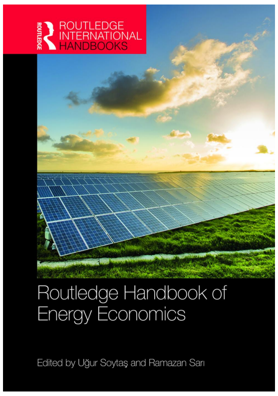

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Uur Soyta, Ramazan Sar

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Nikki Kantelis, Bradley T. Ewing
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Oil spot and futures prices

Nikki Kantelis and Bradley T. Ewing

1 Introduction

This chapter provides an overview of oil spot and futures prices. We begin with an historical overview of how these prices developed and identify some of the major changes that occurred over time. Given the importance of oil in the domestic and global economies, a great deal of research has been conducted to understand the time series dynamics of oil spot and futures prices, particularly in real terms. We provide an empirical analysis that summarizes and confirms the major findings in the literature to date and we add some insight that ties these results to real-world observations. Along the way, we note the areas that have been the topic of recent research. We also extend the line of inquiry and add some new empirical evidence on the interaction between oil prices and upstream exploration and development activity. Finally, we close this chapter with a few concluding remarks that describe today's markets in general terms.

2 History and development of oil spot and futures prices

The first oil discovery in Pennsylvania, and later discoveries in Texas, Oklahoma, and California, were characterized by small wells, most producing less than 100 barrels per day. The Spindletop discovery near Beaumont, Texas, in 1901 was the first gigantic oil gusher and represented a significant portion of US domestic production at the time. Significant further production resulted in excess capacity both in the United States and following other discoveries in Russia, the Middle East and Indonesia. By 1928, the crude oil glut in the market continued to depress crude oil prices.

In 1928, the leaders of the largest oil companies in the world met in Scotland and agreed not to compete against one another outside the United States as a means to helping each other sustain profitability. The mechanism was known as the "as-is" agreement, since each company's relative market share outside the United States was kept at the 1928 ratios. Independent oil companies were not parties to the "as-is" arrangement and ultimately undercut the "as-is" member's price in order to grow their own market share.

Most of the crude oil produced outside the United States was priced on the basis of concession agreements. Concession agreements were specific agreements between an international oil company (IOC) and the host government (national oil company, or NOC) where the crude oil was produced. These agreements were typically negotiated on a 50/50 profit sharing scheme wherein the IOC set the posted price for the crude oil, taking into account a transportation cost from the producing country to the United States.

The concession agreement regime was not acceptable to NOCs generally, since the IOCs set the price, the profit sharing splits, the term of the agreements, and so forth. Problems developed in the concession agreement methodology as early as the 1950s with the nationalization of the Iranian oil industry. In response to this action, the British government imposed an embargo on Iranian oil, bringing Iran close to bankruptcy when refineries and other oil market participants were prevented from purchasing Iranian oil.

During the period (1930s until 1970), the Texas Railroad Commission (TRC) effectively controlled world oil prices as a result of its ability (by government mandate) to impose production restrictions or rations on oil production. However, once US domestic oil production reached its peak in 1970, the only spare production capacity resided in the hands of OPEC (Organization for Petroleum Exporting Countries), who were able to exert more control over oil production and prices. By early 1971, most of the oil companies were forced to negotiate a new round of concession agreements with OPEC, resulting in more attractive terms for the producing nations than the earlier rounds.

Thereafter, and up until the 1980s, most crude oil transacted was traded on a term supply, fixed price basis. Buyers and sellers typically agreed to specific quantities of crude oil at specified fixed prices for scheduled intervals in the future, usually a year in duration. By contrast, a small amount of crude oil was exchanged via spot supply contracts. These arrangements were mostly undertaken for "close-in" operational reasons. Barrels contracted in the spot market provided a good measure of the most current market supply and demand conditions since they represented barrels contracted for immediate or "prompt" delivery.

