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Long Memory versus Structural Changes in the Dynamics of Europe Brent-Oil Prices

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Abstract

In this paper, we examine the potential of long memory and structural breaks properties in the Brent returns and the Brent volatility series. We analyze the series over the period 20/05/1987-22/01/2016, using long memory tests, we demonstrate strong evidence of long-range dependence in the daily return and volatility of oil prices. From structural breaks tests, we find two structural breaks that appear in 1991 and 2008 which coincides, respectively, with the Gulf war and the global financial crisis. We use the Perron and Qu (2010) test in order to discriminate the long memory from the spurious long memory in presence of structural break, the results show strong evidence in favor of long memory. Long memory plays a crucial role in describing the oil price dynamics and we can also confirm that despite the persistence of shocks, the evolution of series is predetermined by a long memory process.

***Keywords**: Volatility, Fractional Integration, Long Memory Process, Spurious Long Memory, Structural Breakss.*

Introduction

Given the fact that oil prices shocks are triggered by different factors such as the market conditions, the OPEC and non-OPEC oil production, the global demand for oil and the geopolitical environment. There is a large attention in modeling the behavior of oil prices

Further, some authors pay attention to the oil returns, whereas others authors are attentive to the oil volatility. For that, several models were employed. Among these models, the authors apply the long memory models. However, Long memory properties on the oil market have been investigated in the case of the oil returns investment (Boone, 2001), the oil consumption (Mohn and Osmundsen, 2008), Lean and Smyth (2009), and energy prices (Serletis, 1992; Lien and Root, 1999; Elder and Serletis 2008; and Kang et al., 2011).

In fact, in financial time series analysis, the long-range dependence phenomenon has been the topic of a wide theoretical and empirical examination. For reviews of the literature, see Robinson (1994) and Baillie (1996). The long memory process illustrates the high-order correlation composition of financial time series. Series showing evidence of long memory, even between distant observations, indicate persistent temporal

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dependence. Such series are distinguished by a slowly declining autocovariance function along with an unbounded spectral density function at the null frequency (Lo,1991; Cheung, 1993; Lobato and Sevin,1998). Hence, the presence of long memory components in the process of oil prices series is a current subject of high attention among authors.

In fact, energy markets are exposed to exogenous shocks. Therefore, it exists a tendency that many unexplained price spikes are kept out of modeling practices; they are often attributed to exogenous shocks. The introduction of structural breakss models has taken into account the structural breaks, which are not visible to the naked eye such as periods of boom and bust markets, periods of crisis.... Several financial time series contain non-linearity due to breaks in government policies, financial panics, economic cycles... Structural breaks models can describe the behavior of these series.

Recently, authors were focusing on the possibility of confounding long memory and structural breaks. Perron (1990) showed that unit roots (d = 1) and structural breaks are easily confounded meaning that, when a stationary process is contaminated by structural breaks, the estimation of the sum of the autoregressive coefficients will be biased towards 1 and the test of the null hypothesis of unit root will be biased. This trend is applied as well in the long memory context. Related references on this issue comprise Granger and Ding (1996), Granger and Hyung (2004) and Teverosovky and Taqqu (1997). However, some documents include theoretical results associated to the circumstance that the variance and autocorrelations have comparable characteristics under long memory and structural breaks, most of the evidence was found among simulations and no theoretical results are offered relating to the distribution of the estimation of the long memory parameter (d) in the presence of a short memory process with structural breaks.

In this study, we model the returns and the volatility of Brent oil price using daily data to capture the dynamics of these series. The oil price employed in this paper is the Brent, which is computed by dollar per barrel. Empirically, we aim to discriminate between long memory and structural breaks by analyzing different measurements. We use different long memory tests, the results with respect to the existence of long memory, this difference indicates that empirical work requires to be particularly careful in addressing long memory topic. We apply the Bai Perron (2003) test in order to detect structural breaks in the studied series. We detect two structural breaks that occur in 1991 and 2008 which coincide, respectively, with the Gulf war and the global financial crisis. These incidents influenced the demand of oil. The Perron and Qu (2010) is used to discriminate between long memory and spurious long memory. The results show strong evidence in favor of long memory.

The remaining part of the article is structured as follows. Section 2 represents a review of the literature. Section 3 illustrates the empirical methodology. Section 4 indicates the data exploited. Section 5 shows the empirical results. Finally, concluding remarks are reported in Section 6.

