

# Revisiting the Dynamic Correlation between Gold and Oil Returns in the Aftermath of 2008 Global Financial Crisis

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**Abstract.** Dynamic relationship between gold and oil market has attracted increasing amounts of scholarly interest. In this paper, we propose a novel nonlinear analysis framework including VAR-BDS, ARIMAX-BDS, non-parametric structural change detection model, DCC-GARCH model to clearly reveal the time-varying correlation between the crude oil price and the gold price after the 2008 GFC. Firstly, the results of VAR-BDS and ARIMAX-BDS show that the interactions between these two markets are suggested to be nonlinear in contrast to previous work. Secondly, by employing non-parametric structural change detection model, we find that the linkage between oil and gold market after the 2008 GFC experience nine different regimes and turn to be nonlinear and asymmetry. Finally, DCC-GARCH model is adopted to examine the different interactions in the case of different regimes depending specific threshold variables. In the end of our paper, some significant implications are summarized, and the link between oil and gold market has go through a nonlinear, dynamic and asymmetric evolution process, also our conclusions present a comprehensive and timely reference information for different market participants confronting with similar global risks.

**Keywords:** Oil price; Gold price; Non-parametric structural change; DCC; GFC.

## 1. Introduction

The prices of crude oil and gold have long been regarded as two vital economic variables not only for individual countries but also for the global economy. As is known to us all, the 2008 GFC has a devastating impact on the global financial market, especially on the crude oil market and the gold market (Kanjilal and Ghosh, 2017). Obviously, to deeply understand the dynamic evolution process of the link between oil-gold market returns after the 2008 GFC is of great help for policymakers and market participants to adopt effective countermeasures to alleviate the risk when confronting with similar global economic risk events.

With the daily data of Brent oil and gold returns from January 03, 2008 to July 17, 2019 which obtained from <https://www.investing.com>, we present a novel nonlinear analytical framework including nonlinear test for the link, non-parametric structural change detection (NSA) and DCC-GARCH model. To be specific, step 1, the model of BDS test combined with autoregressive integrated moving average and vector auto-regression model is used to detect the nonlinearity of the link between oil and gold market. In the Step 2, NSA model is adopted to reveal the nonlinear evolution process of such link after the 2008 GFC. Step 3 presents the examination of DCC-GARCH in different regimes. This framework not only focuses on the test of nonlinear link, but also focuses on the identity of different regimes that the linkage of oil-gold market goes through after the 2008 GFC. And it has good expansibility and applicability to examine the link of other fields like air quantity, environment, technology innovation and other research topic.

## 2. Analysis Framework and Methodology

The analysis framework is designed as follows: firstly, the models of BDS test combined with vector auto-regression and auto regressive integrated moving average are used to test the nonlinear relation between gold and oil market. Secondly, the model of NSA is used to detect the changepoints for the pair of oil-gold as the nonlinear link existence. Finally, we adopt the DCC-GARCH model to explore the dynamic correlation between oil and gold in different periods. Then the details of the NSA and DCC-GARCH model are shown below.

## 2.1 Non-parametric Structural Change Detection in Multivariate Systems(NSA)

The NSA is proposed by Malo et al. (2019) to estimate an unknown number of structural change points in multivariate systems. As the basis of the NSA, the energy distance is a measure of distance based on Euclidean distances proposed by Rizzo and Szekely (2010). And the energy distance is counted as:

$$d_{\alpha}(V_n, W_m) = \frac{mn}{m+n} \hat{\epsilon}(V_n, W_m; \alpha) = \frac{mn}{m+n} (2\hat{\mu}_{vm}^{\alpha} - \hat{\mu}_v^{\alpha} - \hat{\mu}_m^{\alpha}) \quad (1)$$

An array of structural change points for a dataset which followed the multivariate linear model were estimated by energy distances. The change points are then defined as global minimizers of the goodness-of-fit statistic.

$$(\hat{T}_1, \dots, \hat{T}_k) = \operatorname{argmin}_{T_1, \dots, T_k} \sum_{1 \leq i < j \leq k+1} \binom{n_i+n_j}{T} d_{\alpha}(U_i, U_j) \quad (2)$$

Then the bootstrap statistic is used to test the null hypothesis of equal distributions  $H_0: F_1 = \dots = F_{k+1}$ .

