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Market efficiency of oil spot and futures: A mean-variance and stochastic dominance approach

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ABSTRACT

This paper examines the market efficiency of oil spot and futures prices by using both mean-variance (MV) and stochastic dominance (SD) approaches. Based on the West Texas Intermediate crude oil data for the sample period 1989–2008, we find no evidence of any MV and SD relationships between oil spot and futures indices. This infers that there is no arbitrage opportunity between these two markets, spot and futures do not dominate one another, investors are indifferent to investing spot or futures, and the spot and futures oil markets are efficient and rational. The empirical findings are robust to each sub-period before and after the crises for different crises, and also to portfolio diversification.

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1. Introduction

Crude oil is an important commodity for the world economy. With the increasing fluctuations and tension of crude oil prices, oil futures have become one of the most popular derivatives to hedge the risk of oil price hikes or crashes. Spot and futures prices of oil have been investigated over an extended period. Substantial research has been undertaken to analyse the relationship between spot and futures prices, and their associated returns. The efficient market hypothesis is crucial for understanding optimal decision-making with regard to hedging and speculation. It is also important for making financial decisions about the optimal allocation of portfolios of assets with regard to their multivariate returns and associated risks.

Research on the relationships between spot and futures prices of petroleum products has examined issues such as market efficiency and price discovery. Bopp and Sitzer (1987) find that futures prices have a significant positive contribution to past price changes, even when crude oil prices, inventory levels, weather, and other important variables are accounted for. Serletis and Banack (1990) use daily data for spot, two-month futures crude oil prices, and prices of gasoline and heating oil traded on the New York Mercantile Exchange (NYMEX), to test market efficiency, and find evidence in support of the market efficiency hypothesis. In addition, Crowder and Hamid (1993) use cointegration analysis to test the efficiency hypothesis and the arbitrage condition for crude oil futures. Their results support the simple efficiency hypothesis that the expected returns from futures speculation in the oil futures market are zero.

Studies conducted for different time periods also provide useful insights. Between 1990 and 2000, Taback (2003) tests whether Brent spot and futures prices contain a unit root, and finds that both spot prices and futures prices are non-stationary. During the period 1989–2003, Coimbra and Esteves (2004) test the stationarity of Brent crude oil spot and futures prices which omit the impact of the Gulf war from January 1992 to December 2003. For both of these time periods, the null hypothesis of a unit root in crude oil prices cannot be rejected.

Recently, Maslyuk and Smyth (2008) use LM unit root tests with one and two structural breaks to show that oil spot and futures markets are efficient in the weak form. Their result suggests that future spot and futures prices cannot be predicted on the basis of previous prices.

Examining the price discovery process for the crude oil market using monthly data, Quan (1992) finds that the futures price does not play an important role in this process. Using daily data from NYMEX closing futures prices, Schwartz and Szakmary (1994) find that futures prices strongly dominate in the price discovery process relative to deliverable

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spots in all three petroleum markets. In addition, applying cointegration tests in a series of oil markets with pairwise comparisons on post-1990 data, Gulen (1999) concludes that oil markets have grown more unified during the period of 1994–1996 as compared with 1991–1994.

Postali and Picchetti (2006) apply unit root tests to examine international oil prices. They find that the traditional unit root tests reject the unit root null hypothesis for the entire sample of more than one century of annual data. Silvapulle and Moosa (1999) examine the daily spot and futures prices of West Texas Intermediate (WTI) crude by using both linear and non-linear causality testing. They find that linear causality testing reveals that futures prices lead spot prices, whereas non-linear causality testing reveals a bi-directional effect. Bekiros and Diks (2008) test the existence of linear and non-linear causal lead–lag relationships between spot and futures prices of WTI crude oil. They discover strong bi-directional Granger causality between spot and futures prices, and that the pattern of leads and lags changes over time.

Lin and Tamvakis (2001) investigate information transmissions between the NYMEX and London's International Petroleum Exchange, and find that NYMEX is a true leader in the crude oil market. Investigating information transmissions among NYMEX WTI crude prices, NYMEX gasoline prices, NYMEX heating oil prices, and among international gasoline spot markets, including the Rotterdam and Singapore markets, Hammoudeh et al. (2003) conclude that the NYMEX gasoline market is the true leader. In addition, Hammoudeh and Li (2004) show that the NYMEX gasoline price is the gasoline leader in both pre- and post-Asian crisis periods.

Empirical studies indicate that commodity prices can be extremely volatile at times, and sudden changes in volatility are quite common in commodity markets. For example, using an iterative cumulative sum-of-squares approach, Wilson et al. (1996) document sudden changes in the unconditional variance in daily returns on one-month through six-month oil futures and relate these changes to exogenous shocks, such as unusual weather, political conflicts and changes in OPEC oil policies. Fong and See (2002) conclude that regime switching models provide a useful framework for studying factors behind the evolution of volatility and short-term volatility forecasts. In addition, Fong and See (2003) show that the regime switching model outperforms the standard GARCH model on all commonly used evaluation criteria for short-term volatility forecasts.

