Energy Economics 54 (2016) 213–223

Contents lists available at ScienceDirect

Energy Economics

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

An examination of the flow characteristics of crude oil: Evidence from risk-neutral moments

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ARTICLE INFO

Article history:
Received 28 April 2015
Received in revised form 24 July 2015
Accepted 4 December 2015
Available online 15 December 2015

Keywords:
Risk-neutral moments
Crude oil futures
Returns
Volatility

ABSTRACT

This paper examines the information content of risk-neutral moments to explain crude oil futures returns. Implied volatility and higher moments are extracted from observed crude oil option prices using a model-free implied volatility framework and the Black–Scholes model. We find a tenuous and time-varying association between returns and implied volatility and its innovations. Specifically, changes in implied volatility are found to be meaningfully associated with crude returns only over the period spanning the recent financial crisis. The results lead us to conclude that crude oil prices are determined primarily in a flow demand/supply environment. Finally, we document that oil risk is priced into the cross-section of stock returns in the oil and transportation sectors.

1. Introduction

The price of crude oil exhibits sharp spikes rising from shallow valleys that are widely believed to be disruptive to the global economy (e.g., Barsky and Kilian, 2004; Hamilton, 1996; Kilian, 2008a,b; Kilian and Lewis, 2011; Pindyck and Rotemberg, 1984). In a recent and dramatic episode, the price of West Texas Intermediate (WTI) rose from about $25 to over $140 per barrel between January 2007 and July 2008, and subsequently crashed to just 20% of that value by December 2008.[4] Most recently, from late 2014 into 2015, the crude oil price experienced a precipitous drop from its range of $90 to $110 between 2012 and early 2014 to below $50 per barrel. Such spikes are often accompanied by demands for investigations for price-manipulation and/or calls for greater regulation, especially of the derivative markets that allow investors to take large speculative positions in highly leveraged bets. Behind such appeals is the implicit belief that crude oil prices are impacted in a significant manner by factors other than the prevailing market demand and supply conditions.

However, there seems to be very little empirical evidence in support of this belief. A recent article in Forbes states that, "From an academic standpoint, this is simply the market's way of solving the demand and supply equation. Lower oil prices are a consequence of … more supply than demand. It also means that oil producers with higher costs of production than the current price of oil will now be forced to shut down. This will drive down supply, eventually forcing the price to come up to a certain equilibrium."[5] In this context, some recent academic studies characterize the price of crude oil as primarily being determined in a flow-demand/supply environment. For instance, Kilian and Murphy (2014) investigate global crude oil market in the framework of a structural model. The authors provide evidence that fluctuations in the flow demand for oil, rather than speculative trading or supply shocks, were primarily responsible for the price surge between 2003 and mid-2008. Kilian and Vega (2011) find that daily regressions of crude oil and gasoline returns on the surprise components of several U.S. macroeconomic announcements produce insignificant coefficients and low R^2 values. The weak response of returns to economic surprises is interpreted by the authors as being consistent with each (and consequently both) of the following: (a) energy prices are predetermined with respect to domestic macroeconomic aggregates; and (b) crude oil and gasoline prices are determined by flow supply and flow demand. Chatrath et al. (2012) reframe Kilian and Vega's tests by conditioning the responses of crude oil returns to macroeconomic news on the level of inventories. They show that crude oil remains unresponsive to macroeconomic news even during times of extreme inventory build-

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[4] The behavior of sharp peaks/shallow valleys is observed for other global commodities such as wheat, cotton and copper (e.g., Deaton and Laroque, 1992).

[5] How Will The 2014 Drop In Oil Prices Affect The World Economy And Geopolitics? Forbes (published on Jan. 6, 2015) Accessable at http://www.forbes.com/sites/quora/2015/01/06/how-will-the-2014-drop-in-oil-prices-affect-the-world-economy-and-geopolitics/.

http://dx.doi.org/10.1016/j.eneco.2015.12.005
0140-9883/

up (or build-down). Elder et al. (2013) argue that the results reported by Kilian and Vega (2011) and others may be an artifact of a particular identifying restriction commonly found in lower frequency structural vector autoregressive (VAR) models. Using high frequency data they show that oil prices are in fact closely tied with new economic information in ways that appear to be consistent with economic theory.

The purpose of this paper is to examine the relationship between futures (and spot) crude oil returns to the commodity's implied volatility and related higher moments that are obtained from option prices. The analysis is partly motivated by recent research that document the importance of higher-moment risk in the pricing of financial assets, thus implicating market-wide volatility risk as a priced factor in the cross-section of stock returns (see for example, Ang et al., 2006; Adrian and Rosenberg, 2008). Still other studies examine the explanatory power and information content of various volatility estimates, including historical volatility of underlying equity returns, the Black–Scholes (B–S) implied volatility, and more recently, model-free implied volatility. However, the question of how these different volatility estimates affect commodity price movements, which are known to exhibit return characteristics that are different from equity markets (such as mean reversion), is one that seems to have received scant attention in the literature. We believe that an examination of the relationship between crude oil prices and risk-neutral implied volatility represents an important contribution to the literature.

