Peer-reviewed version available at *Int. J. Financial Stud.* **2018**, *6*, 61; doi:10.3390/ijfs6030061

Why the Correlation Between Crude Oil Prices and the US Dollar Exchange Rate Is Time-varying?----Explanations Based on the Role of Key Mediators

Xiangyun Xu Jia Liao Yu Shi

(School of International Economics and Business, Nanjing University of Economics and Finance; School of Business, Shanghai University of International Business and Economics)

Xiangyun Xu, PhD in Economics, associate professor of Nanjing University of Economics and Finance, with research interests in macroeconomics and international economics. Email: xuxiangyun_ecnu@sina.com.cn, Address: School of international economics and business, PO Box 44th, Nanjing University of Economics and Finance, Nanjing, Jiangsu Province, PRC. Post Code: 210023

Jia Liao, PhD in Economics, associate professor of Shanghai University of International Business and Economics, with research interests in international economics. Email: liaojia@suibe.edu.cn, Address: Room 235, Boshi Building, 1900 Wenxiang Road, Songjiang district, Shanghai, China. Post Code: 201620

Yu Shi, Master student in School of International Economics and Business, Nanjing University of Economics and Finance, her email is 314544873@qq.com, Address: School of international economics and business, PO Box 44th, Nanjing University of Economics and Finance, Nanjing, Jiangsu Province, PRC. Post Code: 210023

Abstract: Using DCC-GARCH and EGARCH model, this paper finds that since 1990, the relationship between crude oil prices and the US dollar index is time-varying, demonstrating a process of “very weak correlation—negative correlation—enhanced negative correlation—weakening negative correlation”, but the existing research does not provide enough reasonable explanation. Therefore, this paper proposed a “key mediating factors” hypothesis which points out that whether there is a common “key mediating factor” is important source of the time-varying relationship between two assets. We argue that market trend and financial market sentiment undertook the role of “key mediating factor” during the period of “2002 to the financial crisis” and “financial crisis to 2013”, while other periods lack the “key mediating factors”.

Keywords: crude oil price; dollar index; time-varying; key mediating factor

JEL Classification: C52 G17 Q43

1. Introduction

As two important financial assets, the relationship between oil and US dollar is always an important subject of the international financial market. If there is a stable negative correlation between two assets,

investors can take hedge strategies to diversify investment; if the negative relationship is time-varying, the hedge strategy can only be used in certain period; if the correlation is weak, investment diversification cannot achieve the aim of risk diversification.

Many scholars have conducted extensive research on the relationship between crude oil prices and US dollar exchange rates through different methods. Overall, these studies indicate that two assets have a negative relationship, but the degree of correlation is dynamic. For example, Yousefi and Wirjanto (2004) , Cifarelli and Paladino (2010)found that the dollar exchange rate and oil prices have a negative relationship. Wu et al.(2012)used dynamic copula GARCH model noted that the relationship between the dollar index and oil prices changes over time. The correlation was weak prior to 2003, but became negatively correlated and this negative relationship was strengthened gradually after 2003. Reboredo et al. (2014) found that there is a weak negative relationship between oil prices and major currencies' (dollar, euro, Australian dollar, British pound, Canadian dollar, etc.) exchange rates before the crisis. In addition, as the time scales longer, the degree of correlation gets smaller. And a negative relationship between oil prices and dollar exchange rate were significantly increased on all time scales after the financial crisis. Some literature discuss which one (US dollar exchange rate or oil prices) is dominant, but haven't got consensus. Krichene(2005), Zhang, et al.(2008) and Cheng(2008) believe that it was US dollar exchange rate that leads to oil price fluctuations, while Lizardo and Mollick(2010) argue that, in the long run, crude oil prices help explain US dollar changes. Reboredo et al.(2014) notes that there is an interdependence phenomenon after financial crisis.

Why there is a negative relationship between the US dollar and oil prices? Existing interpretation mainly emphasizes two aspects, one is denomination effect, which emphases crude oil is denominated in US dollar. Krichene(2005) argues that the change in the nominal effective exchange rate (NEER) of US dollar affects the import price of oil in other currencies, thus affecting the global oil demand and crude oil prices. Another is portfolio effect, which emphases that the depreciation of US dollar will lead to a decline in dollar asset yields, leading to investors turning to oil and other assets in their portfolio, resulting in upward of crude oil prices and a negative relationship, vice versa (Kaufmann and Ullman, 2009).

Although the existing literature points out some channels through which US dollar exchange rate and oil price influence each other, these analyses cannot explain why the relationship is time-varying. Such as when the hedge strategy is effective; why the negative relationship is weak during some period, while is strong in other periods.

The contribution of this paper is that we proposed a mechanism of "key mediating factors" for the first time, so as to better explain why US dollar exchange rate and crude oil show a dynamic relationship. We believe that, relative to the previous studies, a more likely explanation is mechanism of "key mediating factors": in a certain period, one or more key mediating factors have important impact on both US dollar and crude oil, leading to opposite movements of two assets, as the impact of the two is time-varying, which makes the correlation is time-varying. In some periods, however, there is no such a key mediating factor,

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 January 2018 doi:10.20944/preprints201801.0296.v1

Peer-reviewed version available at Int. J. Financial Stud. 2018, 6, 61; doi:10.3390/ijfs6030061

and two assets' price fluctuation is driven by individual respective factors, which leads to a weak correlation.

The rest of this paper is structured as follows: section 2 introduces data and empirical model; section 3 presents empirical results and robustness check; section 4 provides an explanation to the empirical results; section 5 concludes.