Literature Review

The phenomenon of long memory in the financial market has been studied in several studies but only a few of these studies, focus on the returns and the volatility of oil prices. Some papers have tested whether times series of oil prices prove long memory properties (Serletis and Andreadis, 2004), Elder and Serletis (2008); Aloui and Mabrouk (2010). Many empirical studies of oil price series confirm evidence of long range dependence in these series. Morana (2001) and Bina and Vo (2007) sugget that the returns and volatility of oil series are differentiated by fat tail distribution, volatility clustering, asymmetry and mean reverse. Gil-Alana et al. (2010) and Barros et al. (2011) used fractional integration method to examine oil production in the OPEC countries and US electricity consumption. Recently, Belkhouja and Boutahary (2011) examined the long memory and the structural breaks in the oil prices and the S&P 500 indices , they found strong evidence for long-range dependence behaviour in the absolute returns and the squared returns. Also, Arouri et al. (2012b) investigated the role of long memory and structural breaks in modeling and forecasting the oil spot and oil futures volatilities. The authors support evidence of long memory.

On the other hand, the subject of structural breaks approach has been documented in numerous studies. Recent empirical studies investigate, through the Bai Perron (2003) test, the presence of structural breaks in oil markets. Liao and Suen (2006) located, in the global oil market during the period 1986–2004, significant structural breaks in November 1999 which occured after the oil glut produced by the 1997 Asian crisis. Fan and Xu (2011) demonstrated the existence of structural breaks in the process of oil price in the international oil market. Fong and See (2002) employed a Markov regime-switching in order to explain the conditional volatility of oil returns. They conclude that the regime-switching model works better than non-switching models. This issue has been also examined by Vo (2009).

Moreover, researchers such as Diebold and Inoue (2001), Granger and Hyung (2004) and Ohanissian (2008) were also interested in whether the long memory property is spurious or not. In fact, the presence of structural breaks may reduce the persistence of volatility and lead to biased estimates and forecasts. Granger et Hyung (2004), Choi and Zivot (2007) and Kang et al., (2011) showed that structural breaks can rigorously modify the results of the long memory tests and may cause a spurious long memory process in some financial series.

Through these findings, we are interested to study the possibility of confounding long memory and structural breaks. Studies have shown that if a short memory process is contaminated by structural breaks, the estimate of fractional differentiation parameter (d) will be biased upwards and autocovariances decline slowly, bringing to suggest the presence of long memory. Motivated by the findings of Perron and Qu (2007), Perron and Qu (2010) modeled the volatility of some assets returns and they propose a simple test that can discriminate the long memory process from the short memory process with structural breaks.

Empirical Methodology

In this section, we introduce, in brief, the long memory and structural breaks tests as well as the long memory versus structural breaks test.

Long Memory Tests

Long memory is a central empirical characteristic of financial time series. It characterizes a series that has a slowly declining correlogram, with an unbounded spectral density function at the null frequency. Baillie (1996) and Baillie and King (1996) suggest that if a series shows a long memory process, the persistent temporal dependence exists even between distant observations. We examine for the presence of long memory components by three tests; the test of Geweke and Porter-Hudack (1983) (GPH), the test of Andrews and Guggenberger (2000) (AG) and the test of Robinson (1995). We apply these tests to the oil returns series and the oil squared returns series as a proxy of conditional volatility (Choi and Hammoudeh, 2009).

The semi- parametric estimation methods of the long memory parameter (d) have been developed by Geweke and Porter-Hudack (1983), the most used log-periodogram regression is as follows:

$$\log\left(I(\lambda_j)\right) = \xi - dlog\left(4 + sin^{2}\left(\frac{\lambda_j}{2}\right)\right) + \varepsilon_{j}\,, (1)$$

where, ξ is a constant , $\lambda j = 2\pi j / T$, j=1, 2,..., n; λj represents the $n = \sqrt{T}$ Fourier frequencies, ε_t is the residual term and I (λj) denotes the sample periodogram defined as:

$$I(\lambda) = \frac{1}{2\pi T}\left|\sum_{t=1}^{T} u_t \, e^{t\lambda_j}\right|^2 \quad (2)$$

where u_t is a covariance stationary time series. Robinson (1995) proposed a log-periodogram estimator of the long memory parameter, that is in fact the extension of the GPH estimator, this estimator is noted $\hat{d}_{Rm}$ and defined by:

$$\hat{d}_{Rm} = \frac{\sum_{j=1+m}^{l}(Y_j-\bar{Y})\ln\{I(\lambda_{j,n})\}}{\sum_{j=1+m}^{l}(Y_j-\bar{Y})^2}, \ (3) \quad 0 \leq m < l < n \qquad \bar{Y} = \frac{1}{l-m}\sum_{j=m+1}^{l} Y_j \, , (4)$$

