MULTISCALE CROSS SAMPLE ENTROPY ANALYSIS FOR CHINA STOCK MARKETS AND INTERNATIONAL CRUDE OIL PRICE

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Abstract

This paper presents multiscale cross sample entropy (MSCE) analysis for the synchrony relationship between China stock markets and international crude oil price. Shanghai and Shenzhen Stock Exchange (SSE, SZSE) Composite Indexes are used to represent China stock markets. WTI (West Texas Intermediate grade) and Europe Brent crude oil spot price is employed as benchmark for international oil price. MSCE is calculated and analyzed with different parameters. The results show that the MSCE between the stock indexes and the oil price decreases as the time scale increases. It implies that they are more synchronous at greater time scale. Under the same condition, the MSCE between SSE and oil price is smaller than the value between SZSE and oil price. This indicates that SSE is more synchronized with world oil price than SZSE. Meanwhile, the MSCE of WTI and stock markets is smaller than the value of Brent oil price and stock markets. This suggests that China stock markets are more synchronized with WTI than Brent oil price.

Keywords: multiscale cross sample entropy; stock market; crude oil price

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1. Introduction

As the economy and industry development in worldwide, nowadays the crude oil has taken an important role in the world economy (see Moya-Martínez, 2014). It is not only a main source of energy but also provides fundamental materials for lots of industries. The stock market which could be a barometer for economy conditions is another crucial component of economy and finance systems (see Cao, 2015). To analyze the relationship between crude oil and stock markets are useful for risk and investment management (see Zhu, 2014).

This topic has attracted many researches in recent years. Aloui (2013) employed time varying copula method to study the dependence of Brent oil price and the stock markets of Eastern European countries and positive dependence was discovered. Ghosh (2016) explored the nonlinear cointegration between Indian stock market and international oil price. Balcilar

(2015), Alsalman (2016), Kang (2015, 2016) and Gatfaoui (2016) researched the relationship between U.S. stock markets and crude oil price. Wen (2012) examined the contagion effect between crude oil and stock markets and found evidence supporting the existence of contagion phenomenon. Wang (2013) used structural VAR analysis to research the relation of oil price shocks and stock markets for oil-importing and oil-exporting countries. Dagher (2013) analyzed the dynamical linkage between Lebaneses stock market and world oil price. Evidences for oil price Granger causing the stock price were found.

Cross sample entropy (Cross-SampEn) is a measure which is developed to assess the asynchrony or dissimilarity between two time series (see Richman, 2000). The larger value means greater asynchrony. And smaller value means more synchronous or similar (see Shi, 2013). Cross-SampEn does not depend on specific models and is appropriate for nonlinear systems. It has already applied in physiology, finance and signal processing domains (see Zhang, 2007; Liu, 2010; Zeng, 2017; Fabris, 2013). Based on Cross-SampEn, Xia (2012) introduced multiscale cross sample entropy (MSCE) which measures the asynchrony of two time series at different scales. China has been the second largest economy in the world and has huge demand for crude oil. But China is heavily dependent on the imported oil. This paper applies MSCE to analyze the multiscale synchrony relationship of China stock markets and world crude oil price.

The rest of the paper is organized as follow. Section 2 introduces the data of stock markets and oil price. Methods are described in Section 3. Section 4 gives the empirical results and discussion. Then Section 5 concludes the paper.

2. Data

This paper uses daily WTI and Europe Brent spot oil price for international crude oil price. For China stock markets, we use the daily closing price of Shanghai and Shenzhen stock exchange (SSE, SZSE) composite indexes. The time span of the data is from January 4th, 2007 to December 30th, 2016 about ten years. WTI and Brent price data is downloaded from EIA (U.S. Energy Information Administration) https://www.eia.gov/. SSE and SZSE data is downloaded from WIND database. All programs are implemented by MATLAB.