2. Data and Empirical Model

2.1 Data

We select Brent crude oil futures and dollar index as proxies for crude oil price and US dollar exchange rate from Wind Info, which is a leading financial information service provider. Let $r_{BOO,t}$ be Brent crude oil yields, $r_{USDX,t}$ is the US dollar index yield, sample range from January 2nd, 1990 to December 31st, 2016, and at last get a total of 6586 observations. Table 1 shows basic descriptions of data.

Table 1: Statistical description of Brent crude oil and US dollar index yields

	$r_{BOO,t}$	$r_{USDX,t}$
Mean	0.000170	-3.06E-07
Maximum	0.147017	0.029498
Minimum	-0.427223	-0.032521
Standard Deviation	0.021708	0.005240
Skewness	-1.265616	-0.065566
Kurtosis	29.47695	4.962633
Jarque-Bera Statistic	194132.2	1061.753
Observations	6972	6972

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 January 2018 doi:10.20944/preprints201801.0296.v1

Peer-reviewed version available at Int. J. Financial Stud. 2018, 6, 61; doi:10.3390/ijfs6030061

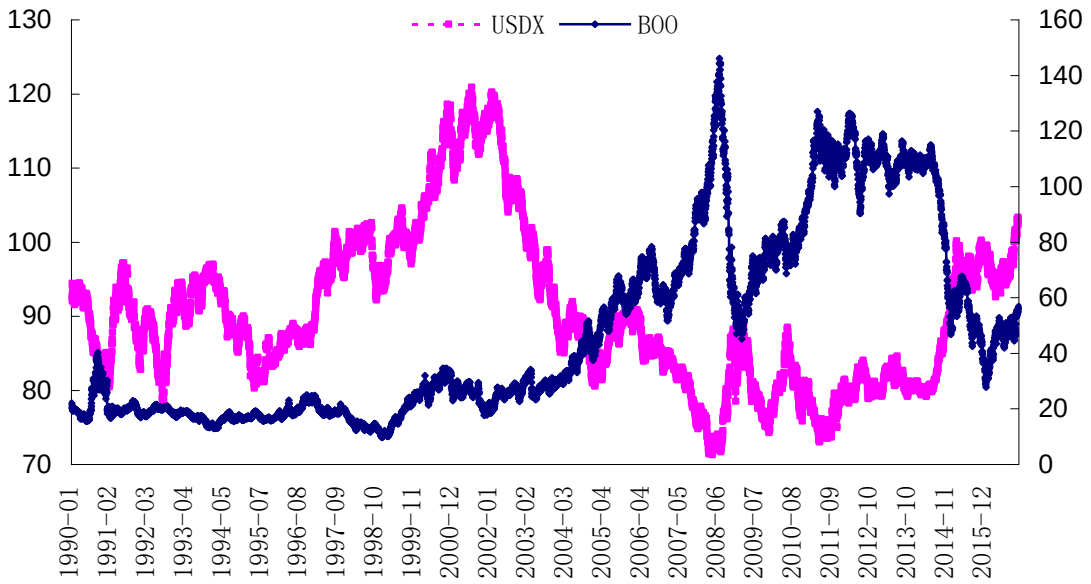


Figure 1: Movement of Brent crude oil prices and the US dollar index

Source: Wind Info, left axis for US dollar index, and the right axis for Brent crude oil price.

Figure 1 shows the evolution of Brent crude oil price and the dollar index since 1990. Overall, a relation between them seems unclear before 2002. But after 2002, it showed a significant negative relationship. The rise of dollar index was accompanied by a decline in oil prices, and the dollar index fell corresponds to the rise of oil prices. However, we still need more accurate ways to detect the correlation between them.

2.2 Modeling by DCC–GARCH

Engel's (2002) DCC-GARCH Model is widely used to analyse the relationship among different markets as it can calculate dynamic correlation effectively, and we use this Model to judge the correlation between oil price and dollar index at different time.

Defining $r_{BOO,t}$ and $r_{USDX,t}$ as oil yield and dollar index yield separately. Set the equation of two asset's average yield as:

$$r_{BOO,t} = \omega + \varepsilon_{1,t}, \quad r_{USDX,t} = \xi + \varepsilon_{2,t} \tag{1}$$

In equation (1), $\omega = (\omega_{BOO}, \omega_{USDX})$ stands for the yield mean vector of oil and dollar index.

Set $\varepsilon_t = (\varepsilon_{1,t}, \varepsilon_{2,t})' \ \varepsilon_t \,|\, \Omega_{t-1} : N(0, H_t)$ (2)

In equation (2), Ω_{t-1} stands for the information set of (t-1) period that is the new interest of return on i (i=1, 2) asset obey multivariate normal distribution with mean as 0 and covariance matrix as $\boldsymbol{H_t}$.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 January 2018 doi:10.20944/preprints201801.0296.v1

Peer-reviewed version available at Int. J. Financial Stud. 2018, 6, 61; doi:10.3390/ijfs6030061

$$H_t = D_t R_t D_t \tag{3}$$

R_t stands as 2*2time-varying correlation matrix, D_t stands as 2*2 diagonal matrix of conditional standard deviation $\sqrt{h_{ii,t}}$ of GARCH Model. Then,

$$D_t = \begin{bmatrix} \sqrt{h_{11,t}} & 0 \\ 0 & \sqrt{h_{22,t}} \end{bmatrix} \tag{4}$$

$$h_{ii,t} = \omega_i + \alpha_{ii}\varepsilon^2_{ii,(t-1)} + \beta_{ii}h_{ii,(t-1)}, \quad \forall i = 1,2 \tag{5}$$

Engel(2002) uses a two-stage method to estimate, by estimating the univariate GARCH equation in the first stage and obtains the conditional standard deviation. Then in the second stage, apply $\sqrt{h_{ii,t}}$ to get standardized residuals $\mu_{i,t} = \varepsilon_{i,t} / \sqrt{h_{ii,t}}$ in order to calculate conditional correlation coefficient.