In this paper, we re-examine the issue of market efficiency by applying the mean-variance (MV) and stochastic dominance (SD) approaches. We first apply the MV criterion and CAPM statistics to analyse the oil spot and futures markets. These techniques have been used in most of the existing literature. Limitations of these approaches are that they are derived under the assumptions of a von Neumann and Morgenstern (1944) quadratic utility function and returns being normally distributed (Feldstein, 1969; Hanoch and Levy, 1969). Thus, the reliability of performance comparisons using the MV criterion and CAPM analysis depends on the degree of non-normality of the returns data and the nature of the (non-quadratic) utility functions (Beedles, 1979; Schwert, 1990; Fung and Hsieh, 1999).

In order to circumvent these limitations, we adopt the SD approach to compare the performance of different prospects. It endorses the minimum assumptions on investors' utility functions. The advantage of SD analysis over parametric tests becomes apparent when the asset returns distributions are non-normal. As the SD approach does not require any assumption about the nature of the distributions, it can be used for any type of distribution. In addition, SD rules offer superior criteria on prospects investment decisions since SD incorporates information on the entire returns distribution, rather than just the first two moments, as are used in the MV and CAPM methodologies. The SD approach has been regarded as one of the most useful tools to rank investment prospects (see, for example, Levy, 1992) as the ranking of the assets has been shown to be equivalent to utility maximization for the preferences of risk averters and risk seekers (Tesfatsion, 1976; Stoyan, 1983; Li and Wong, 1999).

Consider a utility-maximizing investor who holds a portfolio of two assets, namely oil spot and oil futures. The objective is to rank preferences of these two assets to maximize expected wealth and/or expected utility. In this paper, we use the SD test proposed by Linton et al. (hereafter LMW, 2005) to investigate the characteristics of the entire distributions of oil futures and spot returns, rather than considering only the mean and standard deviation, as are used in much of the existing literature.

This paper contributes to the energy economics literature in several ways. This is the first paper that discusses oil prices from the investors' perspective using the MV and SD approaches. Second, a more robust decision tool is used for examining investment decisions under uncertainty to the oil spot and futures markets, in particular, the WTI crude oil market. Third, greater information and inference on investors' behaviour can be made, including the identification of any arbitrage opportunity in these markets, tests of market efficiency and market rationality in these markets, and an examination of the preferences of risk averters in these markets. Finally, we examine the impacts of OPEC's decision on the reduction of production capacity in 1999, the effects of the 2003 Iraq War on these markets, and diversification effects on these markets.

2. Data and methodology

We examine the efficiency of the spot–futures market by investigating the SD relationship between oil spot and its futures for the period January 1, 1989 to June 30, 2008. As it is well known (see, for example, Ripple and Moosa (2005, 2007) and Serletis (1992)) that different maturities have an impact on market investment, hedging, efficiency and predictability, we will analyse the spot–future relationship for different maturities. We collect the WTI crude spot prices together with its futures at maturities of 1, 2, 3 and 4 months from the Energy Information Administration, and analyse their relationships to check the effects of different maturities.

As is standard, the daily log returns, $R_{i,t}$, for the oil spot and futures prices are defined as $R_{i,t} = \ln(P_{i,t}/P_{i,t-1})$, where $P_{i,t}$ is the daily price at day t for asset i, with $i = S$ (spot) and F (futures), respectively. We further examine the effects of two major oil crises (OPEC's decision on the reduction of capacity in 1999 and the 2003 Iraq War) by examining two pairs of sub-periods. The first pair of sub-periods is the pre-OPEC sub-period (pre-OPEC) and the sub-period thereafter (OPEC), using October 29, 1999 as a cut-off point, while the second pair of sub-periods is the pre-Iraq War sub-period (pre-Iraq War) and the sub-period thereafter (Iraq War), using March 20, 2003 as the cut-off point.[1] In order to test this claim formally, we further analyse their relationship by the MV criterion, CAPM statistics, and the SD approach. For computing the CAPM statistics, we use the 3-month U.S. T-bill rate and the Morgan Stanley Capital International index (MSCI) to approximate the risk-free rate and the global market index, respectively.

2.1. Mean-variance criterion and CAPM statistics

For comparative purposes, we first apply the MV and CAPM statistics to analyse the data. The MV model developed by Markowitz (1952) and Tobin (1958), and the CAPM statistics developed by Sharpe (1964), Treynor (1965) and Jensen (1969), are commonly used to compare investment prospects.[2] For any two investment prospects, with variables of returns Y_i and Y_j, means μ_i and μ_j , and

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[1] We have examined other crises. Their effects on oil are similar to OPEC's decision and the 2003 Iraq War, but the magnitudes of their effects are less significant. Since OPEC's decision and the 2003 Iraq War are more strongly related to oil markets, the effects of only these crises are analysed in this paper.

[2] Recently Leung and Wong (2008) have developed a multivariate Sharpe ratio statistic to test the hypothesis of the equality of multiple Sharpe ratios, whereas Bai et al. (2009a,b) have developed new bootstrap-corrected estimators of the optimal returns for the Markowitz mean-variance optimization.

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