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The efficiency of the crude oil markets: Evidence from variance ratio tests

Amélie Charles [a], Olivier Darné [b,*]

[a] Audencia Nantes, School of Management, 8 route de la Jonelière, 44312 Nantes, France
[b] LEMNA, University of Nantes, IEMN–IAE, Chemin de la Censive du Tertre, 44322 Nantes, France

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ABSTRACT

This study examines the random walk hypothesis for the crude oil markets, using daily data over the period 1982–2008. The weak-form efficient market hypothesis for two crude oil markets (UK Brent and US West Texas Intermediate) is tested with non-parametric variance ratio tests developed by [Wright J.H., 2000. Alternative variance-ratio tests using ranks and signs. Journal of Business and Economic Statistics, 18, 1–9] and [Belaire-Franch J. and Contreras D., 2004. Ranks and signs-based multiple variance ratio tests. Working paper, Department of Economic Analysis, University of Valencia] as well as the wild-bootstrap variance ratio tests suggested by [Kim, J.H., 2006. Wild bootstrapping variance ratio tests. Economics Letters, 92, 38–43]. We find that the Brent crude oil market is weak-form efficiency while the WTI crude oil market seems to be inefficiency on the 1994–2008 sub-period, suggesting that the deregulation have not improved the efficiency on the WTI crude oil market in the sense of making returns less predictable.

1. Introduction

Since the end of the 1990s oil prices have been steadily increasing, reflecting rising demand for crude oil, particularly from developing nations. Indeed, in the last decade the oil prices increased more than 700% (in average) and more than 80% (in average) between mid-2007 and 2008 due to rising demand, low spare capacity, weak dollar and geopolitical concerns (especially, tensions in Turkey, Nigeria and Iran). Oil prices have been very volatile, changing their trajectories and behavior with respect to the economic situation. Oil prices exhibit large upward or downward swings primarily caused by fluctuations in demand, extraction costs, and reserves (Pindyck, 1999). Supply and demand remain the main factors determining oil prices. More precisely, oil demands depend on oil consumption by developed and developing countries, and oil supplies depend on geopolitical events, such as troubles between Venezuela and the US or Turkey and Kurdish Iraq or Iran and Israel, among others, as well as oil tank levels and the Organization of the Petroleum Exporting Countries (OPEC) decisions on adjusting production levels. However, oil investor behavior can also be a factor in the recent price behavior, especially, increasing speculative behavior of a more diverse set of investors, including hedge funds, pension funds, and investment banks. All these factors question on the issue of whether or not the crude oil markets are predictable and therefore efficient.

In this paper, we analyze the efficiency of the crude oil markets. The literature on market efficiency and stock market predictability is vast, as researchers have been discussing this theme in depth from the past decades (see Fama, 1970, 1991; Fama and French, 1988; Lo and MacKinlay, 1988; among others). A capital market is considered as efficient if stock prices at any time fully reflect all available and relevant information. Therefore, given only past price and return data, the current price is the best predictor of the future price, and the price change or return is expected to be zero. Stock prices exhibit no serial dependencies, meaning that there are no patterns to asset prices. This implies that future price movements are determined entirely by information not contained in the price series. This is the essence of the weak-form efficient market hypothesis [EMH], which implies a random walk. It is this random walk implication of the weak-form EMH that is most commonly tested in the empirical literature.[1]

Recently, Tabak and Cajueiro (2007), Alvarez-Ramirez et al. (2008) and Maslyuk and Smyth (2009) investigated the efficiency of crude oil markets from time-varying long-range dependence, Hurst exponent dynamics (from detrended fluctuation analysis) and unit root tests, respectively. They found that these markets are weak-form efficient. In this paper, we extend the examination of the weak-form of the EMH in the crude oil markets in two ways.

* Corresponding author. Tel.: +33 0 2 40 14 17 33; fax: +33 0 2 40 14 16 50.
E-mail addresses: acharles@audencia.com (A. Charles), olivier.darne@univ-nantes.fr (O. Darné).