Set $\mu_t = (u_{1,t}, u_{2,t})'$, μ_t : $N(0, R_t)$, then the Dynamic correlation structure equation is,

$$Q_t = (1-a-b)\bar{Q} + a(\mu_{t-1}\mu'_{t-1}) + bQ_{t-1} \tag{6}$$

$Q_t = (q_{ij,t})$ stands as 2*2 time-varying covariance matrix of μ_t, $\bar{Q} = E[\mu_t \mu'_t]$ stands as unconditional covariance matrix of μ_t. a and b are DCC coefficients, and a+ b<1. As the corner of Q_t is not necessarily 1, correlation Matrix R_t is got in the process of standardization.

$$R_t = (Q_t^*)^{-1} Q_t (Q_t^*)^{-1}, \tag{7}$$

In equation (7), $Q_t^* = \begin{bmatrix} \sqrt{q_{11}} & 0 \\ 0 & \sqrt{q_{22}} \end{bmatrix}$, and the element within R_t is $\rho_{ij,t} = q_{ij,t} / \sqrt{q_{ii,t} q_{jj,t}}$, $i, j = 1,2$, while key element is $\rho_{12,t} = q_{12,t} / \sqrt{q_{11,t} q_{11,t}}$, which reflect the conditional correlation of two asset returns.

Quasi-maximum likelihood method is used as estimation method, and the log-likelihood values is

$$L = \left[-0.5 \sum_{t=1}^{T} (2\log(2\pi) + \log|D_t|^2 + \varepsilon'_t D_t^{-2} \varepsilon_t) \right] + \left[-0.5 \sum_{t=1}^{T} (\log|R_t| + \mu'_t R_t^{-1} \mu_t - \mu'_t \mu_t) \right] \tag{8}$$

3. Empirical Model and Robustness Test

3.1 Model Estimation Results

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 January 2018 doi:10.20944/preprints201801.0296.v1

Peer-reviewed version available at Int. J. Financial Stud. 2018, 6, 61; doi:10.3390/ijfs6030061

We firstly take unit root and heteroskedasticity test on each yield before applying DCC-GARCH Model. According to the test's result, the yields of all variables passed the unit root test, and ARCH-LM test values are significant at 1% level of confidence during 1, 6, 10, 20 periods respectively, while ARCH-LM test is not significant when applying the GARCH Model, which verifies the suitability of GARCH Model. Due to space limitation, the exact results are omitted.

Table 2 gives DCC-GARCH empirical results. All GARCH term coefficients are significant at the 1% level, $\alpha_{11}+\beta_{11}, \alpha_{22}+\beta_{22}$ are close to 1, indicating that the conditional variance with high sustainability. DCC parameters a and b are at the 1% level significantly, and $a+b$ is close to 1, indicating that the dynamic conditional correlation is a mean reverting.

Table 2: DCC Estimation Results

Parameters	Coefficient
ω_1	0.000**
α_{11}	0.041***
β_{11}	0.933***
$\alpha_{11}+\beta_{11}$	0.997
ω_1	0.000***
α_{22}	0.032***
β_{22}	0.967***
$\alpha_{22}+\beta_{22}$	0.999
a	0.004***
b	0.995***
LogLikelihood	44886

Note: The asterisks ***, **, and * indicate 1%, 5%, and 10% significance levels, respective.

Figure 2 shows the movement of dynamic condition correlation between Brent oil and US Dollar index, and the correlation coefficient is time-varying. Prior to 2002, the DCC coefficient fluctuate around zero, and the fluctuation range is concentrated in [-0.1, 0.1] range. This describes that within this period, the correlation is relatively low. From 2002, a negative relationship has been established, DCC coefficient

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 January 2018 doi:10.20944/preprints201801.0296.v1

Peer-reviewed version available at Int. J. Financial Stud. 2018, 6, 61; doi:10.3390/ijfs6030061

dropped from 0 to around -0.15 in 2002-2004, and maintained at about -0.20 until July 2008. There was a significant decline since August, 2008, which dropped to below -0.4 by 2009, and fluctuated between [-0.30, -0.45] before June 2013. After June 2013, the correlation coefficient increased sharply and tended to zero, and the negative relationship weakened significantly. Overall, since 1990, the relationship between oil and the dollar is time-varying, and the correlation experienced a "very weak - negative –negative strengthened– weak again" process.

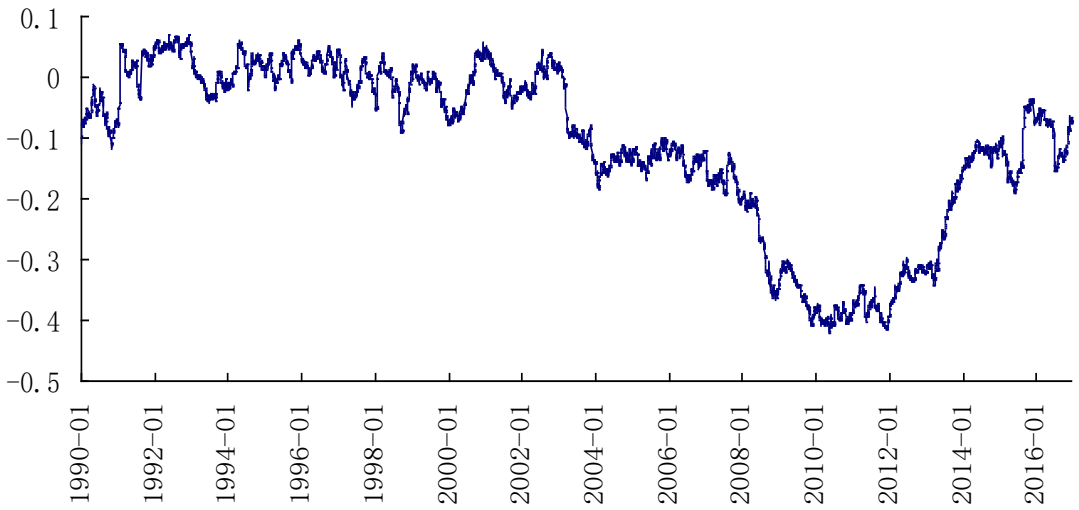


Figure 2: The dynamic conditional correlation between Brent oil price and US Dollar index