As markets are not open on weekends and festivals, we follow Voronkova (2004) and Chiang (2007) to take the price of the latest trading day for these days. We apply formula (1) to calculate the logarithmic return for stock and oil price data.

$$R_t = \ln P_t - \ln P_{t-1} \tag{1}$$

Where R_t is the logarithmic return on day t, P_t and P_{t-1} is the price on day t and $t-1$. Figure 1 shows the detail of the return.
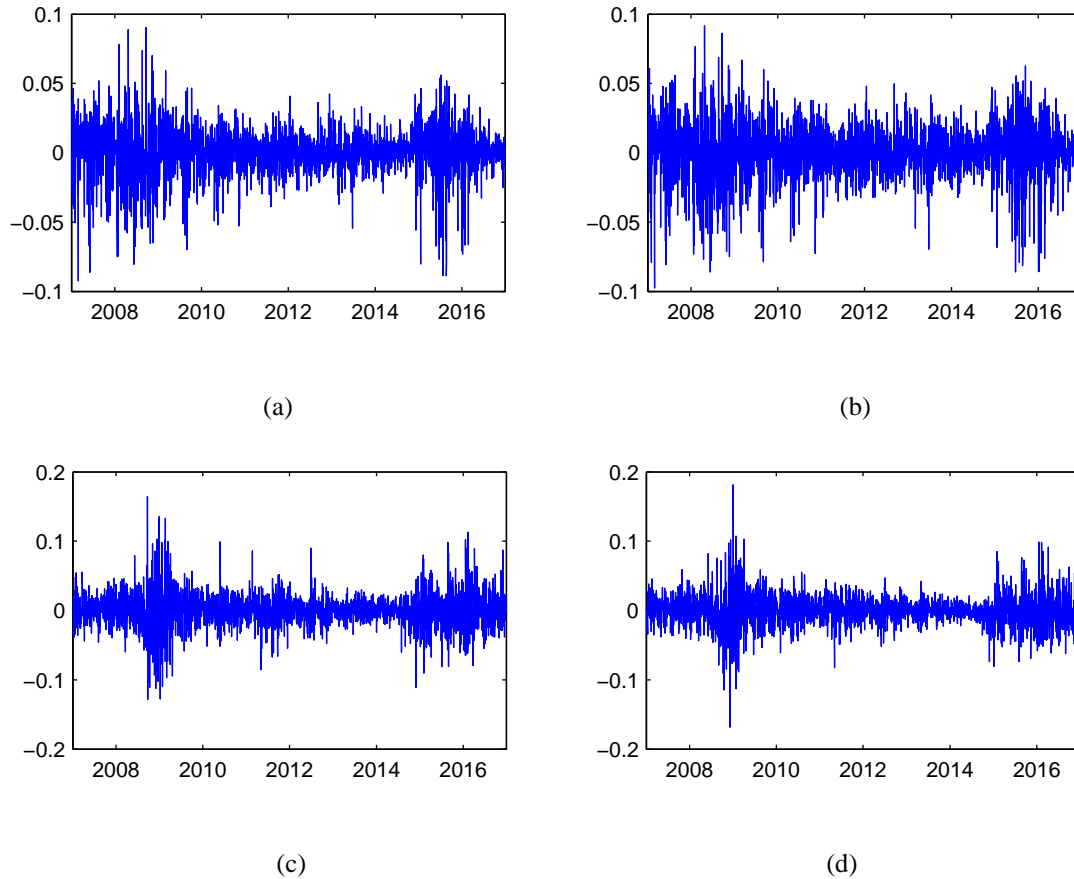
Figure 1. logarithmic return for SSE (a), SZSE (b), WTI (c) and Brent oil price (d)

3. Methods

MSCE is multiscale extension for Cross-SampEn. Its details are as follow (see Xia, 2012). Let $U = \{u(1), u(2), ..., u(N)\}$ and $V = \{v(1), v(2), ..., v(N)\}$ be two time series with length of N. Then we can form two sequences of vectors by formula (2) and (3).

$$x_m(i) = (u(i), u(i+1), ..., u(i+m-1)), \quad \{1 \pounds\ i \pounds\ N - m+1\} \tag{2}$$

$$y_m(j) = (v(j), v(j+1), ..., v(j+m-1)), \quad \{1 \pounds\ j \pounds\ N - m+1\} \tag{3}$$

Where m is the dimension of each vector. In this paper we follow Shi (2013) and Zhang (2007) to take $m = 2$.