Andrews and Guggenberger (2000) suggested an extension of the GPH estimator to be more robust. They maintained the same asymptotic distribution of the estimator GPH. To reduce the estimation bias and eliminate the high order error estimator of Geweke and Porter-Huddack (1983), they substituted the constant in the specification of the periodogram by $\sum_{r=0}^{R} \xi \lambda_j^{2r}$ and the regression is defined as:

$$\log\left(I(\lambda_j)\right) = \sum_{r=0}^{R} \xi \lambda_j^{2r} - 2d\log(\lambda_j) + \varepsilon_j \, , \ (5)$$

Structural breaks tests

To examine structural breaks property in oil returns we use Bai and Perron (2003) multiple structural breaks test. We test for the hypothesis of the presence of one break against the alternative hypothesis of the existence of an additional break (l +1) . It is performed (l +1) tests of the null hypothesis of no structural breaks against the alternative hypothesis of the presence of structural breaks. The test is applied to each plan i with observations between the date $\hat{T}_{i-1}+1$ and the date $\hat{T}_i$ (i = 1, ..., l + 1). The test is defined as follows:

$$F_T\left(l+\frac{1}{l}\right) = \{Q_T\left(\hat{T}_1, \dots, \hat{T}_l\right) - \min_{1\leq i\leq l+1} \inf_{\lambda\in\Lambda_{i,n}} Q_T\left(\hat{T}_1, \dots, \hat{T}_{i-1}, \lambda, \hat{T}_i, \dots, \hat{T}_l\right)\} / \sigma^2 \, , \ (6)$$

with, $\Lambda_{i,n} = \{\lambda; \hat{T}_{i-1} + (\hat{T}_i - \hat{T}_{i-1})\eta \leq \lambda \leq \hat{T}_i - (\hat{T}_i - \hat{T}_{i-1})\eta\}$, $\hat{\sigma}^2$ is a consistent estimator of σ^2.

Long memory versus structural breaks test

It is possible to confuse long memory and structural breaks in time series process. Studies have shown that if a short memory process is contaminated by structural breaks, the estimate of fractional differencing parameter (d) will be biased upwards and autocorrelations decline slowly, bringing to suggest the presence of long memory (Diebold et Inoue, 2001), (Perron and Qu, 2007).

In fact, the existing literature on structural breaks and long memory proposes testing for this two phenomenons independently and then estimating a long memory model with breaks. Motivated by the findings of Perron and Qu (2007), Perron and Qu (2010) propose a simple test which discriminate the long memory process from the short memory process with structural breaks. PQ test statistics is given, under the null hypothesis of a stationary long memory process considered to have power versus a short-memory process affected by structural breaks:

$$t_d(a,b) = \sqrt{\frac{24c_1[T^a]}{\pi^2}}\left(\hat{d}_{GPH}(a) - \hat{d}_{GPH}(b)\right) \xrightarrow{\mathbb{D}} N(0,1), \quad (7) \qquad b = \frac{4}{5} \quad \text{for } 0 < a < b < 1$$

$d_{GPH}(a)$ and $d_{GPH}(b)$ present estimates of the log periodogram of the long memory parameter for the respective frequencies $m = T^a$ and $m = T^b$. We follow Perron and Qu (2007) and we execute the test with $a = \frac{1}{2}$ et .

Data

We use daily oil Europe Brent closing prices (US Dollar/Barrel) over the period 20/05/1987-22/01/2016, this corresponds to 6732 days. Data of Brent oil price were extracted from the U.S Energy Information Administration. The returns'series (RBRENT) are computed as the difference in log prices. Then we determine the volatility proxy (SRBRENT) as the squared returns (Granger and Din,1995).