[1] Note that if the random walk hypothesis is based on the theory of efficiency, the EMH does not imply that prices follow a random walk. Therefore, if prices do not follow a random walk, this does not imply inefficiency of the market. See Lo and MacKinlay (2001) for a discussion on random walk hypothesis and efficiency market hypothesis.

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First, this study is based on a more extensive sample. We study daily data for two crude oil markets, namely, the US West Texas Intermediate and the UK Brent, over the period June 1982–July 2008. We also investigate the EMH over two sub-periods in order to analyze the effects of the important structural change due to policy changes that attempted to increase the efficiency of the North American energy industry in 1993.[2] Second, the weak-form EMH is evaluated from an alternative method relative to the previous studies, namely the variance ratio [VR] tests which are widely used in financial empirical studies (e.g., Lagoarde-Segot and Lucey, 2007; Kim and Shamsuddin, 2008).[3] More precisely, we adopt individual non-parametric VR tests suggested by Wright (2000) as well as its multiple versions proposed by Belaire-Franch and Contreras (2004). These VR tests are robust to heteroscedasticity and non-normality which are features displayed by the crude oil prices (Pindyck, 2004; Narayan and Narayan, 2007; Kang et al., 2009), and powerful against fractionally integrated alternatives which are present in crude oil prices (Alvarez-Ramirez et al., 2002, 2008; Tabak and Cajueiro, 2007). We also apply the wild-bootstrap VR tests suggested by Kim (2006) which are robust to heteroscedasticity and do not rely on asymptotic approximations.

The rest of this paper is organized as follows. Section 2 discusses the variance ratio [VR] tests. Section 3 summarizes the characteristics of the data on the Brent and WTI crude oil markets. Section 4 reports the empirical results. Section 5 concludes.

2. Variance ratio tests

Since the seminal work of Lo and MacKinlay (1988, 1989) and Poterba and Summers (1988), the standard variance ratio test or its improved modifications have been widely used for testing market efficiency.[4]

The VR methodology consists of testing the random walk hypothesis [RWH] against stationary alternatives, by exploiting the fact that the variance of random walk increments is linear in all sampling intervals, i.e., the sample variance of k-period return (or k-period differences), $y_t - y_{t-k}$, of the time series y_t, is k times the sample variance of one-period return (or the first difference), $y_t - y_{t-1}$. The VR at lag k is then defined as the ratio between $(1/k)$th of the k-period return (or the kth difference) to the variance of the one-period return (or the first difference). Hence, for a random walk process, the variance computed at each individual lag interval k ($k = 2, 3\ldots$) should be equal to unity.

In testing the null hypothesis of random walk, the VR test evaluates the hypothesis that a given time series or its first difference (or return), $x_t = y_t - y_{t-1}$, is a collection of independent and identically distributed observations (i.i.d.) or that it follows a martingale difference sequence. Following Wright (2000), the VR statistic be written as

$$VR(x;k) = \left\{ (Tk)^{-1} \sum_{t=k}^{T} (x_t + \cdots + x_{t-k+1} - k\hat{\mu})^2 \right\} \div \left\{ T^{-1} \sum_{t=1}^{T} (x_t - \hat{\mu})^2 \right\}$$

where $\hat{\mu} = T^{-1}\sum_{t=1}^{T} x_t$. If the stock return follows a random walk, the expected value of $VR(x;k)$ should be equal to unity for all horizons k. If this ratio is less than one at long horizons, then we have indications of negative serial correlation (mean-reversion) and ratios greater than one at long horizons implies positive serial correlation (mean-aversion).