Let n_i^m be the number of vectors $y_m(j)$ whose distance to $x_m(i)$ is within the tolerance r. The distance between $x_m(i)$ and $y_m(j)$ is defined in formula (4).

$$d(x_m(i), y_m(j)) = \max\{|u(i+k) - v(j+k)|, 0 \pounds\ k \pounds\ m-1\} \tag{4}$$

Where $i, j \pounds\ N - m$. Following the same definition, we could also calculate n_i^{m+1}. Thus the

Cross-SampEn is defined in formula (5).

$$Cross\text{-}SampEn(m,r,N) = -\ln\frac{\sum_{i=1}^{N-m} n_i^{m+1}}{\sum_{i=1}^{N-m} n_i^{m}} \tag{5}$$

MSCE is the Cross-SampEn at different scale. To calculate it, the coarse-gained series of the original series U and V with scale factor t are formed by formula (6) and (7).

$$x_j^t = \frac{1}{t}\sum_{i=(j-1)t+1}^{jt} u_j, \quad 1 \le j \le \frac{N}{t} \tag{6}$$

$$y_j^t = \frac{1}{t}\sum_{i=(j-1)t+1}^{jt} v_j, \quad 1 \le j \le \frac{N}{t} \tag{7}$$

Then we can calculate the Cross-SampEn of x_j^t and y_j^t according to formula (5).

In this paper we follow Shi (2013) and Zhu (2010) to standardize the original time series U and V with formula (8) and (9):

$$u^*(i) = \frac{u(i) - \bar{u}}{s_u} \tag{8}$$

$$v^*(i) = \frac{v(i) - \bar{v}}{s_v} \tag{9}$$

Where $\bar{u}$ and $\bar{v}$ is the average value of U and V. s_u and s_v is the standard deviation of U and V. Commonly tolerance r is between 0.15-0.25 for the standardized series (see Yang, 2017). We follow Shi (2013) and Hernandez-Perez (2010) to use $r = 0.2$. In order to examine the robustness of the results, we also analyze the results of $r = 0.15$ and $r = 0.25$.

4. Results and Discussion

Figure 2 shows the MSCE value when $r = 0.2$. The horizontal axis is the scale factor t. It can be observed that the MSCE value decreases as the scale factor increases. Since smaller MSCE indicates less asynchrony, it can be inferred that China stock markets and the international crude oil price become more synchronous when time scale gets larger.
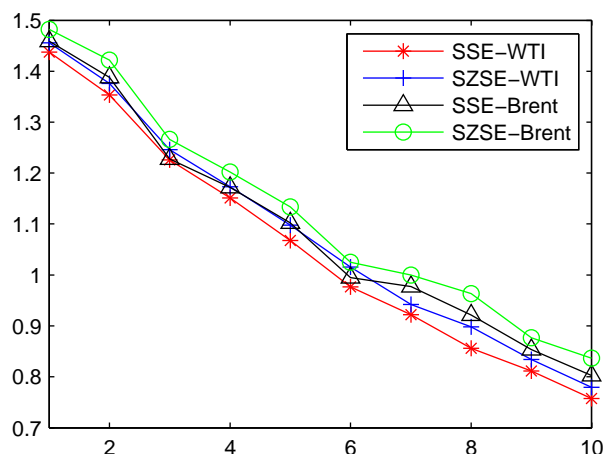
Figure 2. MSCE results for $r = 0.2$.