In the mid-1980s, the introduction of the New York Mercantile Exchange (NYMEX) futures contract for West Texas Intermediate (WTI – Cushing, OK delivery) and the subsequent launch of the Brent Futures (North Sea crude oil) on the Intercontinental Exchange (ICE) provided a new transparent price discovery mechanism. These futures contacts (along with the subsequent introduction of the Oman crude oil futures contract on the Dubai Mercantile Exchange founded in 2007) have evolved into benchmark prices, against which the vast majority of crude oil is currently traded. Benchmark prices are an important component of crude oil formula pricing mechanism, by which most crude oil is currently priced. For example, a cargo of West African crude oil may be priced as ICE Brent futures plus or minus a differential to account for differences in quality, location or timing (commonly referred to as basis). Similarly, US domestic crude oil prices are priced as a differential versus the NYMEX WTI futures contract price. US domestic posted prices (price bulletins published by refinery supply interests) are adjusted daily to reflected daily fluctuations in NYMEX WTI settlement prices. Trade journals such as Argus and Platts are also used as benchmarks in crude oil pricing.

Benchmarks have also emerged for finished petroleum products such as gasoline, heating oil, and gas oil with the introduction of a series of futures contracts for refined products on the various exchanges. Additionally, the trade journals previously mentioned also provide price data for various spot refined products in various trading regions, including the US Gulf Coast, northwest Europe, Mediterranean, and Singapore (to name just a few).

3 Empirical analysis of oil spot and futures prices

According to Hamilton (2009), oil spot and futures prices are linked for several reasons. In fact, Hamilton describes three economic restrictions on the time path of oil prices: storage arbitrage, futures contracts, and oil as a depletable resource. The latter of which is further complicated by heterogeneous geophysical properties and a wide variance in the geographic distribution of reservoirs, basins, and plays. Briefly, storage arbitrage dictates that in equilibrium the expectation of price made in period t for period $(t + 1)$ would equal the price in period t plus the net cost of carry. Future contracts may link the current spot price in t with the futures price in $(t + 1)$ given the latter must equal the expectation of price made in period t for period $(t + 1)$ plus a risk premium. Finally, oil is "mined" or extracted as opposed to manufactured or produced (in the traditional sense), and once "burned" is not reusable. Accordingly, price may exceed marginal cost even if the oil market is perfectly competitive. Hotelling's principle thus describes this scarcity rent as having important implications for commodity speculators.

For purposes of this analysis, we utilize a data set comprised of weekly observations of real West Texas Intermediate (WTI) and UK Brent spot prices and a set of four WTI futures prices. The sample period begins August 1987 and ends February 2018 for a total of 367 observations. We follow the convention used by the Energy Information Administration and compute real petroleum prices such that the latest (most current) observation is the base period and real prices are in current dollars. This convention facilitates the direct comparison of prices across time.

Petroleum prices, rig count, and production data are obtained from the Energy Information Administration (www.eia.gov). CPI data are from the Federal Reserve Economic Database (FRED; http://fred.stlouis.org) maintained at the St. Louis Federal Reserve Bank. According to the EIA, an oil futures price is the price quoted for delivery of a predetermined quantity of crude oil at a specified time and place in the future. Contract 1 is the futures contract that expires on the third business day prior to the 25th calendar day of the month preceding the delivery month. Adjustments are made for contracts that expire on non-business days. Once a contract has expired, Contract 1 for the remainder of the month is the second following month. Contract 2–4 are for delivery months following Contract 1 (www.eia.gov). We let RSW and RSB denote real spot price of WTI and Brent. Futures prices corresponding to Contract 1–4 are denoted RF1, RF2, RF3, and RF4, respectively. Oil rig count is denoted RIGS and is the number of oil producing rigs in the US (onshore and offshore). Total US oil production is denoted PROD.