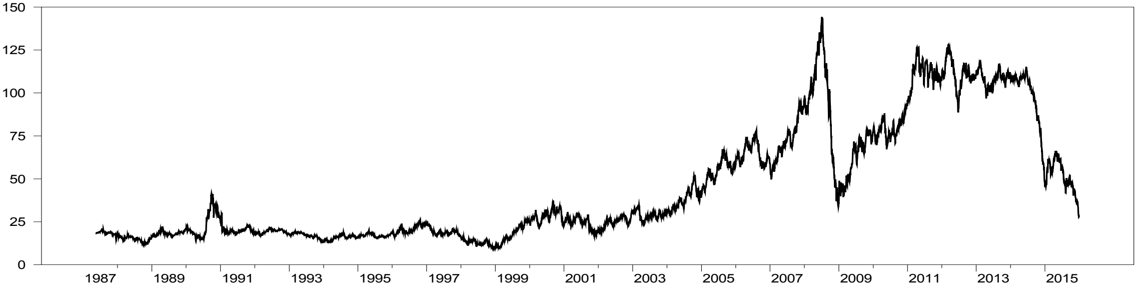

Figure1. Daily price of Brent crude oil market (US Dollar/Barrel)

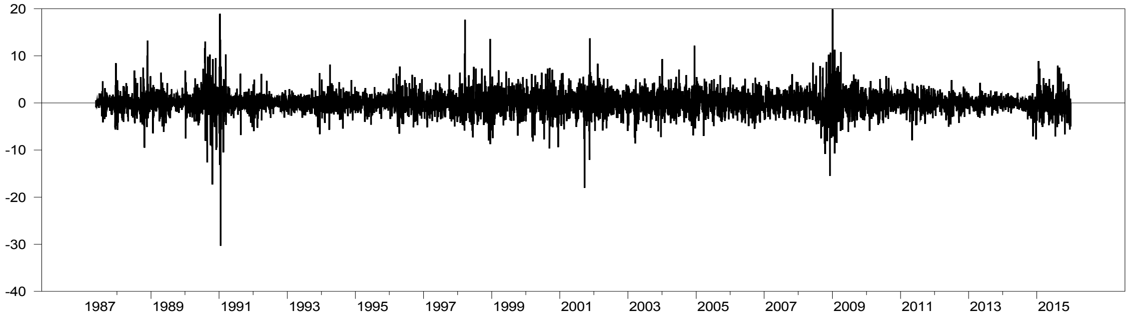

Figure 2. Daily returns of Brent crude oil market (US Dollar/Barrel).

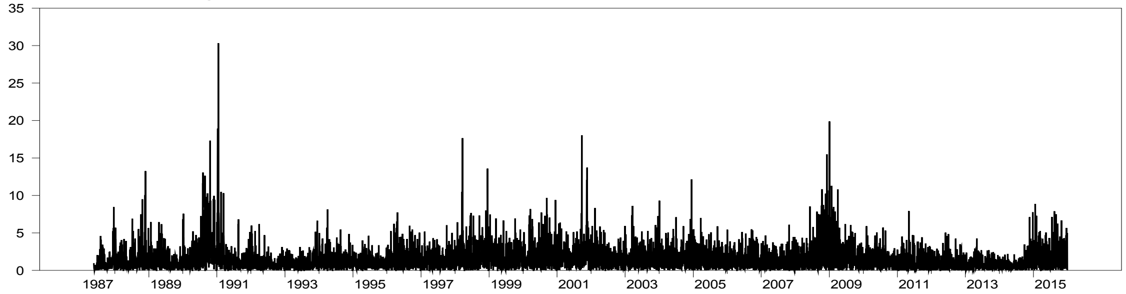

Figure 3. Daily absolute returns of Brent crude oil market (US Dollar/Barrel)

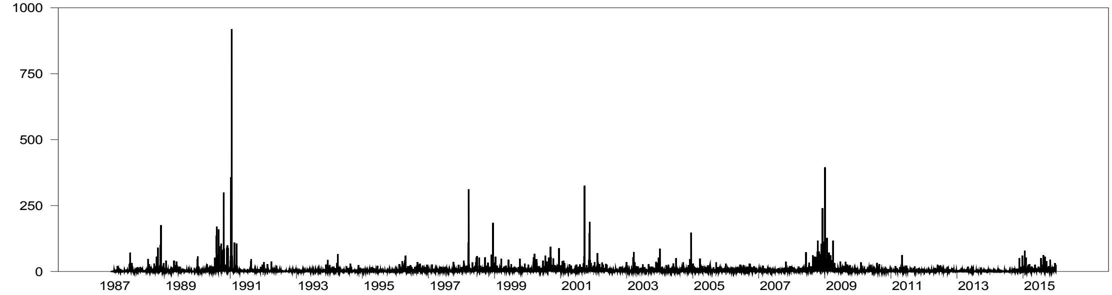

Figure 4. Squared Daily Returns of Brent Crude Oil Market (US Dollar/Barrel)

A simple graphical analysis exposes an interesting pattern. Figures 1 and 2 and 3 show trends of the Brent prices and the Brent returns. The behaviour of the Brent prices and its returns is clearly unsteady and trends in returns indicates evidence of volatility clustering, periods of high volatility are probably pursued by periods of low volatility. The remarkable spikes are evidence of significant unsteady patterns in oil price returns throughout the financial crisis.

