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Parametric and non-parametric approaches in evaluating martingale hypothesis of energy spot markets

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ABSTRACT

This study examined the martingale hypothesis in the spot prices of the petroleum products markets. Under the parametric and non-parametric variance ratio tests, the independent and identically distributed increments and less restrictive martingale increments are evaluated over the period 1986–2009. In order to investigate how the energy markets' efficiency evolved over the long spanning data, we had divided them into three sub-periods according to several important events that strongly influenced the energy price movements. The empirical findings of this study can be summarized as follows: First, both the West Texas Intermediate (WTI) crude oil and New York Harbor (NYH) gasoline markets were somewhat informationally inefficient before the North American Free Trade Agreement (NAFTA) and during the Iraqi invasion of Kuwait in 1990. Second, the martingale hypothesis analysis indicated that after the NAFTA regulation and Iraqi invasion, both the energy markets became more efficient which implied that the energy prices fully reflected all available market information. Finally, although the period after 2002 is related to high volatility with an upward trend in energy demand, the well informed energy market participants somehow are able to anticipate the price fluctuations.

1. Introduction

Petroleum products are one of the most important global energy commodities due to their importance in nowadays industrial, logistic and daily life energy consumptions. The petroleum product price dynamics are proven to be concomitant with the movements of global macroeconomics and financial markets. These phenomena are evidenced in the recent studies by Narayan and Smyth [1], Cologni and Manera [2], Gronwald [3], Miller and Ratti [4], Park and Ratti [5], Nandha and Faff [6]. Recognizing the importance of these energy commodities, there are ample studies [7–12] investigating the underlying stochastic processes of these spot prices. This is because the insightful understanding of the behavior of spot prices provided significant contributions to model and forecast the price movements especially to financial practitioners, energy researchers and policy makers.

Weak-form efficient market hypothesis (EMH) is one of the most frequently debatable issues in asset pricing analysis. According to Fama [13,14], the essence of the EMH indicated asset prices at any time fully reflect all available information in markets. Thus market information is not helpful in providing any abnormal returns. According to the law of iterated expectations [15], if given only limited historical price (information), the changes in prices are unforecastable. To be more specific, a random walk (RW) is well represented by the weak-form EMH. However, the independent and identically distributed (*iid*) RW is too restrictive for most financial markets. Thus, the specification of RW played an important role in the decision making of either to support or oppose the weak-form EMH. According to [15], most of the global financial markets

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can be characterized by less restrictive non-independent and identically distributed (*niid*) RW with heteroscedastic price increments. Hence, a more general martingale process is used to denote both the *iid* RW and *niid* RW (martingale process) in this study. Once a spot price is proven to be martingale, then the return is unpredictable which strongly implied the presence of weak-form EMH. However, the higher moment of the increments is not necessary an independent process. The importance of energy market efficiency can also be viewed from the perspective of mean reversion analysis. For instance, mean reverting energy prices are expected to return to their trend paths over time which indicates a predictability component according to their historical behaviors. On the other hand, for non-reverting *iid* RW, energy prices are normally unanticipated over time and most probably pose a non-stationary market volatility with unbounded values.

There are ample studies documenting the implementation of the *iid* RW test to imply the presence of weak-form EMH in the energy markets. Serletis and Rangel-Ruiz [16] reported that the daily WTI price from 1991 to 2001 is an *iid* RW. Coimbra and Esteves [17] tested the Brent crude oil spot and future prices and indicated the null hypothesis of *iid* RW could not be rejected. Hutchison [18] is not able to reject the *iid* RW in total energy production in Europe and the UK over the quarterly data from 1960 to 1987. Based on the monthly crude oil and refined petroleum products in the United States, Kaufmann and Laskowski [19] reported the presence of *iid* RW. Due to the high volatility and high intensity jumps [7], many energy markets experienced structural changes which might have altered the nature of market efficiency tests. This is because under the structural change the conventional unit root augmented Dickey Fuller (ADF) and Philips and Perron (PP) tests suffered from loss of power in the statistical inferences. After the inclusion of one or multiple structural breaks in the energy markets, some researchers [20–22] reported contrary results against the *iid* RW compared to the aforementioned studies. To the author's best knowledge, most of the energy market EMH tests under the structural change are based on weekly, monthly, quarterly or annually data. Therefore it is worth running the daily data for a martingale hypothesis test over long spanning data and evaluating how the energy markets' efficiency evolved over the selected time periods.