3.2 Robustness Test

In order to test the robustness of the DCC-GARCH model, we further use the EGARCH model established by Nelson (1991) to explore the relationship between two assets at different period. According to the historical trend of WTI prices and the dollar index, and considering movement of the DCC coefficient, the sample is divided into four periods: 1990/01/02-2001/12/31, 2002/01/01-2008/07/03, 2008/07/04-2013/06/19 and 2013/06/20-2015/06/19. Every period is corresponding to a important historical events: (1) official circulation of the Euro and the establishment of Euro Era; (2) Brent oil's price turnout from soaring to plunging at the peak of $146 a barrel, the dollar began to strengthen, and financial crisis broke out soon afterwards; (3) Federal Reserve Chairman Bernanke said the Fed may consider withdrawing from QE policy, and market formed a quantitative easing policy exit expectations.

Through test, we found that EGARCH (1, 1) -GED GARCH model is more appropriate than the other GARCH model, the specific model as following:

$$r_{boo,t} = \omega_0 + \beta r_{usdx,t} + \varepsilon_t \tag{9}$$

$$\ln(h_t) = \omega + \alpha \ln(h_{t-1}) + \gamma\left(\frac{\varepsilon_{t-1}}{h_{t-1}^{1/2}}\right) + \delta\left[\left(\frac{|\varepsilon_{t-1}|}{h_{t-1}^{1/2}}\right) - \left(\frac{2}{\pi}\right)^{1/2}\right] \tag{10}$$

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 January 2018 doi:10.20944/preprints201801.0296.v1

Peer-reviewed version available at Int. J. Financial Stud. 2018, 6, 61; doi:10.3390/ijfs6030061

$$\varepsilon_t | I_{t-1} : GED(0, h_t) \tag{11}$$

h_t is the conditional variance, γ represents a non-symmetry effect, and empirical results are shown in Table 3.

Table 3: EGARCH model results of oil price and the US dollar index

	1990/01/02-2001/12/31 (Period 1)	2002/01/01-2008/07/03 (Period 2)	2008/07/04-2013/06/19 (Period 3)	2013/06/20-2016/12/31 (Period 4)
α	-0.003	-0.082***	0.003	-0.120***
β	0.026	-0.616***	-1.124***	-0.307**
φ	0.146***	0.063***	0.106***	0.031**
γ	0.021**	-0.029**	-0.072***	-0.084***
δ	0.991***	0.969***	0.990***	0.996***
$A-R^2$	0.000	0.026	0.129	0.015
Observations	3071	1699	1293	909

Note: The asterisks ***, **, and * indicate 1%, 5%, and 10% significance levels, respective.

Results of EGARCH and the DCC-GARCH model are consistent. β is not significant and is close to zero before 2002. After 2002, in the period 2 and period 3, β is significant and the value of period 3 is larger than period 2. In addition, $A-R^2$ in period 3 also increased, which means that there is a significant negative relationship between dollar index and oil prices in period 2 and period 3, but the relationship in period 3 is stronger. In period 4, either β or $A-R^2$ was very low, and the correlation between the two is weak. The EGARCH results further showed that the correlation between the dollar index and crude oil prices have experienced a process of "very weak correlation - negative relationship – enhanced negative relationship – weakening correlation".

4. The Hypothesis and Explanation of "Key Mediating Factors"

Our empirical results further confirm that even if the sample period is extended to the period after financial crisis, the relationship between crude oil prices and the dollar is time-varying, which is consistent with previous literatures. But since the previous studies did not provide adequate explanations to why the correlation is time-varying, this paper proposes a hypothesis of "key mediating factors". We believe that: (1) although the price of crude oil and the dollar are influenced by different factors, such as monetary

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 January 2018 doi:10.20944/preprints201801.0296.v1

Peer-reviewed version available at Int. J. Financial Stud. 2018, 6, 61; doi:10.3390/ijfs6030061

policy of United States and the EU, international payments imbalances, macroeconomic prospects of relevant economies and other factors that influence the US dollar exchange rate, and OPEC and non-OPEC oil production, the global overall demand, liquidity and price of alternative products, geopolitical events that influence the price of crude oil, in a certain period, there exist a "key mediating factor" that has a significant impact on both US dollar exchange rate and crude oil price simultaneously, and in the opposite direction, making the two demonstrate a negative relationship. And as the impact of the "key mediating factor" is time-varying, leading the correlation between the two strong or weak in different periods; (2) key mediating factors in different periods are not the same; (3) in some period, there is no such key mediating factor, in such case, the fluctuation of the two assets price is mainly driven by individual factors, resulting in a weak correlation. The specific mechanism is shown in figure 3.