A first step in traditional empirical analysis of time series, and commodity prices in particular, is to determine whether or not the series is stationary. The importance of this step cannot be overstated as econometric modeling may otherwise be subject to spurious regression problem (Stock and Watson 2007). In order to evaluate the univariate properties of RSW, RSB, RF1, RF2, RF3, and RF4 we employed several popular unit root tests including augmented Dickey-Fuller (Dickey and Fuller 1979, 1981), Dickey-Fuller GLS/ERS (Elliott et al. 1996), Phillips and Perron (1988), and the KPSS (1992). Since the tests are well known, we do not provide the empirical specifications here and instead simply report our conclusion. Our results are consistent with the vast literature on time series properties of real oil prices and indicate that both real spot and real futures prices are non-stationary and integrated of order one. However, we do not rule out time-varying volatility, the possibility of breaks in the data series, nor the possibility of periodically collapsing bubbles, which is the subject of more recent studies (Ewing and Malik 2017; Gronwald 2016).

Figure 21.1 plots real spot prices of oil over time. As expected, RSW and RSB generally follow similar patterns with some notable exceptions such as in 2011–2014 when the disparity was quite wide. Also, to a smaller degree, in periods of heightened volatility such as those experienced in the early 1990s and early 2000s and then again after the price drop in June 2014. Given the finding that these series appear to be non-stationary, we formally test for the property of cointegration. A great deal of prior research has focused on testing for the existence of cointegration among commodity prices as this has implications for econometric model specification and forecasting (Banerjee et al. 1993). The general finding is that oil prices are cointegrated such that

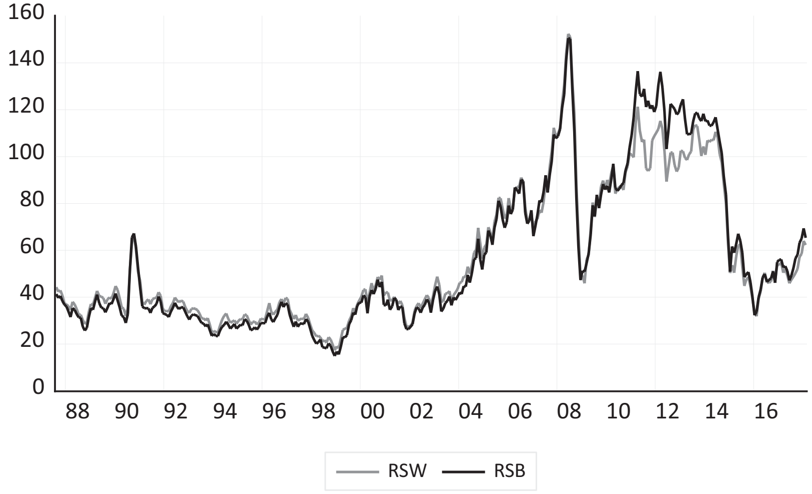

Figure 21.1 Real WTI (RSW) and Brent (RSB) spot prices

perturbations in one or more series die out over time and that the respective series are restricted from drifting "too far" apart from one another over time (Serletis and Banack, 1990). Of course, the notion of how long it takes for the disequilibrium to be erased and just how far is "too far" is still open to debate. Consequently, much research has incorporated error-correction modeling with emphasis on speed-of-adjustment coefficients and determining whether or not one variable "Granger causes" another variable (Bekiros and Diks 2008). Many new studies have incorporated a variety of methods to address these issues and with somewhat mixed results. We utilize the standard Johansen (1991) multivariate (system) method for testing for cointegration and find evidence that spot prices are cointegrated. The Johansen cointegration procedure determines if a long-run relationship exists among a set of time series variables. The vector autoregressive (VAR) model is given by:

$$\Delta X_t = \Gamma_1 X_{t-1} + \ldots + \Gamma_{k-1}\Delta X_{t-k-1} - \Pi X_{t-k} + \varepsilon_t$$