An additional contribution of our study is that it lends itself to further understanding the stock versus flow characterization of crude oil by proposing an alternative framework of tests. In particular, we propose that a pure flow commodity is one where prices are impacted only by immediate net demand, and therefore impervious to speculative activity (e.g., Baumol, 1962; Clower and Bushaw, 1954).[6] The analytical framework proposed in this study is consistent with recent studies such as Kilian and Vega (2011) and Chatrath, et al. (2012), who also deploy spot and futures return sensitivities in their assessment of the crude oil market.[7] While the stock-flow analysis focuses attention on the existence and stability of a set of market-clearing prices in pure stock and flow models, it is worth noting that evaluating return response in the context of traditional asset pricing model and stock-flow analyses may be mutually constitutive, as elements of both may prevail depending on economic circumstances. The current paper assesses whether crude prices respond to changes in market expectations that are embodied by implied moments obtained from option prices. The results from this study carry implications for policy debates on whether oil prices are impacted by factors other than the prevailing demand and supply conditions in the economy.

Our empirical study of the association between crude oil price-dynamics and implied higher moments spans the period 1996 to 2011. Two daily measures of implied volatility are extracted from futures options on crude oil: a model-free estimate that represents the implied volatility for at-the-money, constant-expiry options (henceforth model-free implied volatility); and the standard Black–Scholes model using at-the-money options (henceforth B–S implied volatility).

These measures are employed to answer three questions as they relate to the crude oil market: (i) Does the price of crude oil reflect expected volatility? In addressing this question, we re-examine the assertion in Kilian and Vega (2011), Chatrath et al. (2012) and Kilian and Murphy (2014) that crude oil is primarily a flow commodity. (ii) Is the price sensitivity of crude oil changing over time? It has been argued that commodity markets have experienced a large degree of "financialization" (via index fund investing) in the past decade that may have altered the structure of crude oil price risk premia over time. For instance, researchers note a sharp rise in the correlation among commodities and other asset classes after 2000, adding fuel to the argument that investors are increasingly treating commodities as investment assets (Irwin and Sanders, 2011; Singleton, 2013; Tang and Xiong, 2010).[8] If this is the case, then only more recently in our sample should we expect crude oil prices to more closely reflect market expectations on volatility. To examine this proposition we conduct a year-by-year examination of the empirical relationship between returns and implied volatility during the sample period. And (iii), is oil price risk priced into the returns of stocks in the oil and transportation sectors? At least part of the reason for the intense debate on whether or not crude oil is a pure flow commodity is due to the commodity's influential role in the economy and the potential impact it has on equity prices. Therefore, the third goal of this paper is to examine the influence of oil price and oil volatility risks on a cross-section of stock returns in the oil-sensitive sector of the economy.

The test results are summarized as follows.

1) On the pricing of implied volatility: The regression of crude oil returns, measured using either nearby futures or WTI spot prices, on implied volatility obtains an Adjusted-R^2 that is close to zero. Whereas, the overall regression produces a negative slope coefficient, it exhibits inconsistency (sign instability) when examined over smaller sub-samples. Similar results are obtained when returns are regressed on a measure of implied volatility that is purged of its relationship with realized volatility. The explanatory power of differenced-implied volatility is superior to that of level volatility, and this power improves further when the returns and differenced-implied volatility association is conditioned on risk-neutral skewness and kurtosis. However, additional analysis indicates that any meaningful association between return and even changes to implied volatility is absent for the majority of the investigated sample. Thus, we are unable to strongly support the notion that the crude oil market substantively and consistently "prices" expected volatility, a finding that is in line with a flow-oriented nature of the commodity.
2) On the temporal changes in the return-implied volatility relationship: We provide evidence of a closer association between crude oil returns and implied volatility since the beginning of the recent financial crisis. Returns are negatively related to implied volatility, especially the changes in implied volatility, between 2008 and 2011. Most strikingly, whereas the Adjusted-R^2 from the regression of returns to innovations in implied volatility is near-zero for each of the sampled years between 1996 and 2007, it rises to between 0.19 and 0.33 over the period 2008–2011. The substantial improvement in the relationship may be attributed to the growing financialization of the commodity during this period. However, it is also likely that the observed phenomenon of strengthening relationships between implied volatility and returns over this period are due to massive cross-currents in the marketplace, wherein prices (volatility) of all economically-sensitive assets fell (rose) together. Importantly, excluding this time period, the results are consistent with the view that crude oil prices are determined in a flow environment.

[6] Regulators and policy makers have different expressed views in this respect. On 20 May 2008, the chief economist at the Commodity Futures Trading Commission (CFTC) insisted at a Senate hearing that speculation was not causing the spike in the price of crude. Instead, he suggested that prices were driven "by powerful economic fundamental forces and the laws of supply and demand." Less than a fortnight later, after further pressure from Congress, the CFTC announced it would consider further oversight of energy futures trading ("Oil Traders Face New Regulation", Bloomberg Businessweek, June 9, 2008). Also, see the public policy debate entailed in Masters (2008).

[7] Still other papers such as Baker (2012), Tang and Xiong (2010) and Hamilton and Wu (2013) take direct aim at explaining oil price spikes using some combination of rising spot prices, increased commodity derivatives trade, and changing risk premia.

[8] A recent J. P. Morgan's report ("Rise of Cross-Asset Correlations", May 2011) indicates that the correlation between U.S. commodities and equities which was −0.05 over 1990–1995, rose to about 0.40 by the end of 2009. The report also indicates a sharp rise in the correlation among other asset classes, and suggested a strong relationship between institutional trading and rising correlations. For instance, it is noted that the correlation between commodity groups themselves rose from around 0.10 between 1990 and 2000 (when commodity ETFs were practically nonexistent) to around 0.35 by 2010, by which time commodity ETF holdings were in the vicinity of $120 billion.