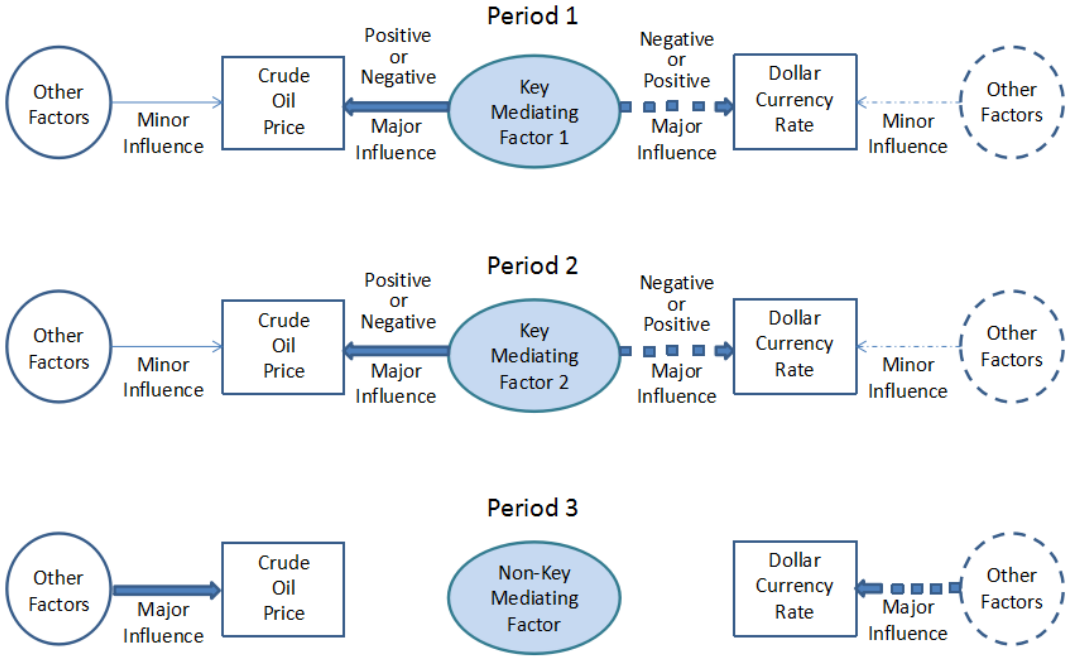


Figure 3: Mechanism Diagram of "Key Mediating Factors" Hypothesis

According to history of financial market in the 1990s, we believe that there are two factors that have served as the key mediating factor since2002, one is market trend and another is financial market sentiment. While in the period before 2002 and after 2013, there is a lack of corresponding "key mediating factor".

(1) Market Trend

Asset price always show certain trend characteristics in some period, which will affect investors' expectations, and then affect the relationship between different assets' price. We argue that the important reason for negative correlation between US dollar and crude oil from 2002 to global financial crisis is that, dollar and oil prices show a clear opposite trend during this period. Specifically, the dollar underwent a long-term downward trend, while commodities (including crude oil) experienced a "super cycle".

As early as 1999, before the official circulation of euro within the EU Members, many economists

already have begun to discuss the possible impact of euro on the international status of the dollar and its value. As a representative view, Portes and Rey (1998) believes that the euro's emergence will increase the depth of European financial markets, reduce transaction costs, improve the attractiveness of euro assets, and increase the proportion of euro use in trade and reserve assets. Thus, dollar's international status will be impacted, and dollar value will fall. After January 1st, 2002, the market recognition of the international status of euro has been further improved. Euro continuously appreciated against dollar, not only individual investors took a positive view of euro, many central banks also use euro to replace dollar to achieve foreign reserves diversification. Although euro came through short-term depreciation against dollar, euro continued appreciating until the 2008 financial crisis and its international status rose continually. Since euro has largest weight (57.6%) in dollar index calculations, dollar depreciation trend against the euro also brought a trend decline in dollar index.

Long-term downward dollar index corresponds to persistent rise of commodities, including crude oil. Many studies have shown that the reason of oil's "super cycle" is multiple, including: the increment in global demand represented by emerging markets, global loose monetary policy, supply control and financial speculation. (Büyükşahin et al, 2009; Cifarelli and Paladino, 2010; Fattouh and Scaramozzino, 2011; Erten and Ocampo, 2012) The up of oil prices and other commodity prices let market participants form a sustained rise expectation. Fattouh and Scaramozzino (2011) pointed out that, most market participants believed that long-run equilibrium price of oil was between $ 20 to 22 before oil prices start to rise at 2003, but then many participants began to think oil long-run equilibrium price will continue to upward. In fact, market was flooded with all kinds of predictions and reports about rising oil prices, such as Goldman Sachs advocated a "super rise" theory before the financial crisis, which suggests that crude oil price will continue to rise substantially as supply of crude oil is limited and demand for oil in non-OECD countries will continue to grow. Until May 6th, 2008, Goldman Sachs report still claimed that WTI crude oil prices could rise to $ 200 a barrel in next two years, and the "Super rise" cycle will continue. The expectation reversed suddenly after the financial crisis, for example, Merrill Lynch forecast that oil prices could fall to $ 25 a barrel in 2009 if the impact of the economic recession in United States, Europe and Japan spread to China. Goldman Sachs also point out that the oil price in the first quarter of 2009 would fall to $ 30 a barrel, and the annual average price would fell to $ 45 a barrel in a research report of December 2008.