Empirical Results

Descriptive Statistics

Table 1 recapitulates the descriptive statistics for daily oil Brent prices (OPBRENT) and daily Brent returns an squared daily Brent returns (SRBRENT) . The difference between the minimum and maximum values for prices shows that variations in the trends of the prices are significant.

Table1. Descriptive Statistics of Oil Price

	OPBRENT	RBRENT	ARBRENT	SRBRENT
Mean	44.8675	0.0303	1.5386	5.0061
Min	9.1000	-30.3170		0
Max	143.9500	19.8771		919.1229
Std. dev.	34.3129	1.1704	1.6245	17.9363***
Skewness	0.9851***	-0.1310***	3.4244***	24.2934***
Kurtosis	-0.4289***	10.8545***	27.6554***	1003.3967***
JarqueBera	1265.0564***	36673.7606***	252516.9744***	313934657.3550***

Skewness coefficient is negative for Brent returns which illustrate evidence for asymmetric properties. Excess kurtosis is highly significant and leads us to say that series have fatter tails and longer right tails than the normal distribution. The Jarque-Bera statistic indicates the rejection of normality of the series involved, the rejection of normality indicates a nonlinear behavior of different series. Nonlinearity of these series allows us to opt for a long memory process.

Autocorrelation

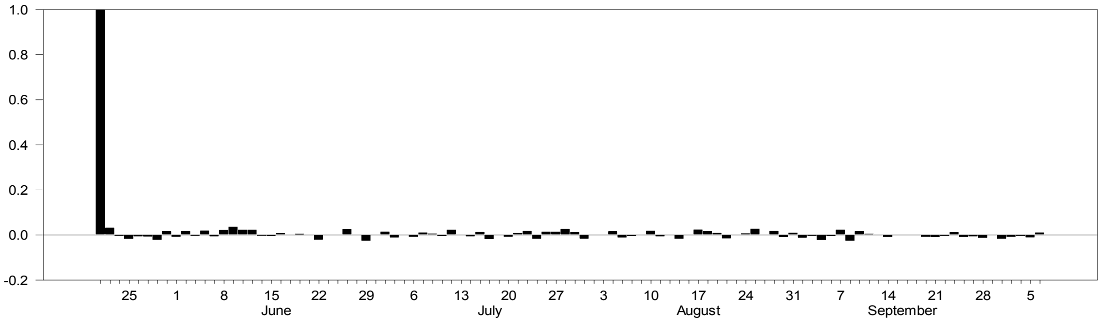

Figure 5.The Autocorrelation Function of RBRENT Series

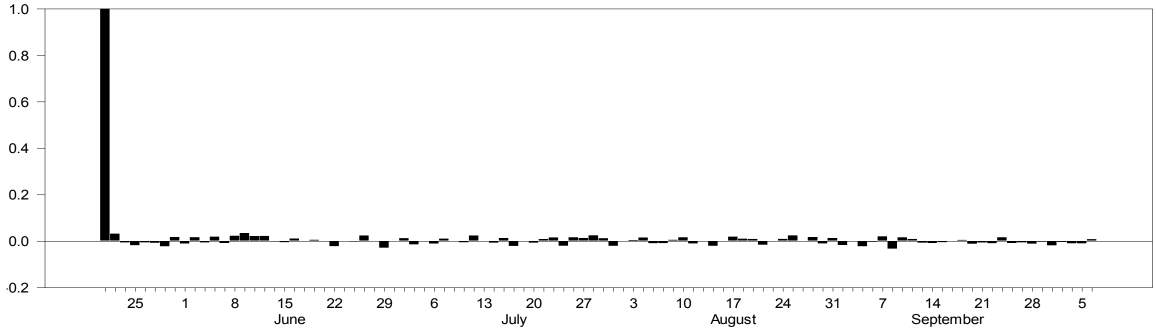

Figure 6. The Partial Autocorrelation Function of RBRENT Series

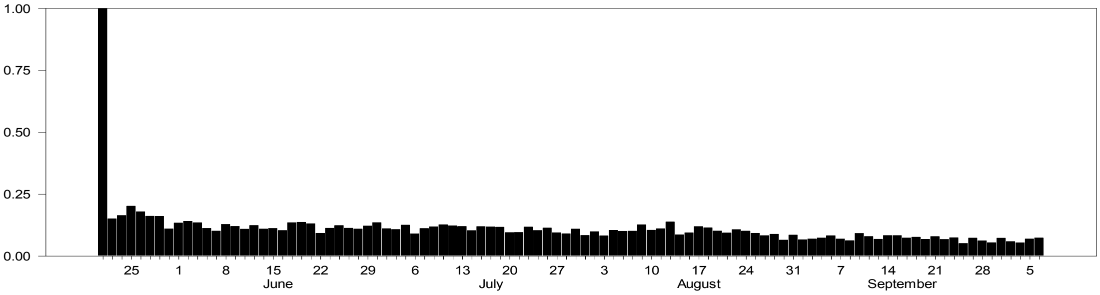

Figure 7. The Autocorrelation Function of ARBRENT Series

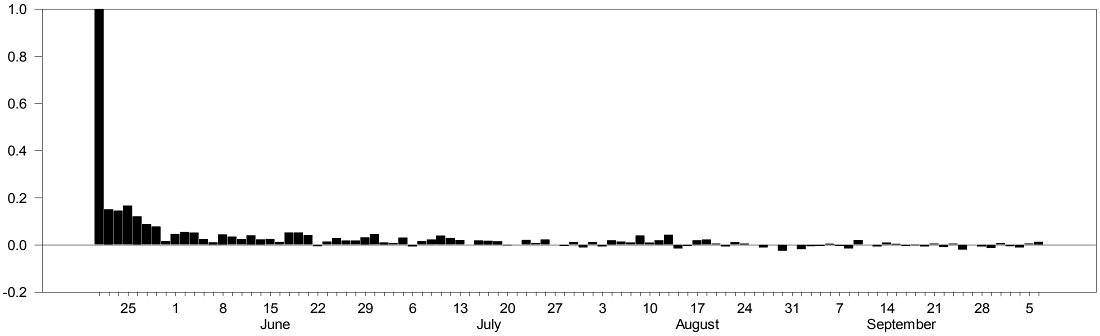

Figure 8. The Partial Autocorrelation Function of ARBRENT Series

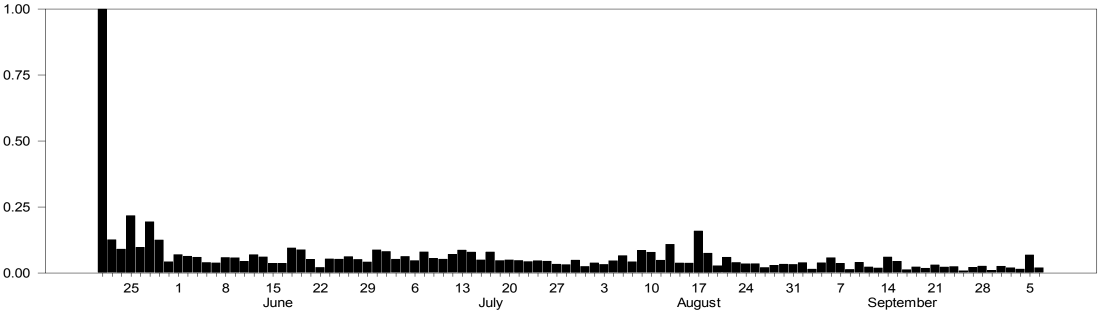

Figure 9. The Autocorrelation Function of SRBRENT Series

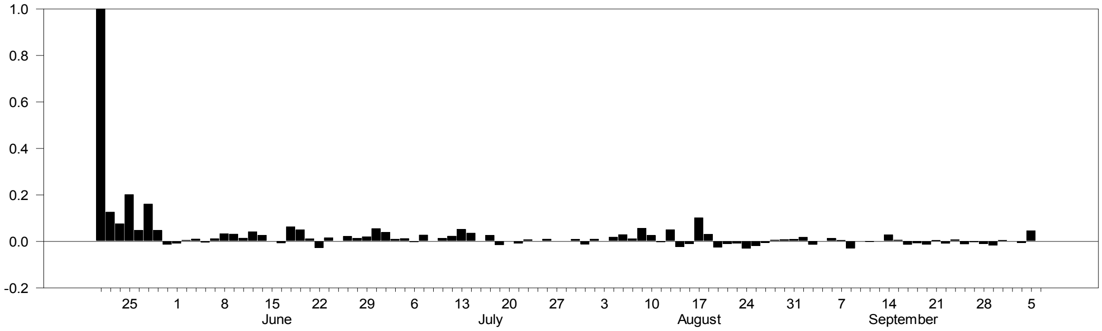

Figure 10. The Partial Autocorrelation Function of SRBRENT Series

