ISSN 1749-3889 (print), 1749-3897 (online)
International Journal of Nonlinear Science
Vol.21(2016) No.2, pp.85-90

Dynamic Analysis of Correlation and Risk of the International Crude Oil Import Costs

Zhenqi Ding[1] *, Lixin Tian[1,2],Yang Yang[1]
[1]Energy Development and Environmental Protective Strategy Research Center, Jiangsu University, Zhenjiang, Jiangsu, 212013. P.R. China
[2]School of Mathematical Sciences, Nanjing Normal University, Nanjing, Jiangsu, 210023. P.R. China
(Received 28 May 2015 , accepted 22 January 2016)

Abstract: In recent years, the correlation and risk of the international crude oil import costs have became the focus of attention of all countries. In this paper, we use the monthly data of the international crude oil import costs of France, Germany, Italy, Spain, UK, Japan, Canada and USA from 2003 to 2015. Based on the random matrix theory, we construct time moving windows and create the correlation coefficient matrix $C(t)$ in each time moving window. The correlation and risk of the international crude oil import costs are analyzed by means of the average correlation coefficients. We further analyze the risk of the international crude oil import costs by the method of absorption rate. The research results show that: the correlation of the international crude oil import costs is very high. And the second is that the international crude oil import costs are very risky and it's still increasing.

Keywords: international crude oil import costs; the average correlation coefficient; random matrix theory; correlation coefficient matrix.

1 Introduction

The random matrix theory mainly studies some statistical properties of the eigenvalues and the eigenvectors of random matrix. It is a hot research topic in the fields of Applied Mathematics, probability statistics and modern physics.

Johansson studied a certain random groeth model in two dimensions closely related to the one-dimensional totally asymmetric exclusion process [1]. The results showed that the shape fluctuations and appropriately scaled converged in distribution to the Tracy-Widom largest eigenvalue. Tulion provided a tutorial on random matrices [2]. Furthermore, the application of random matrix theory to the fundamental limits of wireless communication channels was described in depth. Hao Meng investigated the systemic risk and spatiotemporal dynamics of US housing market 1975-2011 at the state level based Random Matrix Theory(RMT)[3]. He found richer economic information in the largest eigenvalues deviating from RMT predictions for the housing market.

The crude oil is a kind of basic energy product, the change of international crude oil import costs affect all aspects of the economy. The fluctuations of the international crude oil import costs have brought tremendous impact on the global economy. It also caused the academic circles to carry on the more and more discussion to the related questions of international crude oil import costs and they built theories and models to make the appropriate explanations from different angles at the same time.

There are many scholars to study the relationships between crude oil prices. Such as, Bekiros, Stelios D. researched the linear and nonlinear causality between spot and futures prices based on daily data of West Texas Intermediate (WTI) crude oil spot and futures prices [4]. Jose AlvarezC Ramirez studied the long-term characteristics of the three benchmark crude oil spot price by fractal theory , the spot price fluctuations in the market of the three benchmark crude oil have different characteristics in different periods [5,6].