where X is the vector of variables under examination; k denotes the number of lags; ε is a vector of white noise error terms; $\Gamma_1 = -I + \Pi_1 + \ldots + \Pi_i$; and $\Pi = I - \Pi_1 - \ldots - \Pi_k$. The long-run relationship among the variables is contained in the p × p Π matrix. If the Π matrix has rank zero, r = 0, then the variables in X are nonstationary, implying the absence of cointegration. If r < p, then there are r nonzero cointegrating vectors among the variables in X and p – r common stochastic trends. We can factor the Π matrix into $\alpha\beta'$ where ∝ is a p × r matrix of the vector error correction parameters and β represents a p × r matrix of cointegrating vectors. The null hypothesis that the number of cointegrating vectors is r against the alternative r + 1 is examined using the maximum eigenvalue test (λ_{max}). The null hypothesis that the number of cointegrating vectors is less than or equal to r against a general alternative is examined using the trace test (λ_{trace}). We find that there is a cointegrating relationship among RSW and real futures prices. In terms of the latter, when all five series are entered in the system we find evidence of up to four cointegrating vectors which is generally taken to mean that the long run relationship among these variables is particularly stable. Figure 21.2 provides a plot of RSW and the four futures prices. Rather than plotting these variables separately, the series are shown together to emphasize

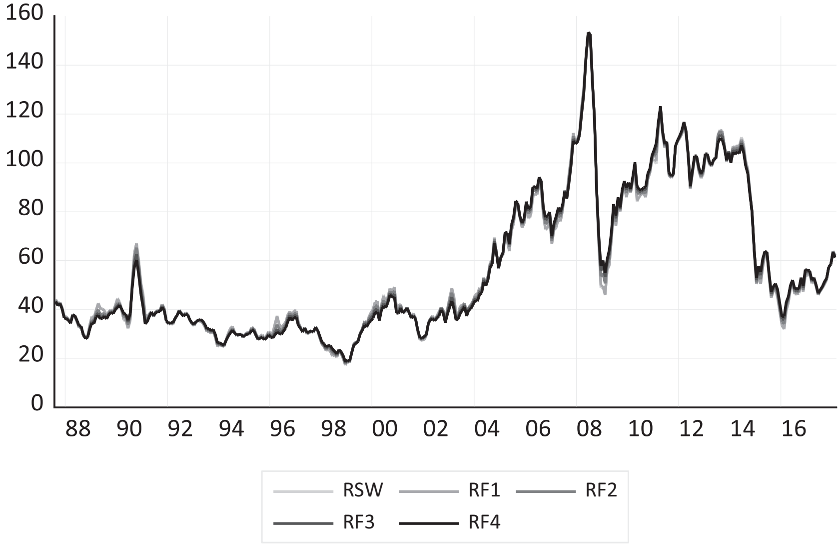

Figure 21.2 Real WTI spot and futures prices

the relative "closeness" of movements over time. In fact, the notion of a stable long-run relationship is strongly evident in the graph, as well. We interpret this finding as being consistent with the notion Hamilton (2009) put forth, namely, that spot prices may help to predict futures prices. As noted above, this allows for and may even encourage the development of commodity futures speculation. In terms of energy policy, the notion of scarcity rent may be used for decisions pertaining to investment tax credits, production incentives, and/or determining appropriate depletion allowances.

4 Oil prices and upstream activity

Following the oil price boom of 2012 to mid-2014 and the interest in unconventional oil exploration and development, there has been interest in studying the relationship between oil prices and upstream activity (Apergis, Ewing and Payne 2017). Recent studies have documented the increases in new well efficiency (Apergis, Ewing and Payne 2016a) and modeled relationships among oil prices, interest rates, production, and even energy ratios such as reserve life (Ewing 2017; Apergis, Ewing and Payne 2016b). Given these findings, we turn our attention to real spot and futures prices and traditional measures of upstream activity, namely, oil rig count and crude oil production.

