Energy Economics 45 (2014) 1–9

Contents lists available at ScienceDirect

Energy Economics

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

Leverage effect in energy futures

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ARTICLE INFO

Article history:
Received 3 March 2014
Received in revised form 22 May 2014
Accepted 14 June 2014
Available online 25 June 2014

JEL classification:
C10
G10
Q40

Keywords:
Energy commodities
Leverage effect
Volatility
Long-term memory

ABSTRACT

We propose a comprehensive treatment of the leverage effect, i.e. the relationship between returns and volatility of a specific asset, focusing on energy commodities futures, namely Brent and WTI crude oils, natural gas and heating oil. After estimating the volatility process without assuming any specific form of its behavior, we find the volatility to be long-term dependent with the Hurst exponent on a verge of stationarity and non-stationarity. To overcome such complication, we utilize the detrended cross-correlation and the detrending moving-average cross-correlation coefficients and we find the standard leverage effect for both crude oils and heating oil. For natural gas, we find the inverse leverage effect. Additionally, we report that the strength of the leverage effects is scale-dependent. Finally, we also show that none of the effects between returns and volatility is detected as the long-term cross-correlated one. These findings can be further utilized to enhance forecasting models and mainly in the risk management and portfolio diversification.

1. Introduction

The leverage effect is one of the well-established phenomena of the financial economics. Historically, Black (1976) discusses a possible relationship between returns and changes in volatility of stocks. The argumentation is based on changes in earnings, where decreasing expected earnings of the company push the price down and in turn it decreases the market value of the company which drives the leverage (ratio between debt and equity) up. Negative relationship between returns and volatility is thus referred to as 'the leverage effect'. However, in the modern, high-speed, markets where the market prices of assets are driven by many more forces than simple expected earnings, such an explanation of the effect serves as just a little more than an anecdote. The leverage effect can be simply understood as a negative relationship between returns and volatility which are driven by opposite forces. When negative news reaches the market, volatility of the corresponding asset usually increases because of an uncertain future development. Contrarily, the negative news drives the prices down forming a negative return. The leverage effect thus seems a natural connection of the two characteristics (returns and volatility) of the traded assets.

The leverage effect is usually tightly connected, and sometimes even interchanged, with a notion of the asymmetric volatility. The standard asymmetric volatility is characterized by a lower volatility connected to a bull (growing) market and a higher volatility connected to a bear (declining) market. The definition and interconnection between the two effects – the leverage effect and the asymmetric volatility – are thus very close and sometimes hard to distinguish between. Nonetheless, most authors agree on several characteristics of the relationship between returns and volatility — returns and volatility are negatively correlated, the correlation is quite weak yet still persists over quite long time (with slowly decaying cross-correlations), and the causality goes from returns to volatility and not vice versa (Bollerslev et al., 2006; Bouchaud and Potters, 2001; Bouchaud et al., 2001; Pagan, 1996).

Here we analyze the leverage effect in the future contracts of energy commodities, namely WTI and Brent crude oils, natural gas and heating oil. We try to provide a coherent treatment of the leverage effect starting from the long-term memory characteristics of volatility and its potential non-stationarity, then moving to the estimation of the correlation between returns and volatility under borderline (non-)stationary and a typical seasonality of futures contracts, and finally checking the slow decay of the cross-correlation function characteristic for long-range cross-correlated processes. We find that the leverage effect in its purest form (significant negative correlation between returns and volatility) is found for three out of four studied commodities. For the crude oil futures, the level of correlations is comparable to values found for other financial assets whereas the heating oil futures are characterized by a weaker effect. Interestingly, we find that the strength of the leverage effect is scale-dependent, i.e. the correlation coefficients vary across scales, which opens a potential new topic of research.

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http://dx.doi.org/10.1016/j.eneco.2014.06.009
0140-9883/

Additionally, we show that the cross-correlations are not identified as hyperbolically decaying, i.e. there are no long-range cross-correlations between returns and volatility of the studied commodities. An important aspect of our analysis stems in not assuming anything about the relationship between returns and volatility which distinguishes our study from the other studies which are majorly built around assuming some kind of asymmetric volatility model (the leverage effect and asymmetric volatility are assumed ex ante to be frequently found ex post there).

The paper is structured as follows. In Section 2, we provide a literature review of recent studies on the leverage effect and asymmetric volatility on energy markets. Section 3 introduces the most important methodological aspects of our work — volatility estimation, long-term memory and its tests and estimators, estimation of correlations under borderline (non-)stationarity and seasonality, and long-range cross-correlations testing. Section 4 presents the analyzed dataset and results. Section 5 concludes.

2. Literature review

In this section, we review recent literature on the topic of leverage effect and asymmetric volatility in energy commodities in chronological order.

Fan et al. (2008) examine WTI and Brent crude oil prices with various specifications of the generalized autoregressive conditional heteroskedasticity (GARCH) models for purposes of risk management. They find significant two-way spillover effect between both crude oil markets as well as asymmetric leverage effect in the WTI returns but not in the Brent returns. Interestingly, the uncovered leverage effect implies that positive shocks have much higher impact on the future dynamics of the series than the negative ones which is opposite to the leverage effect found in stocks and it can be thus treated as an inverse leverage effect.