*Corresponding author. *E-mail address*: 245082251@qq.com

IJNS.2016.04.15/903

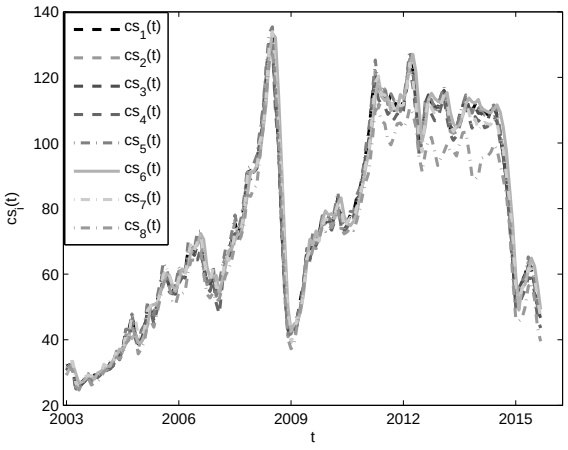

Figure 1: International crude oil import costs

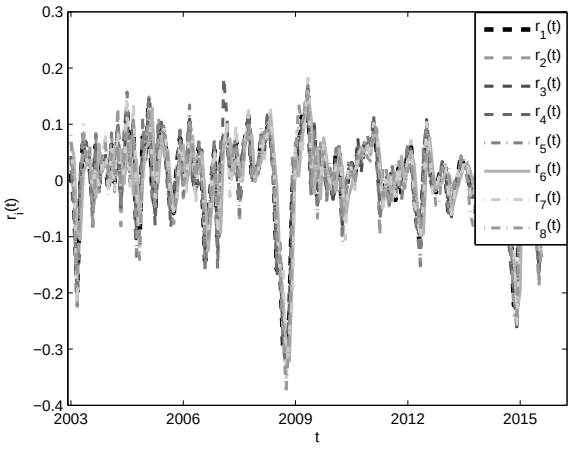

Figure 2: The logarithmic return of international crude oil import costs

A large number of domestic and foreign literature studied on the crude oil price risk. For example, Pierre Giot and Sbastien Laurent used Risk Metrics, Skewed Student APARCH and Skewed Student ARCH and other VaR methods to study daily spot price risk between Brent and WTI [7]. J. David Cabedo and Ismael Moya used historical simulation (HS) method of VaR and HSAF method combining with ARMA forecasting model to study international crude oil price risk, the method improves the standard HS method for VaR estimate, it is more effective than VaR estimate given by the ARCH model [8]. Basher, Syed A. used an international multi-factor model approach and allowed unconditional and conditional risk factor to survey the relationships between oil price risks and the returns in emerging stock market [9]. Ying Fan used GARCH-type model based on the generalized error distribution (GED) to analyze the existence of significant two-way risk spillover effects between WTI and Brent crude oil market [10].

In summary, the correlation and risk of the international crude oil import costs are important issues in the energy market. A large number of previous studies on crude oil prices study the correlation between crude oil prices for two or three states, they didn't study the correlation of the international crude oil import costs. In the study of risk, the correlation and risk of the international crude oil import costs are not combined.

This paper is organized as follows. The second part introduces the methods. The third part is the empirical analysis. We get conclusions in the fourth part.

2 Method

2.1 Random matrix

For random matrix:

$$R = \frac{1}{L} A A^T. \tag{1}$$

Here A is an $N \times L$ random matrix, it is constituted of N independent sequence of length L. Each sequence is subject to $N(0,1)$ distribution.

2.2 The correlation coefficient

I define $cs_i(t)$ as the monthly international crude oil import costs data of the selected states at time t , so the logarithmic return at time t is defined as:

$$r_i(t) = lncs_i(t) - lncs_i(t-1). \tag{2}$$

t \ countries	France	Germany	Italy	Spain	UK	Japan	Canada	USA
2003.01	31.98	31.02	30.66	30.56	32.24	29.14	31.58	29.42
2003.02	32.36	32.31	32.02	31.19	33.23	31.22	33.20	31.89
2003.03	31.14	30.67	31.52	30.75	31.67	32.57	33.41	30.43
.....	.....	.....	.....	.....	.....	.....	.....	.....
2006.01	60.72	60.97	58.97	57.05	62.13	57.80	58.88	54.50
2006.02	61.10	59.10	59.20	58.87	60.52	61.57	60.80	54.01
2006.03	60.75	59.85	58.81	59.20	60.93	61.15	59.31	54.63
.....	.....	.....	.....	.....	.....	.....	.....	.....
2015.09	47.76	47.32	46.68	43.56	47.89	49.24	46.95	39.53