Figures 21.3 and 21.4 provide plots of RSW and RF4, with values shown on left axis, and either RIGS (Figure 21.3) or PROD (Figure 21.4) shown on the right axis. A casual review indicates that rig count follows real prices generally with a lag. Moreover, drops in rig counts following oil price declines appear greater in magnitude than increases in rig counts following oil price upswings. Clearly, this is consistent with the technical aspects of oil exploration and production and capital requirements associated with drilling. Perhaps what is more interesting is how this relationship may be changing or intensifying in recent years and cycles. Specifically, as new rigs have become more efficient (as well as the introduction of many new and improved production technologies), production has either rebounded more quickly or remained higher

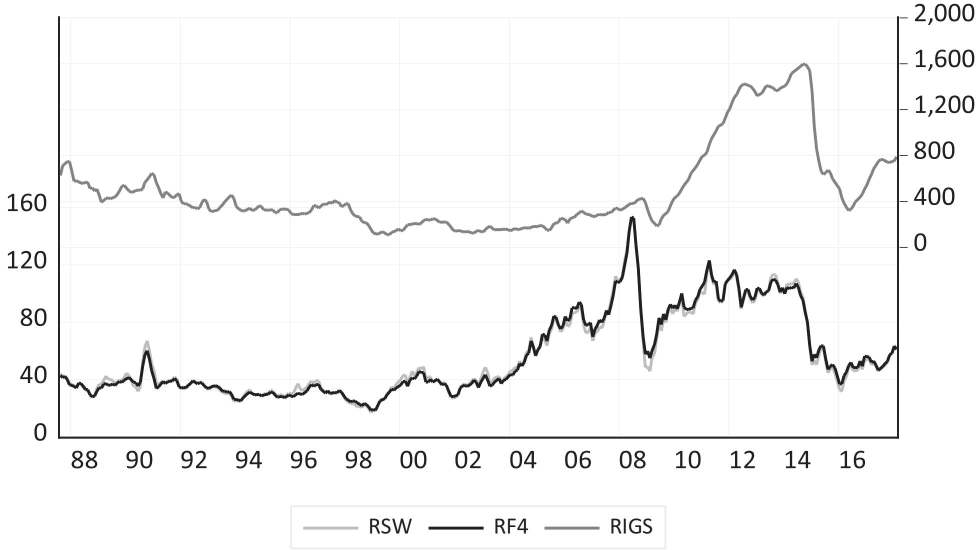

Figure 21.3 Oil rig count, real WTI spot and futures prices

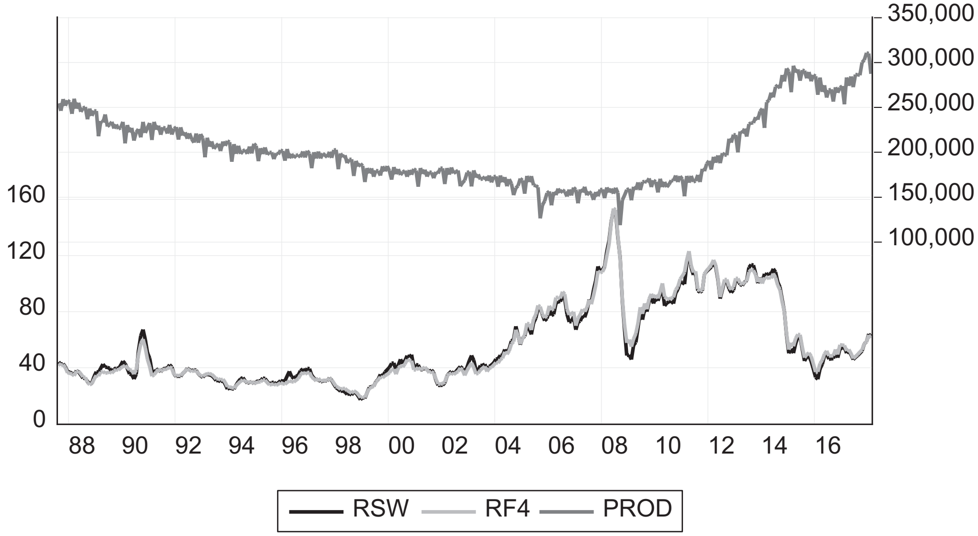

Figure 21.4 Oil production (BBL/month), real WTI spot and futures prices

(relative to the past), even with less price recovery. Some reasons associated with this phenomena are given in Ewing et al. (2015) and include a number of drilling/completion technology trends such as horizontal drilling, slick-water fracking, multiple well pads, and multi-zone completions, to name a few. Here, we repeat our empirical analysis and examine the univariate and multivariate properties concerning RSW, RF4 with RIGS and then with PROD. As before, unit root testing suggest that all series are nonstationary and require first-differencing to render the series stationary. There is some evidence that both rig count and production exhibit more dependency on past observations than prices. However, we proceed to test for long run stable relationship using the cointegration methodology of Johansen. We find strong evidence of a cointegrating relationship among spot, futures, and production but only weak evidence of this type of relationship among spot, futures, and rig count. The findings regarding price and upstream activity represent a relatively new but potentially important direction for future research and inquiry.

