Energy Economics 30 (2008) 2673–2685

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

The relationship between crude oil spot and futures prices: Cointegration, linear and nonlinear causality

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ARTICLE INFO

Article history:
Received 11 December 2007
Received in revised form 16 March 2008
Accepted 16 March 2008
Available online 27 March 2008

JEL classification:
C14
C51
Q40

Keywords:
Nonparametric nonlinear causality
Oil Futures Market
Cointegration
GARCH-BEKK filtering

ABSTRACT

The present study investigates the linear and nonlinear causal linkages between daily spot and futures prices for maturities of one, two, three and four months of West Texas Intermediate (WTI) crude oil. The data cover two periods October 1991–October 1999 and November 1999–October 2007, with the latter being significantly more turbulent. Apart from the conventional linear Granger test we apply a new nonparametric test for nonlinear causality by Diks and Panchenko after controlling for cointegration. In addition to the traditional pairwise analysis, we test for causality while correcting for the effects of the other variables. To check if any of the observed causality is strictly nonlinear in nature, we also examine the nonlinear causal relationships of VECM filtered residuals. Finally, we investigate the hypothesis of nonlinear non-causality after controlling for conditional heteroskedasticity in the data using a GARCH-BEKK model. Whilst the linear causal relationships disappear after VECM cointegration filtering, nonlinear causal linkages in some cases persist even after GARCH filtering in both periods. This indicates that spot and futures returns may exhibit asymmetric GARCH effects and/or statistically significant higher order conditional moments. Moreover, the results imply that if nonlinear effects are accounted for, neither market leads or lags the other consistently, videlicet the pattern of leads and lags changes over time.

1. Introduction

The role of futures markets in providing an efficient price discovery mechanism has been an area of extensive empirical research. Several studies have dealt with the lead–lag relationships between spot and

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doi:10.1016/j.eneco.2008.03.006

futures prices of commodities with the objective of investigating the issue of market efficiency. Garbade and Silber (1983) first presented a model to examine the price discovery role of futures prices and the effect of arbitrage on price changes in spot and futures markets of commodities. The Garbade–Silber model was applied to the feeder cattle market by Oellermann et al. (1989) and to the live hog commodity market by Schroeder and Goodwin (1991), while a similar study by Silvapulle and Moosa (1999) examined the oil market. Bopp and Sitzer (1987) tested the hypothesis that futures prices are good predictors of spot prices in the heating oil market, while Serletis and Banack (1990), Cologni and Manera (2008) and Chen and Lin (2004) tested for market efficiency using cointegration analysis. Crowder and Hamed (1993) and Sadorsky (2000) also used cointegration to test the simple efficiency hypothesis and the arbitrage condition for crude oil futures. Finally, Schwarz and Szakmary (1994) examined the price discovery process in the markets of crude and heating oil.

The recent empirical evidence on causality is invariably based on the Granger test (Granger, 1969). The conventional approach of testing for Granger causality is to assume a parametric linear, time series model for the conditional mean. Although it requires the linearity assumption this approach is appealing, since the test reduces to determining whether the lags of one variable enter into the equation for another variable. Moreover, tests based on residuals will be sensitive only to causality in the conditional mean while covariables may influence the conditional distribution of the response in nonlinear ways. Baek and Brock (1992) noted that parametric linear Granger causality tests have low power against certain nonlinear alternatives.

Recent work has revealed that nonlinear structure indeed exists in spot and futures returns. These nonlinearities are normally attributed to nonlinear transaction cost functions, the role of noise traders, and to market microstructure effects (Abhyankar, 1996; Chen and Lin, 2004; Silvapulle and Moosa, 1999). In view of this, nonparametric techniques are appealing because they place direct emphasis on prediction without imposing a linear functional form. Various nonparametric causality tests have been proposed in the literature. The test by Hiemstra and Jones (1994), which is a modified version of the Baek and Brock (1992) test, is regarded as a test for a nonlinear dynamic causal relationship between a pair of variables. The Hiemstra and Jones test relaxes Baek and Brock's assumption that the time series to which the test is applied are mutually and individually independent and identically distributed. Instead, it allows each series to display weak (or short-term) temporal dependence. When applied to the residuals of vector autoregressions, the Hiemstra and Jones test is intended to determine whether nonlinear dynamic relations exist between variables by testing whether the past values influence present and future values. However, Diks and Panchenko (2005, 2006) demonstrate that the relationship tested by Hiemstra and Jones test is not generally compatible with Granger causality, leading to the possibility of spurious rejections of the null hypothesis. As an alternative Diks and Panchenko (2006) developed a new test statistic that overcomes these limitations.

Empirically it is important to take into account the possible effects of cointegration on both linear and nonlinear Granger causality tests. Controlling for cointegration is necessary because it affects the specification of the model used for causality testing. If the series are cointegrated, then causality testing should be based on a Vector Error Correction model (VECM) rather than an unrestricted VAR model (Engle and Granger, 1987). When cointegration is not modelled, evidence may vary significantly towards detecting linear and nonlinear causality between the predictor variables. Specifically, the absence of cointegration could mean the violation of the necessary condition for the simple efficiency hypothesis (Dwyer and Wallace, 1992), which implies that the futures price is not an unbiased predictor of the spot price at maturity. This implies an absence of a long-run relationship between spot and futures prices, as it was reported in works of Choudhury (1991), Krehbiel and Adkins (1993), Crowder and Hamed (1993). Alternatively, based on the cost-of-carry relationship, a failure to find cointegration may be attributed to the nonstationarity of the other components of this relationship such as the interest rate or the convenience yield (Moosa and Al-Loughani, 1995; Moosa, 1996).

The aim of the present study is to test for the existence of linear and nonlinear causal lead–lag relationships between spot and futures prices of West Texas Intermediate (WTI) crude oil, which is used as an indicator of world oil prices and is the underlying commodity of New York Mercantile Exchange's (NYMEX) oil futures contracts. We apply a three-step empirical framework for examining dynamic relationships between spot and futures prices. First, we explore nonlinear and linear dynamic linkages applying the nonparametric Diks–Panchenko causality test, and after controlling for cointegration, a