To examine the different synchrony degree of SSE and SZSE with oil price, we subtract their MSCE value and the results are displayed in table 1. It can be observed that the MSCE between SSE and oil price is smaller than the value between SZSE and oil price at different scales. It can be inferred that SSE is more synchronized with world crude oil price than SZSE. In China, large and traditional companies are mainly listed on Shanghai stock market. These companies are more influenced by crude oil price comparing with growth enterprises which are mainly listed on Shenzhen stock market.

Table 1. The difference of MSCE for SSE and SZSE with oil price when $r = 0.2$

t	$MSCE_{\text{SZSE-WTI}} - MSCE_{\text{SSE-WTI}}$	$MSCE_{\text{SZSE-Brent}} - MSCE_{\text{SSE-Brent}}$
1	0.0185	0.0235
2	0.0224	0.0344
3	0.0201	0.0381
4	0.0221	0.0300
5	0.0299	0.0311
6	0.0390	0.0303
7	0.0200	0.0226
8	0.0419	0.0422
9	0.0227	0.0233
10	0.0224	0.0341

In order to investigate the different influence of WTI and Brent oil price on SSE and SZSE, we subtract their MSCE value with the same stock market. The results are exhibited in table 2. It can be seen that the MSCE for WTI oil price and stock markets is smaller than the value of Brent oil price and stock markets. This implies that SSE and SZSE are more synchronous with WTI than Brent oil price.

Table 2. The difference of MSCE for WTI and Brent oil price with stock indexes when $r = 0.2$

t	$MSCE_{\text{SSE-Brent}} - MSCE_{\text{SSE-WTI}}$	$MSCE_{\text{SZSE-Brent}} - MSCE_{\text{SZSE-WTI}}$
1	0.0213	0.0263
2	0.0344	0.0464
3	0.0025	0.0205
4	0.0208	0.0287
5	0.0347	0.0359
6	0.0182	0.0095
7	0.0554	0.0580
8	0.0648	0.0651
9	0.0421	0.0427
10	0.0452	0.0569

In order to check the robustness of the results, we analyze the results when $r = 0.15$ and $r = 0.25$. Figure 2 displays the MSCE value for these parameters. It can be also seen that the value is in downtrend as the scale factor gets greater. This also implies China stock markets and world oil price are more synchronous in greater time scale.
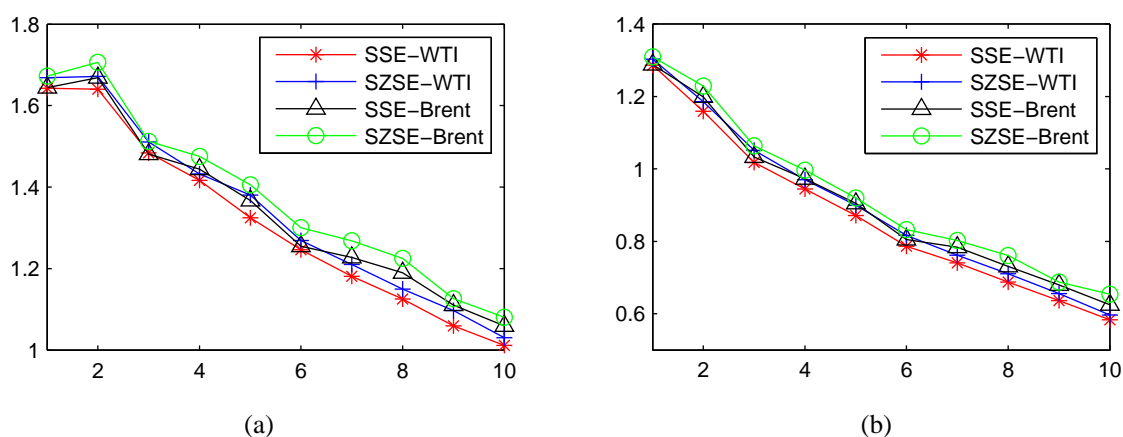

(a)   (b)

Figure 3. MSCE value for $r = 0.15$ (a) and $r = 0.25$ (b)

Table 3 shows the MSCE difference of SSE and SZSE with oil price when $r = 0.15$ and $r = 0.25$. They are also all positive indicating that the MSCE of SSE and oil price is smaller and SSE is more synchronized with world oil price.