Zhang et al. (2008) study an interrelation between the US dollar exchange rates and crude oil prices with a special focus on spillover effects which they separate into three — mean spillover, volatility spillover and risk spillover. Apart from a significant long-term cointegration relationship, the authors find significant volatility asymmetry. In a similar way to the previous reference, they find the inverse leverage effect which they attribute mainly to the non-renewable property of oil and very different roles and behavior of suppliers and demanders of the commodity.

Aloui and Jammazi (2009) examine the relationship between crude oil and stock markets utilizing a two regime Markov switching exponential GARCH model. They show that the volatility clustering and the leverage effect can be significantly reduced by allowing for the regime switching. Transition between regimes is mainly connected to economic recessions together with stock market behavior. Agnolucci (2009) compares predictive powers of GARCH-type and implied volatility models on the WTI future contract. Apart from showing that the GARCH-type models outperform the implied volatility models, the author also finds no leverage effect for the WTI contract. Cheong (2009) then focuses on both WTI and Brent crude oil markets and applies GARCH specification. The author finds that the WTI volatility is more persistent than the one of the Brent crude oil. Even though the leverage effect is found for the Brent market and not for the WTI market, the out-of-sample forecasting exercise provides an evidence that a reduced GARCH model with no asymmetric volatility outperforms the others.

Wei et al. (2010) study both the WTI and Brent futures and compare a wide portfolio of GARCH-type models. Focusing on the performance of 1-day, 5-day and 20-day forecasting, they find that no single model is a clear winner in the horse race of testing. However, the authors favor the non-linear specifications of GARCH which can control for long-term memory as well as asymmetry. Similar to the previous studies, the results on asymmetry are mixed for the two markets. Even though the asymmetry is found for a strong majority of specifications for the Brent market, the WTI shows mixed evidence.

Chang and Su (2010) focus on the relationship between crude oil and biofuels. Specifically, they are interested in the dynamics of volatility (using the exponential GARCH model) conditional on various phases of the market with respect to the crude oil prices. A significant asymmetric volatility reaction is found only for the soybean futures during the high oil prices. Other futures show no significant asymmetry. Du et al. (2011) examine the linkage between the crude oil volatility and agricultural commodity markets using the stochastic volatility approach in the Bayesian framework. The authors show that speculation, scalping and petroleum investors form important aspects of the volatility formation. In the model, they find a weak leverage effect between instantaneous volatility and prices.

Reboredo (2011) inspects the crude oil dependence structure with various copula functions. He shows that the correlation structure is similar during both bear and bull markets and further states that the crude oil market is strongly globalized. For the favored model of the marginals – exponential GARCH – the volatility asymmetry is found for all studied crude oil series. The same methodology is then applied in Reboredo (2012) where the relationship between oil price and exchange rates is examined. In general, the connection between the oil and exchange rate markets is reported to be very weak. The evidence of volatility asymmetry is mixed as well. Wu et al. (2012) propose a copula-based GARCH model and use it to model dependence between crude oil and the US dollar. In their specification, the leverage effect is not significant for either of the studied futures.

Chang (2012) employs a combined regime switching exponential GARCH model with Student-t distributed error terms to model crude oil futures returns. The model is able to capture the main stylized facts of the crude oil futures. Importantly, the model combines both the regime switching and asymmetric volatility to capture nonlinear dependencies between returns, volatility and higher moments. In accordance to other works, no leverage effect is found for the WTI futures.

Ji and Fan (2012) analyze the effect of crude oil volatility spillovers on non-energy commodities. After controlling for exchange rates, the authors utilize a bivariate exponential GARCH model with time-varying correlation structure. They show that the crude oil plays a core role in the commodities structure as its volatility spills over to other, non-energy, markets as well. The strength of these spillovers even increases after the 2008 financial crisis. Volatility asymmetry is studied as a difference in reaction to bad and good news. The authors find the effect to be significant for majority of the studied pairs.

Nomikos and Adriosopoulos (2012) investigate dynamics of eight energy spot markets on NYMEX. The authors combine a mean-reverting and a spike model with GARCH-type time-varying volatility focusing on risk management issues as well as their forecasting performance. The leverage effect is found for WTI, heating oil and heating oil-WTI crack spread, and the inverse leverage effect is uncovered for gasoline, natural gas, propane and gasoline-WTI crack spread.

Copulas are further utilized by Tong et al. (2013) who study tail dependence between crude oil and refined petroleum markets. Positive dependence is found in both tails so that the markets tend to move together in both bear and bull periods. Asymmetry in tail dependence is found between crude and heating oils, and between crude oil and jet fuel. Interestingly, the upper tail dependence is stronger than in the lower tail for the pre-crisis period. The authors report that the leverage effect, which is found in its standard form, is much stronger for the post-crisis period.

Salisu and Fasanya (2013) study the WTI and Brent crude oil with respect to the structural breaks while controlling for potential volatility asymmetry. Persistence as well as asymmetry of volatility is reported even after controlling for two structural breaks (Iraqi/Kuwait conflict