The purpose of this study is to extend the examination of martingale hypothesis of crude oil and gasoline spot prices under the consideration of structural break. In summary, the objective of this study is threefold: First, long spanning daily data over 24 years (1986–2009) with 3 sub-periods are used to study how the weak-form efficiency of the energy markets evolved over the these periods. The sub-periods are referred to as Period I (regulation period before NAFTA and the energy hike due to Iraqi invasion to Kuwait), Period II (deregulation period after NAFTA) and Period III (high volatility and energy crisis). Two structural break tests are performed to each of the sub-periods in order to avoid the parameter instability during the estimation and statistical inference. Second, parametric (Lo and MacKinlay,[1] [23]) and non-parametric [24] variance ratio (VR) tests are conducted to analyze the variance linearity, autocorrelation and finally the martingale hypothesis. Overall, five test statistics (two from LOMAC and three from Wright) are used to evaluate the aforementioned analysis. Finally, based on the previous individual VR empirical results, multiple VR tests [25] are conducted to overcome the over rejection and size distortion issue in the individual tests.

The rest of the article is organized as follows: Section 2 provides the data description; Section 3 describes the VR tests; Section 4 discusses the empirical results and finally, Section 5 concludes the findings and implications of this study.

2. Data source

According to the Energy Information Administration (http://www.eia.doe.gov), the spot price is defined as the price for a one-time open market transaction for immediate delivery of a specific quantity of a product at a specific location where the commodity is purchased "on the spot" at current market rates. Therefore, the fluctuations of the spot prices provide demand and supply information of a particular energy resource across the globe. This study has selected two important energy resources such as the daily spot prices of West Texas Intermediate (WTI) Cushing and New York Harbor (NYH) conventional gasoline from 3rd January 1986 to 30th November 2009 and 1st June 1986 to 30th November 2009 respectively. The data are obtained from Energy Information Administration, illustrated in Fig. 1.

In order to examine the time evolving martingale hypothesis, we have subdivided the data into three sub-periods. For WTI and NYH (in terms of years), Period I started from 1986 to 1993, Period II from 1994 to 2001 and finally Period III from 2002 to 2009. The associated number of observations for each period for WTI are 2039, 1992 and 2003 while 1936, 2003 and 2017 for NYH. In other words, each sub-period was 8 years long with a total of 6034 and 5956 observations for WTI and NYH respectively. The data division is selected in such a way that each of the sub-periods provide some important events such as new policy regulation (NAFTA in 1993 to improve North American energy industry efficiency), geopolitical events (e.g. Venezuela and United States), Iraqi invasion of Kuwait (2nd August 1990), OPEC production (crude oil price has been raised to approximately USD36 per barrel in December 2000 when OPEC decided to curtail crude oil production by 4.2 million barrels daily), war (price slumped to around USD18 and USD25 per barrel in December 2001 and April 2003 during the US invasion of Iraq), high demand from the global markets (e.g. from giant emerging countries such as Republic of China and India after 2000). Therefore Period I is initiated before the NAFTA and the Iraqi invasion while Period II is after the NAFTA (deregulated period) which ended in 2001. Finally, Period III is selected based on Askari and Krichene [7] who claimed that during 2002–2006, the oil price dynamics are characterized by high volatility and strong upward drift resulting from rigid crude oil supply and expanding by world demands for crude oil. For this period, we have extended the period from 2002 to

[1] LOMAC hereafter.