Inferring Petroleum-Complex Fundamentals through Price-Relationship Data

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Introduction

This paper will discuss inferring crude-oil-market fundamentals through price-relationship data, largely through the perspective of a commodity futures trader. In doing so, the paper will briefly cover (1) the promise of big data; (2) the reality of data "black holes"; (3) the wealth of futures price data; (4) what futures prices potentially reveal about petroleum-complex fundamentals; and (5) caveats on the use of price data.

The Promise of Big Data

After the 1970s energy crisis, the United States committed to a very "ambitious and comprehensive effort to collect detailed information on the production, processing, distribution and consumption of energy," as described by Kemp (2015). "The result is [that] the market has [very] good real-time data on what is happening to fuel supply and demand in the United States" via the U.S. Energy Information Administration (EIA), observed Kemp (2015). A further consequence is that there is a great deal of promise for the use of "big data" in the U.S. energy markets, whether it is for (1) algorithmic trading, (2) industry cost reduction, or (3) tapping the value of data embedded in the energy industry, as noted by Anderson (2017a).

The Reality of "Black Holes"

Emerging Markets

Even though there are a number of potential applications for big data in the U.S., one should also note the reality of "black holes" in emerging markets and even in some aspects of the petroleum-complex markets in the U.S. As pointed out by Kemp (2015), emerging markets accounted "for more than half of global oil demand for the first time in 2013 and 2014," so now most of the oil market is not transparent. As a result, the head of Citi's commodity research department, Ed Morse, stated in CFTC Talks (2017): with "emerging markets … [becoming] increasingly dominant in the international economy, we have more and more 'black holes'" in data coverage. For example, "China … has a lot of missing barrels, a lot of missing molecules, [and] a lot of missing tons of grains because their inventory [data] is a state secret. … So [data] black holes are getting larger and larger and impacting our understanding of [commodity] fundamentals," concluded Morse in CFTC Talks (2017).

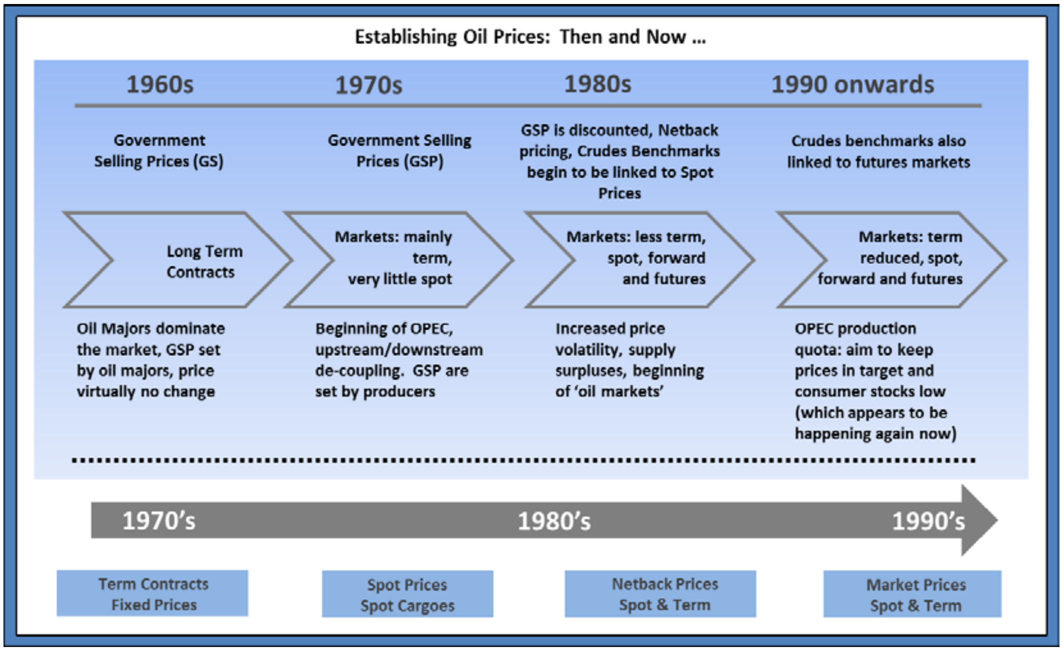
Some Markets in the U.S.