Moving window 1

Moving window 2

Moving window 3

Figure 3: Time moving windows

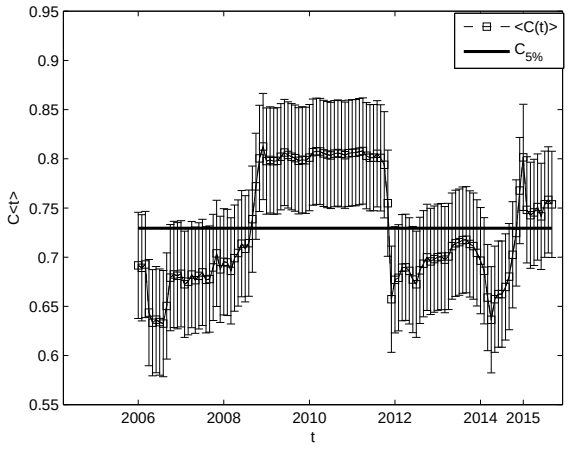

Figure 4: Average correlation coefficients

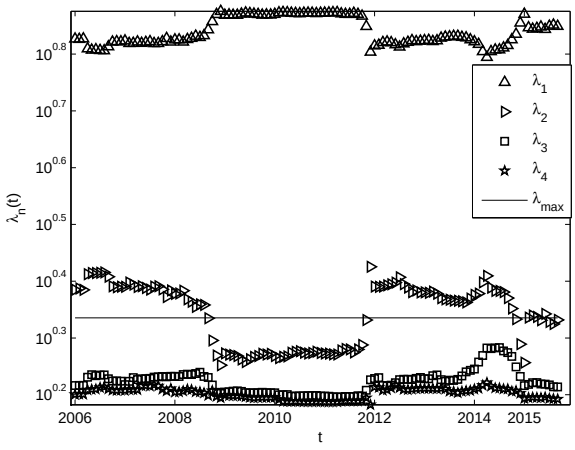

Figure 5: Eigenvalues

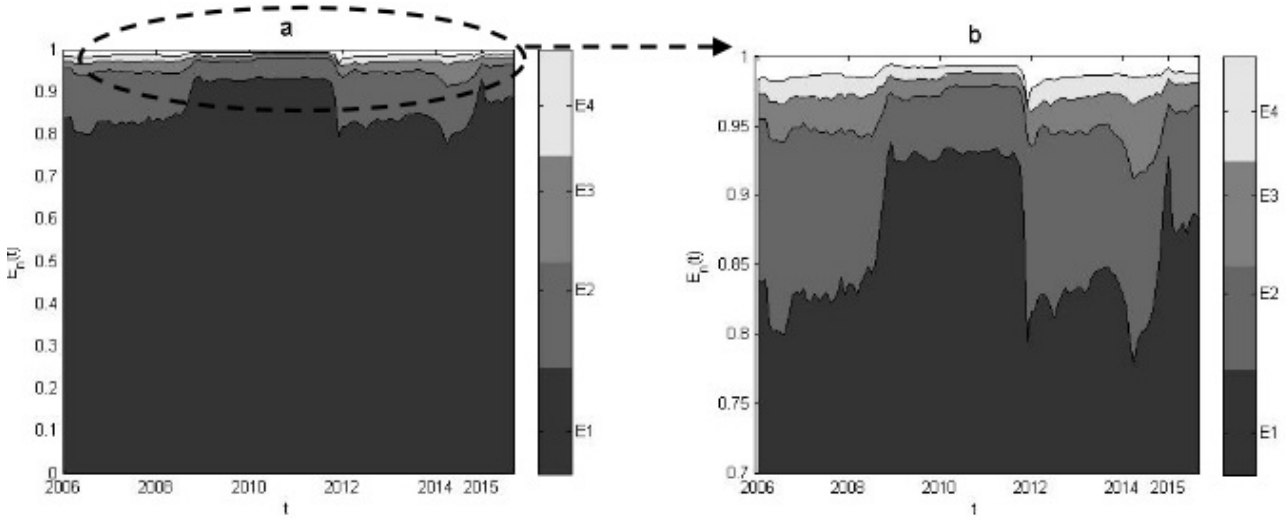

Figure 6: Absorption rate

The logarithmic return at time t is recorded as $r_i(t), \quad i = 1, 2, \cdots, N$. According to the random matrix theory, length L of the moving window should be more than N.For each moving window $[t - L + 1, t]$ at time t , we compute the correlation matrix $C(t)$, whose element C_{ij} is the Pearson correlation coefficient between the return time series of the selected states i and j,

$$C_{ij} = \frac{1}{\sigma_i \sigma_j} \sum_{k=t-s+1}^{t} [r_i(k) - \mu_i][r_j(k) - \mu_j], \tag{3}$$

where μ_i and μ_j are sample means and σ_i and σ_j are the standard deviations of the two states i and j respectively.

2.3 Absorption rate

In order to measure the risk of the international crude oil import costs, we use the following formula

$$E_n = \sum_{i=1}^{n} \lambda_i / N, \tag{4}$$

where E_n is recorded as absorption rate, λ_i are the eigenvalues of the correlation coefficient matrix C(t) in each time moving window,N is number of states.

3 Empirical Analysis

3.1 Data Sources and Processing

The data is monthly data of the international crude oil import costs of France, Germany, Italy, Spain, UK, Japan ,Canada and USA from 2003 to 2015 in IEA. Each state has 153 data, a total of 1224 data. Respectively, we represent the data with the symbols $cs_1(t), cs_2(t), cs_3(t), cs_4(t), cs_5(t), cs_6(t), cs_7(t), cs_8(t)$. Because the fluctuation of the data is relatively large, we use equation (2) to process the international crude oil import costs data of France, Germany, Italy, Spain, UK, Japan ,Canada and USA. The resulting data is recorded as $r_1(t), r_2(t), r_3(t), r_4(t), r_5(t), r_6(t), r_7(t), r_8(t)$(Figure 1,2)

3.2 Time moving window

In order to analyze the international crude oil import costs by the method of random matrix theory, we construct the corresponding moving windows based on the selected data. Remember the values of the states as $r_i(t), i = 1, 2, \cdots, 8$ at time t. Because of $N = 8$, according to the random matrix theory, we select the moving windows of the length $L(> N)$. For example we select $L = 36$, we can get the time moving windows (Figure 3).

3.3 Correlation and risk analysis

We use the Pearson correlation coefficient by the equation (3) to construct the correlation coefficient matrix C(t),and calculate the average correlation coefficient of the matrix $C(t)$ in each moving window. The calculated results are shown in Figure 4.