5 Concluding remarks

Pricing in today's market is very transparent compared to the past. The next development is likely to be a transparent pricing mechanism in Asia, particularly as the structure of liquefied natural gas (LNG) contracts change and the market develops for US crude and gas exports to that region. Recently, China debuted a crude oil futures contract on the Shanghai Futures Exchange (ShFE) denominated in yuan. The 25 March 2018 launch is viewed as an opportunity for China, the largest energy consuming nation, to have more control over crude oil pricing, especially as it exerts its influence in global trade.

Over time the oil market and the relevant benchmark prices have responded to structural changes in the industry. For example, beginning in early 2011, with increased US domestic crude oil, (via the shale revolution), and lack of adequate infra-structure to get crude oil to refining centers, the (monthly) real Brent/WTI spread widened significantly to a high of $29.97 per barrel by November 2011 (Figure 21.5). Since late 2015, when Congress lifted the 40-year old crude oil export ban, coupled with significant pipeline investment (particularly in the Permian Basin), the Brent/WTI price differential has narrowed. Going forward, the price gap between Brent/WTI will continue to fluctuate. A wider Brent/WTI differential makes US domestic crude oil attractive for export, but a narrowing of the price gap will act as a ceiling on US crude oil exports. Recent improvements to handle larger vessels at the Louisiana Offshore Oil Port (LOOP) and continued pipeline projects are likely to contribute to the continued appeal of domestic crude oil. Given these observations and the summary of price patterns described here, we expect a fruitful avenue of future research will be to explore oil prices with midstream and upstream operations.

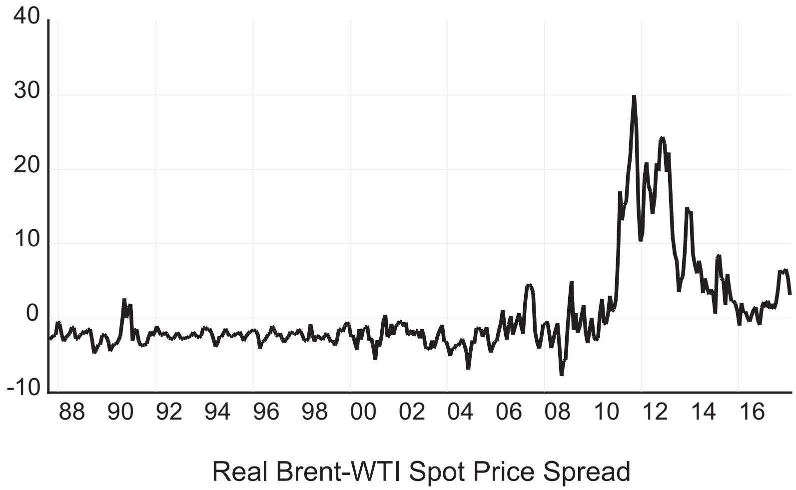

Figure 21.5 Spread between real Brent and real WTI prices (per BBL)

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