But to be complete, not every physical market location in the U.S. has immediately available data. The following example is from Martin (2017) of J.P. Morgan Commodities Research. The August and September 2017 hurricanes "hit the Texas refining system hard." The "true impact" of refinery outages could not be immediately and directly understood because not all affected markets published data, so Martin (2017) noted that commodity researchers would be looking "at price signals as a guide for the underlying [crude oil and product] market dynamics." And that introduces the central concept of this paper: how oil-market traders and analysts have learned to make use of price-relationship data to attempt to infer petroleum-complex fundamentals.

The Wealth of Futures Price Data

Because we have such a wealth of futures price data, an analyst does not need to be a member of a cartel or a large corporation to gain insights into the oil market. Figure 1 on the next page provides a diagram on the evolution of pricing in the oil markets since the 1960s from long-term contracts to more spot-oriented market pricing, which enables us to potentially deduce market fundamentals.

Figure 1



Graphic Based on Tchilinguirian (2006), Slide 4.

Even when fundamental data on the oil markets are sparse or opaque, large-scale supply-and-demand shifts leave footprints in futures-price relationships, from which one can potentially infer the market's fundamentals (Till, 2008).

What Futures Prices Reveal about Petroleum-Complex Fundamentals

We will now launch into the heart of the paper, which is what price data can potentially reveal about petroleum-complex fundamentals. This section discusses how price relationships can (a) incentivize fundamental behavior; (b) drive fundamental behavior, (c) provide proxies for physical market information, (d) furnish an understanding of Chinese demand (through 2008), (e) signal how well domestic U.S. crude oil surplus was absorbed (from 2011 through 2013), and (f) indicate what the market's perception is of the marginal cost of production for crude oil.

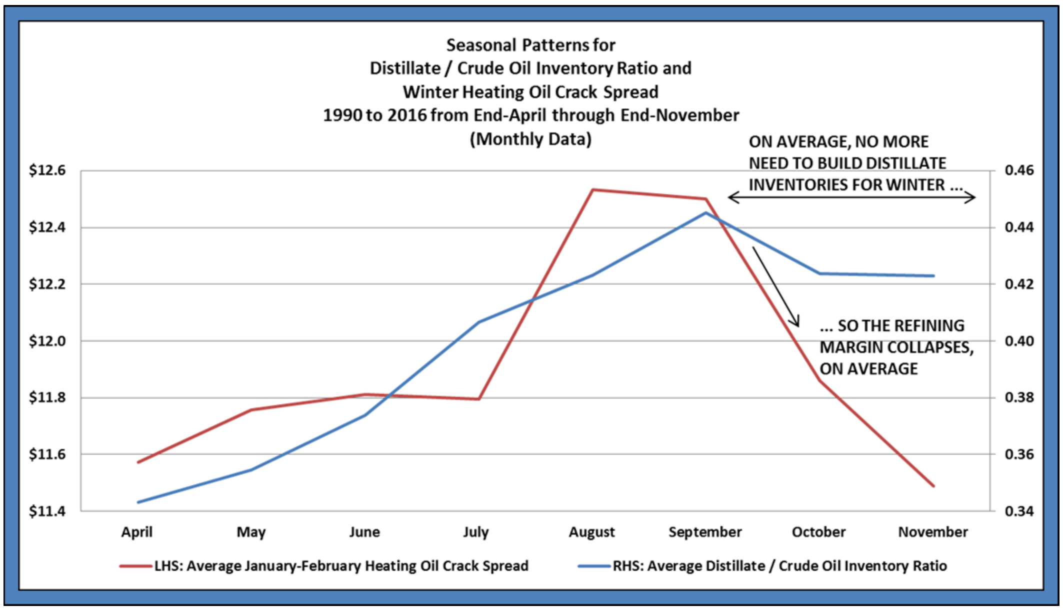
<u>Incentivizing Fundamental Behavior</u>

A futures trader interprets a commodity's price as part of a dynamic process. A commodity's price moves in whatever direction is needed in order to elicit a supply or demand response that will balance a commodity market. It may be useful to review the technical aspects of this interplay.