## 2.2 Dynamic Conditional Correlation–GARCH (DCC-GARCH)

The model of DCC–GARCH proposed by Engle and Sheppard (2001) is adopted to detect the time-varying correlations between two or more series. The DCC model was designed to allow for two stage estimation. In the first stage, each residual series is estimated by univariate GARCH models. And the shape of univariate GARCH model is denoted as Eq. (3) where the  $r_t$  represents the return of oil and gold.

$$\sigma_t^2 = \alpha_0 + \alpha_1 r_{t-1}^2 + \dots + \alpha_q r_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + \dots + \beta_p \sigma_{t-p}^2 \quad (3)$$

In the second stage, the standard deviation estimated from the stage one is used to estimate the dynamic correlation. The multivariate GARCH model assumes that returns from  $K$  assets are conditionally multivariate normal with zero mean and covariance matrix  $H_t$ . Then the element of  $R_t$  is calculated by the form of  $\rho_{ijt} \frac{q_{ij}}{\sqrt{q_{ii}q_{jj}}}$ . At last, we obtain the dynamic correlation between the return of oil and gold.

$$H_t = D_t R_t D_t \quad (4)$$

## 3. Empirical Results

Step 1, we have adopted the ARIMAX-BDS and VAR-BDS model to explore the nonlinear correlation between Brent oil and gold returns. And the results show that the link between oil-gold returns can be considered as nonlinear. Step 2, by adopting NSA model and taking Brent oil returns as the threshold variable, we find that the linkage of oil and gold market experience 9 different nonlinear regimes. Furthermore, in each different regime, the dynamic interactions are captured by the DCC-GARCH model. The results are present in Table1. From the details in Table1, we could argue that all the DCC-GARCH fit models in nine regimes are correct as  $a + b \leq 1$ . It is noticeable that the correlation between oil-gold returns after the GFC is asymmetric, which suggests that the link between the two markets has apparent periodic characteristic and is time-varying under different regimes. Meanwhile, the significant effects of the recent volatility on the dynamic relationship between the two markets only appear in the first three segments of the global financial crisis.

To put these values into perspective, Fig.1 demonstrates the time-varying link between the two markets. The similar results can also be obtained clearly mentioned above. And the dynamic link between oil-gold returns fluctuated greatly especially during the periods of the first, second and third segment from 2008 to 2010. Besides, such results also demonstrate that the global financial crisis would trigger large volatility in the crude oil and gold market and have a significantly detrimental

impact on the orderly and healthy development of commodity markets, such as crude oil and gold market that have a profound influence on global economy development.

Table 1. The DCC-GARCH results indifferent regimes with the threshold of Brent.

	Segmen t1	Segmen t2	Segmen t3	Segmen t4	Segmen t5	Segmen t6	Segmen t7	Segmen t8	Segmen t9
a	0.007* *	0.069* *	0.090* **	0.012	0.049	0.004	0.026	0.000	0.077
b	0.993* **	0.888* **	0.837* **	0.903* **	0.659* **	0.793* **	0.924* **	0.909* **	0.294* *
a+	1	0.957	0.927	0.915	0.708	0.801	0.950	0.909	0.371
b									

Note: \*\*\*1%, \*\*5%, \*10%.

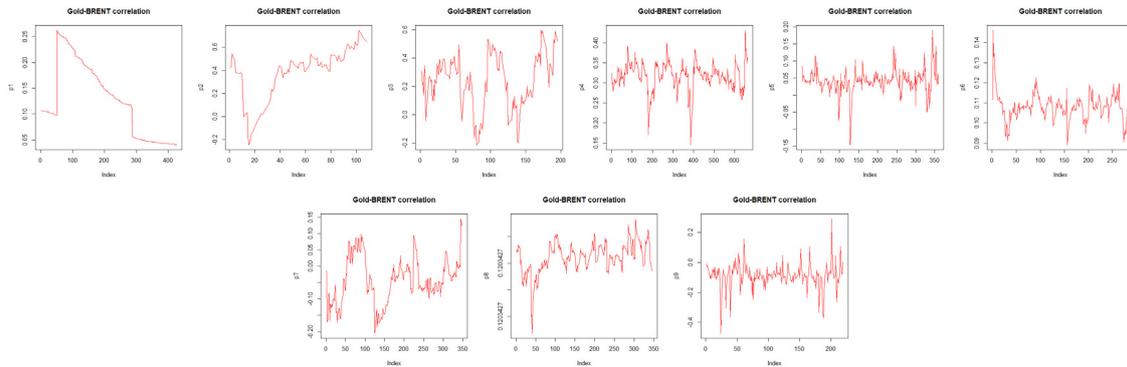


Figure 1. Time-varying conditional correlation in nine segments after GFC

#### 4. Conclusion

In this paper, with a sample from January 3, 2008 to July 16, 2019, we provide a comprehensive framework including the nonlinear test, NSA, and time-varying correlation examination to examine the dynamic link between oil-gold returns after the GFC. And the results show that the relation between the oil and gold market after the GFC is nonlinear instead of linear. In addition, we find the link between the oil and gold market goes through nonlinear process with 9 different regimes. The DCC results show that the recent volatility on the dynamic relationship between the two markets only appear in the first three segments of global financial crisis. Moreover, the effect has a trend of increase. The findings of the study have significant practical implications for policymakers and financial market participants.

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