Lo and MacKinlay (1988) proposed the asymptotic distribution of $VR(x;k)$ by assuming that k is fixed when $T \to \infty$. They show that under the assumption of conditional heteroscedasticity, then under the null hypothesis that $V(k) = 1$, the test statistic $M(x;k)$ is given by[5]

$$M(x;k) = \frac{VR(x;k) - 1}{\phi^*(k)^{1/2}}$$

which follows the standard normal distribution asymptotically, where:

$$\phi^*(k) = \sum_{j=1}^{k-1} \left[\frac{2(k-j)}{k} \right]^2 \delta(j)$$

$$\delta(j) = \left\{ \sum_{t=j+1}^{T} (x_t - \hat{\mu})^2 (x_{t-j} - \hat{\mu})^2 \right\} \div \left\{ \left[\sum_{t=1}^{T} (x_t - \hat{\mu})^2 \right]^2 \right\}$$

2.1. Wright (2000) tests

A well-known problem with the VR test is that the standard VR tests such as Lo and MacKinlay (1988) tests, which are based on asymptotic approximations, are biased (severe size distortions and low power) and right-skewed in finite samples, resulting in misleading statistical inference. Wright (2000) proposed a non-parametric alternative to conventional asymptotic VR tests using ranks. Wright's (2000) tests have two advantages over Lo–MacKinlay test when sample size is relatively small: (i) as the rank (R_1 and R_2) tests have exact sampling distribution, there is no need to resort to asymptotic distribution approximation, and (ii) the tests may be more powerful than the conventional VR tests against a wide range of models displaying serial correlation, including fractionally integrated alternatives. The tests based on ranks are exactly under the i.i.d. assumption. Moreover, Wright (2000) showed that rank-based tests display low size distortion, under conditional heteroscedasticity.[6]

Given T observations of first differences of a variable, $\{x_1, \ldots, x_T\}$, and let $r(x)$ be the rank of x_t among $(x_1, \ldots, x_T)$. Under the null hypothesis that x_t is generated from an i.i.d. sequence, $r(x)$ is a random permutation of the numbers of $1, \ldots, T$ with equal probability. Wright (2000) suggested the R_1 and R_2 statistics, defined as

$$R_1(k) = \left(\frac{(Tk)^{-1} \sum_{t=k}^{T} (r_{1,t} + \cdots + r_{1,t-k+1})^2}{T^{-1} \sum_{t=k}^{T} r_{1,t}^2} - 1 \right) \times \phi(k)^{-1/2}$$

$$R_2(k) = \left(\frac{(Tk)^{-1} \sum_{t=k}^{T} (r_{2,t} + \cdots + r_{2,t-k+1})^2}{T^{-1} \sum_{t=k}^{T} r_{2,t}^2} - 1 \right) \times \phi(k)^{-1/2}$$

where the standardized ranks $r_{1,t}$ and $r_{2,t}$ are given by

$$r_{1,t} = \frac{r(x_t) - T + 1/2}{\sqrt{(T-1)(T+1)/12}}$$

$$r_{2,t} = \Phi^{-1} \frac{r(x)}{T+1}$$

where $\phi(k) = 2(2k-1)(k-1)(3kT)^{-1}$, and Φ^{-1} is the inverse of the standard normal cumulative distribution function. The R_1 and R_2 statistics follow the same exact sampling distribution. The critical

[2] See Serletis and Andreadis (2004) and Serletis and Rangel-Ruiz (2004) for a discussion on these policy changes.

[3] Lo and MacKinlay (1989) examined the VR, Dickey–Fuller unit root and Box–Pierce serial correlation tests which are often employed to test the weak-form efficiency (Hoque et al., 2007; Kim and Shamsuddin, 2008) and found that VR test was more powerful than the others under the heteroscedastic random walk.

[4] See Hoque et al. (2007) and Charles and Darné (2009) for a review.

[5] Lo and MacKinlay (1988) also propose a test statistic under the assumption of homoscedasticity. We focus only on VR statistic which is robust under heteroscedasticity since, as shown in Section 3, all the data display heteroscedasticity.

[6] Wright (2000) also suggested sign-based tests.