Erten and Ocampo (2012) argues that the rise in commodity prices makes investors believe financial trading on commodities has become an important way to hedge in portfolio. When the market has opposite expectations about the trend of two assets price, this will lead investors to form a hedge strategy in financial markets. They will take a long position in one market and a short position in another, leading to a negative relationship between two assets. Especially, once the market believes that this negative relationship becomes a law, participants will reinforce hedge strategy. This explain why after 2002, the relationship between the dollar and oil is negative, even if oil or dollar fluctuated in reverse direction, the negative relationship still maintained. While after the 2008 financial crisis, market expectations about the

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 January 2018 doi:10.20944/preprints201801.0296.v1

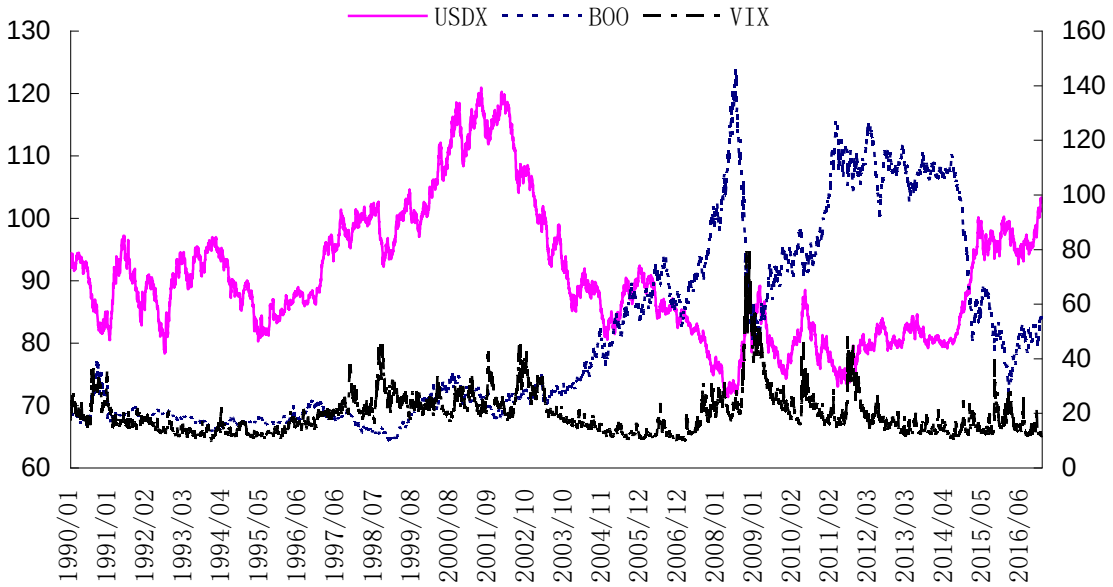
Peer-reviewed version available at Int. J. Financial Stud. 2018, 6, 61; doi:10.3390/ijfs6030061

dollar and oil price trends reversed, although this reversal was caused by market panic, the hedge strategy were still useful by inertia, which further reinforces the negative relationship.

(2) Financial Market Sentiment

After the outbreak of the financial crisis in 2008, market sentiment has become a key factor affecting the dollar exchange rate and oil prices. Many scholars noticed that the panic in financial markets has a direct impact on dollar exchange rate, particularly in turbulent period, dollar is considered as a “safe-haven” currency. Cairns et al. (2007) believes that due to dollar's own international status and its advantage on global mobility and acceptability, many foreign investors hold the dollar as a safe asset, especially compared with currencies of developing and emerging countries. When market is in turmoil, the stability of earnings is significantly more important. Ranaldo and Söderlind (2007) noted that increased risk, the decline of stock market and the "safe haven" currency's appreciation are directly related. McCauley and McGuire (2009) has a detailed analysis how does financial market volatility and the risk appetite's decline lead all types of investors to buy dollar and dollar assets (particularly U.S. Treasury bonds) in the initial period of financial crisis, and results in substantial appreciation of the dollar. These studies have shown that global risk appetite and financial market volatility will directly affect US dollar exchange rate.

We take the VIX index as a measure to financial market panic, and market panic has already started to rise since August 2007 and kept rising rapidly after "Lehman Brothers"’ bankruptcy in August 2008. Although supported by government bailout, Fed’s QE policy, swap line of central banks, the market panic declined, European debt crisis still triggered market uncalm. Especially in April 2010 and August 2011, Greece, Spain, Portugal, Italy and other European countries got in trouble in sovereign debt default. However, under the help of European Central Bank and the IMF, European debt crisis has moderated and VIX index also declined. Figure 4 show that there is a significant positive correlation between VIX and dollar index.



Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 January 2018 doi:10.20944/preprints201801.0296.v1

Peer-reviewed version available at Int. J. Financial Stud. 2018, 6, 61; doi:10.3390/ijfs6030061

Figure 4: Dollar index, Brent crude oil and VIX index

Note: Left axis is dollar index, right axis is Brent crude and the VIX

In contrast with the dollar, relationship between VIX and oil prices is negative significantly. When the market panics rose, the oil prices fell; and when the market panics eased, the oil prices rose. This is mainly due to two reasons: first, after the financial crisis, the rising or falling of market panics reflects the pessimistic and optimistic sentiment of market towards future macro-economy. Future macroeconomic deterioration or improvement will reduce or increase oil demand, leading to a decline or rise in crude oil price; second, after 2000, the financialization of commodity markets (including crude oil) grows fast. The price of oil and other commodities are mainly determined by financial markets, especially by futures markets (Tang and Xiong, 2012; Cheng and Xiong, 2013), financial invest and speculation has became a important power to oil price. Market panic will lead investors to short oil assets and invest in safe assets. While market gets calm and investors' risk appetite strengthens, market investors tend to sell safe assets and buy oil assets, leading oil prices to rise. These two forces combined together, making a negative correlation between the oil price and VIX index. Furthermore, Figure 5 shows the dynamic correlation coefficients between the VIX index calculated by the above DCC-GARCH method and the US dollar index and crude oil price respectively.