Figure 4 shows the evolution of the average correlation coefficient with time, we can obtain the correlation of the international crude oil import costs is very high. The average correlation coefficients of the international crude oil import costs begin to rise because of the dollar's decline and the impact of the international financial crisis in 2008. After 2012, the international crude oil import costs are relatively stable. Because the oversupply of crude oil in the second half of 2014, all kinds of countries take appropriate measures to cut or stop production to result in the average correlation coefficients of the international crude oil import costs beginning to rise. In a word, The average correlation coefficients of the crude oil price market is rising after the economic crisis, it indicates that the instability and risk of international crude oil import costs also increase.

3.4 International crude oil import costs market information

Firstly, we take $N = 8, L = 36$ to construct the correlation coefficient matrix C(t) according to equation (3) and equation (1), then we get the eigenvalues of the matrix $C(t)$. We extract the top four eigenvalues for each time window. Figure 5 shows the evoluted image of the top four eigenvalues over time. Since the first largest eigenvalue is entirely above the maximum eigenvalue $\lambda_{\max}$ of RMT according to equation (1), the largest eigenvalue λ_1 contains a large number of information of crude oil price market. While the second largest eigenvalue λ_2 is above the eigenvalue $\lambda_{\max}$ partly, it shows the second largest eigenvalue λ_2 contains some market information. The third and the fourth largest eigenvalues λ_3, λ_4 are below the eigenvalue $\lambda_{\max}$, it indicates that there is little market information. So we only study the first and the second largest eigenvalues λ_1, λ_2.

We use equation (4) to calculate absorption rate. The evolution of the absorption rate is shown in Figure 6.

It can be seen from figure 6, from an overall point of view, the absorption rate of the international crude oil import costs is very large. The result shows that the risk of the international crude oil import costs is very large. The risk of the international crude oil import costs gradually increases after the 2008 economic crisis, we analyze the phenomenon combined with previous part, we can obtain that the synchronicity of the international crude oil import costs is gradually increasing, the risk and instability of the international crude oil import costs are also increasing.

4 Conclusions

This paper is based on the correlation and risk of the international crude oil import costs. The dynamic behavior of the correlation and the risk of the international crude oil import costs is analyzed from the theory. The evolution of the international crude oil import costs is given by the method of numerical simulation. We get the following conclusions:

(1). The international crude oil import costs in each state are not randomly independent from the random matrix theory, the correlation of the international crude oil import costs is very high. We use the average correlation coefficients of matrix $C(t)$ to measure the correlation of the international crude oil import costs. The average correlation coefficients can not only measure the correlation of the international crude oil import costs, but also can measure the stability and risk of the international crude oil import costs. The average correlation coefficients of the international crude oil import costs are rising after the economic crisis, this shows that instability and risk of the international crude oil import costs are also increasing.

(2). By the method of absorption rate,we further obtain that the instability and risk of the international crude oil import costs are also increasing with the gradual increase of the synchronicity of the international crude oil import costs in different states.This conclusion is consistent with the average correlation coefficients of the international crude oil import costs.

Acknowledgments

This paper is supported by the National Natural Science Foundation of China (No:51276081), and the Major Project of Natural Science Foundation of Jiangsu Province Colleges and Universities (14KJA110001).

References

[1] K. Johansson. Shape Fluctuations and Random Matrices, *Communications in Mathematical Physics*, 209(2)(1999): 437-476.

[2] A. M. Tulino and S. Verd. Random Matrix Theory and Wireless Communications, *Foundations and Trends in Communications and Information Theory*, 1(6)(2004): 1-182.

[3] H. Meng et al. Systemic risk and spatiotemporal dynamics of the US housing market. *Scientific Reports*, 4(1)(2014): 3655-3655.

[4] S. D. Bekiros and C. G. H. Diks. The relationship between crude oil spot and futures prices: Cointegration, linear and nonlinear causality, *Energy Economics*, 30(5)(2008): 2673-2685.

[5] J. Alvarez-Ramirez. Multifractal Hurst analysis of crude oil prices. *Physica A Statistical Mechanics Its Applications*, 313(4)(2002): 651-670.

[6] J. Alvarez-Ramirez. Symmetry/anti-symmetry phase transitions in crude oil markets. *Physica A Statistical Mechanics Its Applications*, 322(4)(2003): 583-596.

[7] P. Giot and S. Laurent. Market risk in commodity markets: a VaR approach. *Core Discussion Papers*, 25(5)(2003): 435-457.

[8] J. D. Cabedo and I. Moya. Estimating oil price Value at Risk using the historical simulation approach. *Energy Economics*, 25(3)(2003): 239-253.

[9] B. A. Basher and P. Sadorsky. Oil Price Risk and Emerging Stock Markets. *Global Finance Journal*, 17(2)(2006): 224-251.

[10] Y. Fan. Estimating Value at Risk of crude oil price and its spillover effect using the GED-GARCH approach, *Energy Economics*, 30(6)(2008): 3156-3171.