Time-Varying Jump Intensities and the Interconnectedness of the North American Crude Oil Complex

Neil A. Wilmot,
University of Minnesota Duluth, 218-726-7439, nwilmot@d.umn.edu

Overview

Since the turn of the millennium, energy markets have experienced a number of shocks, particularly on the supply side. The rise of unconventional methods of production in the United States and the changing role of OPEC have impacted energy commodity markets. The financialization of commodity markets also played a role in the volatility observed in energy markets. The commingling of such events, over the last 15 years, could have impacts on the interconnectedness of energy commodity markets. The hypothesis pertaining to the interconnectedness of energy commodity markets dates to the early work of Adelman (1992), and continues today with the investigation of a 'global pool' hypotheses in oil markets [Wilmot, 2013; Dar 2018], typically with a focus on the univariate or bilateral properties of the commodities price series.

Yet, a particularly salient feature of many commodity markets is the unexpectedly rapid changes that result from the arrival of new information. The discontinuous arrival of information necessitates a stochastic process that incorporates this feature, and as such jump processes have become an important tool in the analysis of energy markets. Recent research has established the relevance of discontinuities for modeling oil prices, and recognized that the arrival of new information can lead to "jumps" [Askari and Krichene, 2008; Lee et al, 2010; Mason and Wilmot, 2014; Postali and Picchetti, 2006; Wilmot and Mason, 2013].

In general, the adoption of a stochastic process which incorporates the discontinuous arrival of information has allowed for multiple jumps to occur in a period, however the jump intensity is assumed to be constant over time. This latter feature is of particular importance for energy markets as they are frequently hit with unexpected news. Examples include natural disasters (hurricanes, earthquakes), geopolitical developments (nationalization, strikes) strategic actions (OPEC), and other unforeseen events (spills, pipeline disruptions). These sorts of effects can lead to periods of unexpectedly large changes in energy futures prices, either upwards or downwards. Chan and Maheu (2002) developed a conditional jump model (*ARJI*), with a time conditional jump intensity, which is modelled as an autoregressive moving average (*ARMA*) form. The jump model is coupled with a generalized autoregressive conditional heteroscedasticity (GARCH) specification of volatility. The results indicate significant evidence of time variation in the conditional jump intensity. Recently, Wilmot and Mason (2019) have applied the model to three energy commodity futures prices (crude oil, natural gas, coal). Based on daily futures price returns, the results demonstrate the importance of incorporating time-varying jump intensities in energy markets.

Herein, the autoregressive conditional jump intensity model (*ARJI*) is adopted, with an emphasis on the time-varying jump intensity, for use in examining the interconnectedness across tiers of the North American crude oil market. As Fatouh (2011) notes, the pricing formulae used in oil markets centre on key 'physical' *benchmarks* such as West Texas Intermediate (WTI). If jumps are important at the *benchmark* level, what role have they to play in the *secondary* (Louisianna Light, Mars, Mex. Maya, Louisianna Heavy, *etc*.) markets? According to Fattouh (2011) as the market becomes thinner – lower volume of production – the pricing process becomes more difficult. Furthermore, the author notes that markets with low volumes of production influence the price for markets with higher volumes. Do discontinuities in one crude oil market influence arrival of discontinuities in another? The potential presence of bilateral relationships across an array of crude oil prices, from different regions of North America, is investigated. Finally, the period of study is dissected into sub-periods (pre- and post 2008) due to what would be described as a structural break, with one possible cause due to the rapid increase shale oil production [Brown and Yucel, 2013; Killian, 2017]

Methods

Using daily data on crude oil (spot) prices, from *secondary* North American markets and the WTI *benchmark* series. A series of time-varying jump intensity values, based on the *ARJI* model of Chan and Maheu (2002) are obtained.

The *ARJI* model should be useful in capturing time series dynamics of the conditional jump intensity. To investigate the existence of spillovers multivariate GARCH methods are employed. The model allows for an examination of linkages across and within the crude oil tiers.

Results

Prior to estimation of the jump diffusion process, conventional tests were utilized to determine the existence of a unit root. The ADF, Phillips – Perron, as well as the modified ADF test indicate that price (levels) appear to be nonstationarity while (log) returns (calculated as 1st – differences) are stationary over the period of study. The role of discontinuities (jumps) for the idiosyncratic (or *secondary*) crude series is noted, which aligns with previous results for the benchmark series (Wilmot and Mason, 2013). Univarite GARCH results demonstrate the time-varying properties of the autroregressive jump intensity terms, across the various blends. Preliminary results from the multivariate GARCH analysis suggests evidence of a bi-directional relationship. The finding of the CCC model indicate positive and statistically significant correlation between the secondary crude oils, with a high correlation of 0.91 occuring between blends with differing characterisitics. The BEKK specification supports the bi-directional hypothesis, both between the *benchmark* and *secondary* blends, and across the variaous *secondary* blends. Significance is observed across the 'shock' coefficeints as well as the previous uncertainty in the volatility equations.

Conclusions

Evidence of a bi-directional relationship could have implications for producers, traders, and governments. The result that suggest that *secondary* crudes can impact the *benchmark* could have broad implications, particularly for the dynamics of hedging strategies. The data are generally available starting in 2000, through the end of 2018. The period contains numerous events (Great Recession, Katrina, Shale Revolution) that are likely to produce a structural break. Based on the results of a structural break analysis, sub periods were formulated

References

Adelman, M.A. 1984. International oil agreements. *The Energy Journal*, 5(3), 1–9.

Askari, H., and Krichene, N., 2008. Oil price dynamics (2002–2006). *Energy Economics*. 30, 2134–2153.

Brown, S.P., and Yucel, M.K., 2013. The shale gas and tight oil boom: US states' economic gains and vulnerabilities. *Council on Foreign Relations*.

Chan, W. H., and Maheu, J.M., 2002. Conditional jump dynamics in stock market returns. *Journal of Business and Economic Studies*. 20, 377–389.

Dar, A.B. 2018. The globalization-regionaliation debate in internation crude oil markets: old wine in new bottles. *OPEC Energy Review,* 42(3) 244 – 261

Fattouh, B. 2011. The dynamics of crude oil price differentials. *Energy Economics*, 32, 334–342.

Kilian, L. (2017). The Impact of the Fracking Boom on Arab Oil Producers, *The Energy Journal* 38: 137–160.

Lee, Y. H., Hu, H. and Chiou, J., 2010. Jump dynamics with structural breaks for crude oil prices. *Energy Economics* 32: 343 – 350.

Mason, C.F. and N.A. Wilmot. 2014. Jump Processes in Natural Gas Markets. *Energy Economics*. 46 (Dec): S69 – S79

Postali, F. and Picchetti, P. 2006. Geometric Brownian motion and structural breaks in oil prices: A quantitative analysis, *Energy Economics* 28: 506 – 522.

Wilmot, N.A., 2013, Cointegration in the Oil Market among Regional Blends. *International Journal of Energy Economics and Policy*, 3(4) 424 - 433.

Wilmot, N.A., and Mason, C.F. 2013. Jump processes in the market for crude oil. *The Energy Journal*, 34(1), 33–48.

Wilmot, N.A., and Mason, C.F. 2019. Jumps in energy commodity markets. in *Handbook of Energy Finance: Theory, Practice and Simulations*. Ed. Goutte, S. and Nguyen, K.D. World Scientific *Forthcoming*