Figure 3 demonstrates the sample autocorrelation function and the partial autocorrelation of the Brent returns and the squared Brent returns series. The autocorrelation functions of the Brent squared returns are larger, they shows a very slow decay with an hyperbolic rate which denotes that the time series are strongly autocorrelated up to a long lag and indicates a very persistent behavior. This suggests that the Brent volatility series exhibits a long memory process.

Stationarity

The null hypothesis of a unit root for the ADF and PP tests is rejected with large negative values and the null hypothesis of stationarity for the KPSS test is not rejected at the 1% significance level. Thus, we considered that the Brent returns and the Brent volatility series present a stationary process.

Tabl 2. Results of Stationarity Tests

	RBRENT	ARBRENT	SRBRENT
ADF	-83.6653	-4.1868	-10.3547
KPSS	0.1711*	1.8863**	0.6376**
PP	-83.6496	-76.1956	-77.4651

Results of Long Memory Tests

Table 3 shows the obtained results of the three long memory tests (GPH, Robinson and AG). The results of the Robinson and AG tests are more or less identical with the values of the GPH test. For the Brent returns and the Brent volatility series, the values of the estimated d are between 0 and 0.5. The series provide evidence of long memory.

Table3. Results of Long Memory Tests

	RBRENT	ARBREENT	SRBRENT
GPH	0.0704	0.5633	0.3777
AG	0.0724	0.5634	0.3748
Robinson	0.0300	0.5000	0.3500

Results of Structural Breaks Tests

The results of Bai Perron test are reported in Table 3. The test shows two breaks dates for the returns and the volatility oil series. The first break is related to the gulf war, this period was ended with higher risks and uncertainty in the world oil market with critical repercussions for world oil production.The second break is associated with the global financial crisis 2008-2009 which affected the oil demand. These two breaks appear to mirror the experience of oil markets, they reflect the major global incidents, like the global financial crises (see, Narayan and Liu (2011)).

Table 4. Results of Bai Perron Test