Building Distillate Inventories before Winter (1990 to 2016)

Figure 2 shows the typical seasonal pattern of building distillate inventories from April through the fall in the U.S. before the winter. In this graph, distillate inventories are represented as a fraction of the prevailing crude oil inventories. The graph illustrates that on average, once sufficient inventories are built, the winter heating oil crack spread collapses: there is no more need to incentivize the production of heating oil. For clarification, the heating oil crack spread is the difference between the price of heating oil and the price of crude oil and provides the profitability of refining crude oil into heating oil.

Figure 2
Building Distillate Inventories before Winter (1990 to 2016)



Source: Premia Research LLC.

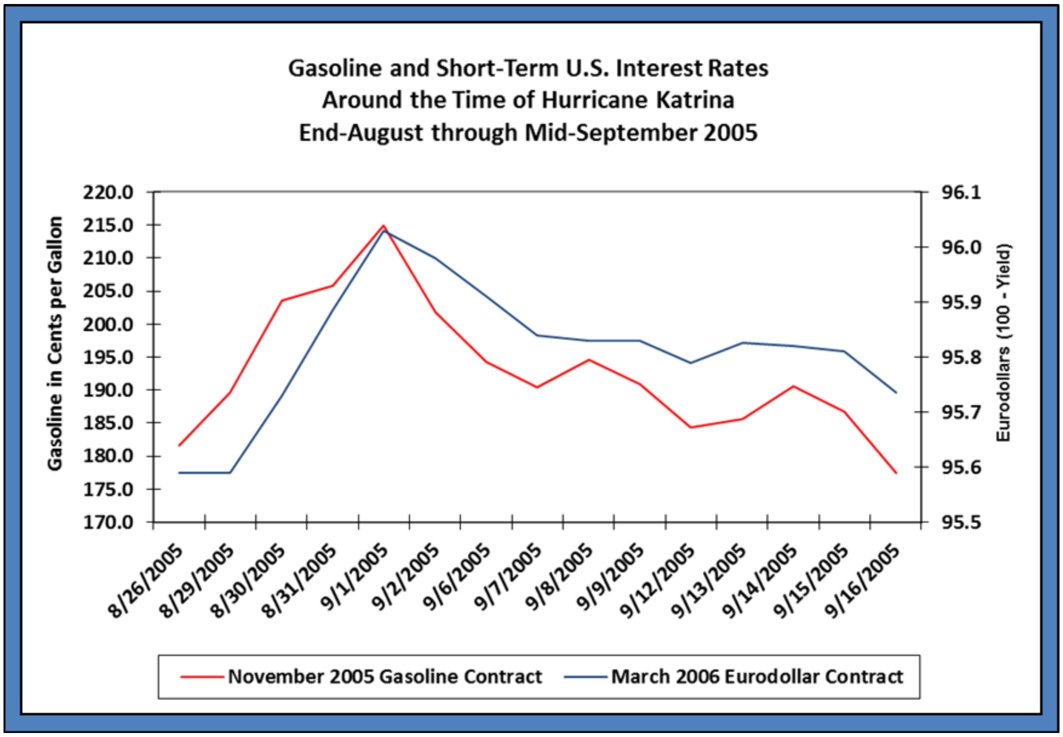
Data Source: The Bloomberg.

Notes on Data: Bloomberg ticker for EIA Distillate Inventory Data: "DOESDIST Index"; Bloomberg ticker for EIA Crude Oil Inventory Data: "DOESCRUD Index"; and definition of January-February Heating Oil Crack Spread: January Heating Oil contract price minus February WTI Crude Oil contract price in dollars per barrel.

Hurricane Katrina (2005)

One can also examine the aftermath of Hurricane Katrina in the United States in 2005 for another good example of the dynamic interplay between an oil product's price and its supply-and-demand situation. According to a 2005 *Dow Jones Newswire* report, "[Hurricane] Katrina shut in nearly all of oil and gas production in the Gulf of Mexico. The large scale supply disruption and fear of an economic shock triggered a massive [domestic and international] government[al] response." The dramatic governmental response caused gasoline prices to decline from their post-Katrina peak, as shown in Figure 3 on the next page.