We can see that after the 2008 financial crisis, the DCC coefficient of dollar index and crude oil price with VIX is positive and negative respectively, and the value increased significantly until 2013, when the correlation comes to zero. This means that VIX index became the "key mediating variable" after financial crisis.

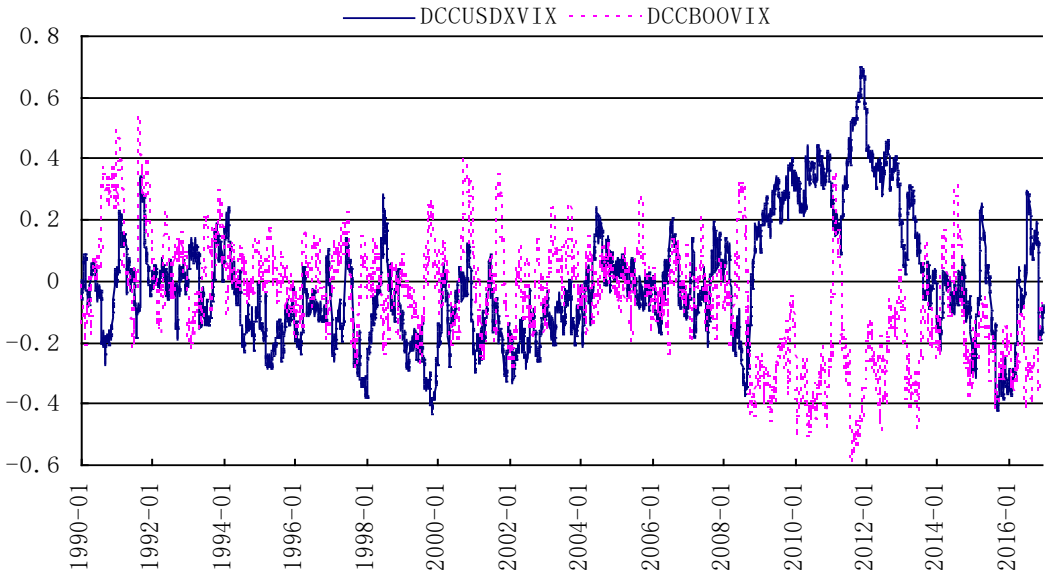


Figure 5: The DCC coefficients Between VIX with Dollar index and Brent crude oil

Before the financial crisis, the overall relationship between the dollar index and the VIX index is not

significant, and only when the VIX index fluctuated sharply, there was a negative correlation, which was obviously different with post-financial crisis period (Figure 5). Before the financial crisis, VIX fluctuated significantly in the following four periods: 1990-1991 years, October 1997 to December, the second half of 2001 to the first half of 2003, and the second half of 2007 to the first half of 2008. Except for the second half of 2007 to the first half of 2008, DCC coefficients of the other three periods are negative, and DCC coefficients tends to zero when VIX index calmed down. In the second half of 2007 to the first half of 2008 period, there is neither a significant positive nor a negative relationship. This paper argues that this is mainly due to difference of reasons which led to VIX change. In 1990 to 1991, the reason of market volatility was the United States' attack on Iraq; from October 1997 to December due to the Asian financial crisis; the second half of 1998 was due to the United States long-term asset management company (LTCM) crisis; and from the second half of 2001 to the first half of 2003 was due to the United States "911" terrorist attacks and bankruptcy of Enron, WorldCom and other companies. As the market panic mainly stems from the US's domestic problems, participants in the foreign exchange market are more likely to regard the rise of VIX index as a "local" problem in the United States, leading dollar fell in FX market. With the VIX index declined, investors consider the United States' "local" problems have been alleviated, they expected dollar would appreciate in the short term, and caused dollar's exchange rate to rise. Since there is no global level financial or economic crisis before 2008, VIX index reflects "local" features in US financial markets mainly. Dollar's "safe haven" feature does not appear and this results in weak correlation between dollar and VIX index, and even shows a short-term negative relationship in some periods.

The outbreak of the financial crisis and subsequent debt crisis in Europe made VIX index not only reflect the problems of United States financial markets, but also to a large extent reflect investors' expectation of global financial market stability, and the rise or fall of the VIX index stimulates the risk aversion or risk-taking of the market, which leads to a significant positive relationship between the two. When the crisis gradually passes away, the overall market sentiment calms down again, and the relationship between the two tends to zero again.

Similarly, before the financial crisis, the correlation between oil prices and the VIX index is also not significant (Figure 5), except for the time period 1990 to1991, which shows a significant positive correlation. In other periods, even in some period of time with VIX volatility, the relationship between the two is also not significant. The root cause of the positive relationship during 1990 to 1991 was that at that time important Middle East oil-producing countries such as Iraq and Kuwait were under war. On the one hand, the market is worried about the impact of oil supply; On the other hand, the United States' large-scale military action triggered panic in the financial market, making people take a short position on the dollar, resulting in a negative relationship between them. Similarly, with the financial crisis passed away, VIX index gradually becomes stable, the correlation once again tends to zero.

