- Return Series

$$r_t = 100 \times \log(P_t / P_{t-1})$$

Returns

Monthly prices at time, *t*

Results and Discussions

Descriptive Statistics

	Crude Oil			Fed Funds	REER
	Brent	**WTI**	**Dubai**		
Mean	0.015163	0.013674	0.012842	-0.063824	0.004839
Std. Dev.	2.1928	2.3921	2.0401	8.1920	0.29033
Minimum	-16.967	-17.092	-14.408	-78.846	-2.3019
Maximum	15.164	16.414	14.705	90.287	1.7331
Skewness	-0.058046	-0.17394**	-0.14304**	0.32505**	-0.062001
Exc. Kurt.	3.7825**	4.9497**	3.5926**	30.916**	4.1624**
Jacque-Bera	3267.5**	5617.6**	2963.6**	218180**	3956.6**
No. of Obs.	5476	5476	5476	5476	5476

Note: ** denotes the rejection at 1 percent significance level

≤

Results and Discussions

MF-DFA

q	Crude Oil			Fed Funds	REER
	Brent	**WTI**	**Dubai**		
-6	0.6258	0.5861	0.6244	0.8757	0.6361
-4	0.5928	0.5563	0.6007	0.8237	0.6066
-2	0.5570	0.5268	0.5761	0.7218	0.5724
0	0.5218	0.5033	0.5400	0.5718	0.5298
2	0.4931	0.4826	0.5109	0.5244	0.4959
4	0.4544	0.4493	0.4645	0.4139	0.4441
6	0.4186	0.4161	0.4230	0.3476	0.3935

- Scaling exponents (Hq) is in decreasing trend with q → Multifractal
- Autocorrelation: Persistent (when q ≤ 0), Anti-persistent (when q > 2), MF-DFA = DFA (when q = 2)

Results and Discussions

MF-DCCA

q	Brent-WTI	WTI-Dubai	Brent-Dubai	Brent-FF	WTI-FF	Dubai-FF	Brent-REER	WTI-REER	Dubai-REER	FF-REER
-6	0.6983	0.7041	0.7393	2.6587	2.6565	2.6461	0.6510	0.6346	0.6694	0.7261
-4	0.6644	0.6709	0.6884	2.5926	2.5823	2.5805	0.6328	0.6143	0.6472	0.6809
-2	0.6210	0.6316	0.6352	2.4229	2.4060	2.4132	0.6121	0.5967	0.6244	0.6247
0	0.5757	0.5894	0.5882	0.6341	0.6280	0.6352	0.5895	0.5777	0.6006	0.5708
2	0.5410	0.5571	0.5525	0.5631	0.5569	0.5631	0.5706	0.5618	0.5808	0.5381
4	0.5088	0.5218	0.5138	0.5054	0.4999	0.5005	0.5441	0.5290	0.5475	0.4495
6	0.4802	0.4881	0.4767	0.4581	0.4539	0.4563	0.5132	0.4926	0.5100	0.3820

- Scaling exponents (Hxy) is in decreasing trend with q → Multifractal
- Cross correlation: Persistent (when $q \leq 4$), Anti- persistent (when $q > 4$), MF-DCCA = DCCA (when $q = 2$)

Results and Discussions

The Strength of Multifractality

- MF-DFA

q	Crude Oil			Fed Funds	REER
	Brent	WTI	Dubai		
ΔH	0.2072	0.1700	0.2014	0.5281	0.2425

- Autocorrelation is significant multifractal.
- Risk (Volatility) of Fed Funds (interest rates) is double the risk (volatility) of crude oil prices and the dollar

ΔH

Results and Discussions

The Strength of Multifractality

- MF-DCCA

q	Brent-WTI	WTI-Dubai	Brent-Dubai	Brent-FF	WTI-FF	Dubai-FF	Brent-REER	WTI-REER	Dubai-REER	FF-REER
ΔH	0.2181	0.2160	0.2626	2.2006	2.2026	2.1898	0.1378	0.1420	0.1594	0.3441

- – Cross-correlation is significant multifractal
- – Changes in interest rates have a largest impact on crude oil

Conclusion

- To examine the presence of multifractality using nonlinear models – the MF-DFA and MF-DCCA approaches

- Dubai crude oil price and Fed Funds series demonstrate the presence of autocorrelation.

- All types of crude oil prices, interest rates and the dollar series exhibit the presence of cross-correlation between series

Conclusion

- Autocorrelation and cross-correlation of small fluctuations orders are persistent as compared to that of large fluctuation orders which are anti-persistent

- Strength of multifactality
  - Autocorrelation and Cross-correlation significant multifractal

Conclusion

- MF-DFA: Financial risk measure of interest rates is double the financial risk measure of crude oil prices
  - Volatility (risk) of interest rates higher than crude oil prices

- MF-DCCA: Financial risk measure of crude oil-Interest rates is the highest
  - Interest rates have large impact on crude oil prices

Conclusion

Implications

- Shed some light to policy makers to recognise in advance the extent of oil price effects on real market and to provide guidance in designing and planning appropriate fiscal policy tools.

- Fiscal stimulus needs to be associated with monetary policy in order to counterbalance the detrimental effect from both investment and industrial production.

Conclusion

Implications

- The application of the appropriate policy tools lessen the detrimental impact of oil price to the global economy, if not evade.

-End of Presentation-

Thank You