Table 3. The difference of MSCE for SSE and SZSE with oil price when $r = 0.15$ and $r = 0.25$

t	$r = 0.15$		$r = 0.25$	
	$MSCE_{SZSE\text{-}WTI} -$ $MSCE_{SSE\text{-}WTI}$	$MSCE_{SZSE\text{-}Brent} -$ $MSCE_{SSE\text{-}Brent}$	$MSCE_{SZSE\text{-}WTI} -$ $MSCE_{SSE\text{-}WTI}$	$MSCE_{SZSE\text{-}Brent} -$ $MSCE_{SSE\text{-}Brent}$
1	0.0261	0.0284	0.0170	0.0211
2	0.0316	0.0372	0.0264	0.0303
3	0.0265	0.0310	0.0337	0.0313
4	0.0155	0.0316	0.0252	0.0237
5	0.0564	0.0379	0.0285	0.0153
6	0.0228	0.0453	0.0298	0.0272
7	0.0291	0.0409	0.0212	0.0186
8	0.0241	0.0355	0.0227	0.0301
9	0.0372	0.0162	0.0189	0.0082
10	0.0183	0.0212	0.0128	0.0294

Table 4 displays the MSCE difference for WTI and Brent oil price with stock indexes when $r = 0.15$ and $r = 0.25$. Only when t is 3 and $r = 0.15$, the value is negative which is very near to 0. Other value is all positive implying smaller MSCE for WTI with stock indexes. This also indicates more synchrony between China stock markets and WTI oil price.

Table 4. The difference of MSCE for WTI and Brent oil price with stock indexes when $r = 0.15$ and $r = 0.25$

t	$r = 0.15$		$r = 0.25$	
	$MSCE_{SSE\text{-}Brent} -$ $MSCE_{SSE\text{-}WTI}$	$MSCE_{SZSE\text{-}Brent} -$ $MSCE_{SZSE\text{-}WTI}$	$MSCE_{SSE\text{-}Brent} -$ $MSCE_{SSE\text{-}WTI}$	$MSCE_{SZSE\text{-}Brent} -$ $MSCE_{SZSE\text{-}WTI}$
1	0.0016	0.0039	0.0025	0.0066
2	0.0283	0.0339	0.0401	0.0440
3	-0.0027	0.0018	0.0145	0.0121
4	0.0270	0.0431	0.0276	0.0261
5	0.0430	0.0245	0.0336	0.0204
6	0.0089	0.0314	0.0188	0.0162
7	0.0465	0.0583	0.0432	0.0406
8	0.0642	0.0756	0.0431	0.0505
9	0.0504	0.0294	0.0429	0.0322
10	0.0473	0.0502	0.0410	0.0576

5. Conclusions

This paper applies MSCE to research the synchronous dependence between China stock markets and world oil price at different scales. Shanghai and Shenzhen stock markets are chosen to stand for China stock markets. WTI and Brent oil price is taken to represent international oil price. The results show that all MSCE value tends to decrease as the time scale factor increases. This indicates more synchrony between China stock markets and

international crude oil markets at greater time scale. The MSCE between SSE and oil price is found to be smaller than the value between SZSE and oil price. It implies SSE is more synchronized with world oil markets than SZSE. In addition, the MSCE between WTI and stock indexes is smaller than the value between Brent oil price and stock indexes. This indicates that China stock markets are more synchronized with WTI than Brent oil price.

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