	RBRENT	ARBRENT	SRBRENT
Best 2 breakpoints	09/01/1991 01/01/2009	16/01/1991 02/04/2009	18/01/1991 01/01/2009
Test statistic	1.1241**	12.550**	10.4281**

Results of Long Memory versus Structural Breaks Test

From the results showed in table 5, we note that the test shows no significance for the two series (PQstat>-1.96). The PQ test results lead us to retain the hypothesis of true long memory processes. We can confirm that despite the persistence of shocks, the series evolution are predetermined by a long memory process and seems to follow a very distant trend.

Table 5. Results of PQ Test

	RBRENT	ARBRENT	SRBRENT
PQstat	-1.0277	-1.5415	-0.5138
Critical value 95%		-1.96	

Saummary and Conclusion

In the literature, it is frequently believed that volatility is characterized by a long memory process. Based on these findings, this paper targets to investigate oil price volatility using daily data from the Brent oil market in order to know whether the oil price volatility process is characterized by a long memory or structural breaks. We empirically discriminate between long memory and structural breaks. We use different long memory tests, the results show evidence of long memory. We apply the Bai Perron (2003) test in order to identify structural breaks in the studied series. We identify two structural breaks that occur in 1991 and 2008 which coincide, respectively, with the Gulf war and the global financial crisis. These events influenced the demand for oil. The Perron and Qu (2010) is used to make the discrimination between long memory and spurious long memory. The results show strong evidence in favor of long memory. Therefore, we can say that long memory plays a crucial role in describing the oil price dynamics. Investors in this market can use the long-range dependence property, through past information and statistical models that accommodate long memory characteristics, in order to understand higher profits.

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