It is particularly important to note that, from July 2014, the US dollar index and oil prices showed an opposite trend, with oil prices falling sharply, and the US dollar index continuing to rise, seemingly

showing a negative correlation. However, in fact, the dynamic correlation coefficient of the two didn't tend to be negative, but tend to be zero. It shows that the rise of the US dollar and the fall in the international oil prices are not completely corresponding, and the opposite of the overall trend is only a coincidence or short-term phenomenon. This paper argues that this is also in line with the theory of "key mediating variables". The decline in international oil prices is mainly affected by Saudi Arabia's refusal to reduce oil production, geopolitical tensions between Russia, Europe and the United States, slowing economic growth in China, and increasing shale gas oil production. The rise of the US dollar index is mainly due to the fact that recovery of US economy makes the Fed exit QE, while Bank of Japan and European Central Bank implement a new round of QE. Therefore, there is no common "key mediating factor". In addition, due to crude oil prices fell quickly and suddenly, the market has not formed a long-term, steady downward trend expectation, therefore, there is obvious hedge strategy in financial market. The fluctuation of crude oil and US dollar is affected by their respective factors, lacking the common "key-mediating factor", which leads to a weak correlation.

It can be said that the market expectation and the hedge strategy are the mediating factor of the negative relationship in the period when the market trend are obvious. In the period of financial crisis, financial market sentiment is main mediating factor of the negative relationship. While during non-crisis period and when market trend are not obvious, as there is no key mediating factor that simultaneously impact two assets, making the correlation very weak.

5. Conclusions

By DCC-GARCH model, we find that after 1990, the dynamic relationship between oil prices and the dollar index is time-varying, and experienced "very weak - negative relationship - negative relationship enhancement - weak" process. Before 2002, the correlation was weak; after 2002, there established the negative relationship and continue to strengthen; after 2008 financial crisis, the negative relationship further increased and maintained at a high level until 2013; after 2013, the correlation was weakened again. The main cause of this time-varying relationship is whether intermediary variable exists or not, which has a major impact on the two market volatility at the same time. Specifically, from 2002 to 2008, oil prices and the dollar index respectively showed a significant rise and decline, triggered a market hedge strategy; after 2013 financial crisis, financial market sentiment and continued hedge strategy inertia has become intermediary of negative relationship; and the lack of a common key mediating factor led to a weak correlation in other periods.

As this article mainly focuses on the relationship between the oil prices and US dollar and main reasons behind, future studies need more refined research to deepen the understanding of the relationship between the two. For example, the interdependence and causality between the dollar and oil prices within a certain period, how "index transaction" specifically affects oil price fluctuations and interacts with the foreign exchange market, how monetary policy, especially Fed's monetary policy affects US dollar

Peer-reviewed version available at *Int. J. Financial Stud.* **2018**, *6*, 61; doi:10.3390/ijfs6030061

exchange rate and oil prices, etc. These are the possible future research directions.

References

Aloui, R., Ben Aïssa, M.S., Nguyen, D.K., 2013, Conditional dependence structure between oil prices and exchange rates: A copula-GARCH approach，*Journal of International Money and Finance* 32, 719–738

Büyükşahin, Bahattin, Jeffrey H. Harris. 2011, Do Speculators Drive Crude Oil Futures?" *Energy Journal* 32: 167-202

Cairns J, Ho C, McCauley R., 2007, Exchange rates and global volatility: implications for Asia-Pacific currencies , *BIS Quarterly Review*, March, 41–52

Cifarelli, G. and G. Paladino, 2010, Oil price dynamics and speculation: A multivariate financial approach, *Energy Economics* 32, 363–372.

Cheng, K. C., 2008, Dollar depreciation and commodity prices. World Economic Outlook (pp.48–50), IMF

Cheng Ing-Haw and Xiong Wei, 2013, The Financialization of Commodity Markets, NBER Working Paper No. 19642

Fattouh, Bassam, Pasquale Scaramozzino, 2011, Uncertainty, Expectations, and Fundamentals: Whatever Happened to Long-Term Oil Prices? *Oxford Review of Economic Policy* 27, 186-206

Hamilton, James D., 2009, Causes and Consequences of the Oil Shock of 2007–08, *Brookings Papers on Economic Activity*, SPRING, 215-261

Kaufmann, R.K. B. Ullman, 2009. Oil prices, speculation, and fundamentals: Interpreting causal relations among spot and futures prices, *Energy Economics* 31, 550–558.

Krichene, N., 2005, A simultaneous equations model for world crude oil and natural gas markets, IMF working paper WP/05/32

Lizardo, R.A., Mollick, A.V., 2010, Oil price fluctuations and U.S. dollar exchange rates, *Energy Economics* 32, 399–408.

McCauley R., McGuire P., 2009, Dollar appreciation in 2008: safe haven, carry trades, dollar shortage and overhedging, *BIS Quarterly Review*, December, 85-93

Ranaldo A, Söderlind P., 2007, Safe haven currencies, Swiss National Bank Working Papers No.17

Reboredo, J.C., Rivera-Castro, M.A., Gilney F. Zebende, 2014, Oil and US dollar exchange rate dependence: A detrended cross-correlation approach, *Energy Economics* 42, 132–139

Richard Portes and Helene Rey, 1998, Euro vs dollar, Will the euro replace the dollar as the world currency? *Economic Policy*, April, 306-342

Sari, R., Hammoudeh, S., Soytas, U., 2009, Dynamics of oil price, precious metal prices, and exchange rate,

Energy Economics 32, 351–362.

Tang Ke, Xiong Wei, 2012, Index Investment and the Financialization of Commodities, *Financial Analysts Journal* 68(6), 54-74

Wu Chih-Chiang，Chung Huimin, Chang Yu-Hsien, 2012, The economic value of co-movement between oil price and exchange rate using copula-based GARCH models. *Energy Economics* 34, 270–282.

Yousefi, A., Wirjanto, T.S., 2004, The empirical role of the exchange rate on the crude-oil price formation. *Energy Economics* 26, 783–799

Zhang, Y. -F., Fan, Y., Tsai, H. -T., & Wei, Y. -M., 2008, Spillover effect of US dollar exchange rate on oil prices, *Journal of Policy Modeling* 30, 973–991