Figure 3



Source: Premia Research LLC.

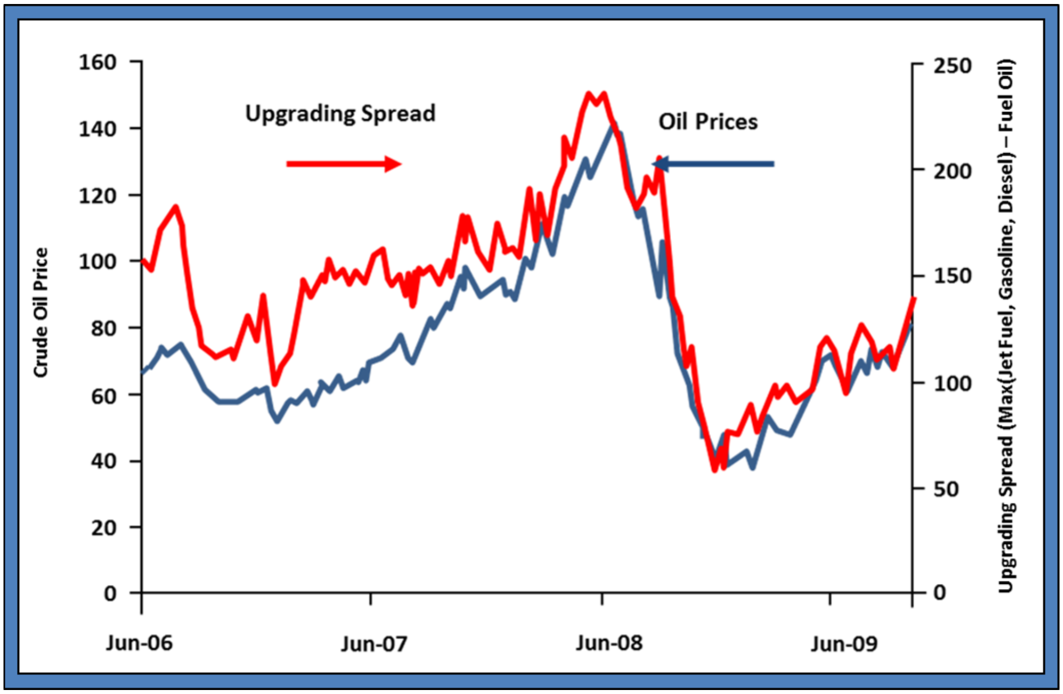
Data Source: The Bloomberg.

Further, and as also illustrated in Figure 3, with that response, fears of an economic slump diminished, which in turn caused deferred interest-rate contracts to decline, as the market resumed pricing in the expectation that the Federal Reserve Board could continue tightening interest rates at the time (Till, 2008).

Refinery Constraints (2008)

Another example of price incentivizing fundamental behavior is from 2007 through mid-2008. At that time, "refiners were using more marginal capacity and could not raise gasoline or diesel output without producing excess fuel oil," explained Ribeiro *et al.* (2009) of J.P. Morgan Global Asset Allocation & Alternative Investments Research. As the International Energy Agency (2006) had earlier noted, "[f]or refiners to run profitably, gasoline and diesel prices ha[d] to rise to offset the discounts needed to clear the fuel oil surplus and to encourage marginal refiners to process additional crude oil." This phenomenon became visible in the upgrading spread, which can be defined as the difference between the maximum price of transportation fuels and the price of fuel oil. When the upgrading spread widened as much as it did from 2007 to mid-2008, as shown on Figure 4 on the next page, analysts inferred that there was "a shortage of refinery capacity" and that there was "insufficient flexibility in the refining system to meet the demand for lighter products" that are used as transportation fuels, as stated in Ribeiro *et al.* (2009). When markets are tight, prices increase "to provide the right incentives for both current production and future investment," as put forth by the J.P. Morgan researchers. And in fact, "the first half of 2009 [was to] represent … the first large increase in refinery capacity additions," observed Tchilinguirian (2008), having previously noted that "oil refining capacity [had] peaked in 1981" in Tchilinguirian (2006).

Figure 4
Oil Prices and the Upgrading Spread
June 2006 through October 2009
(Weekly Data)



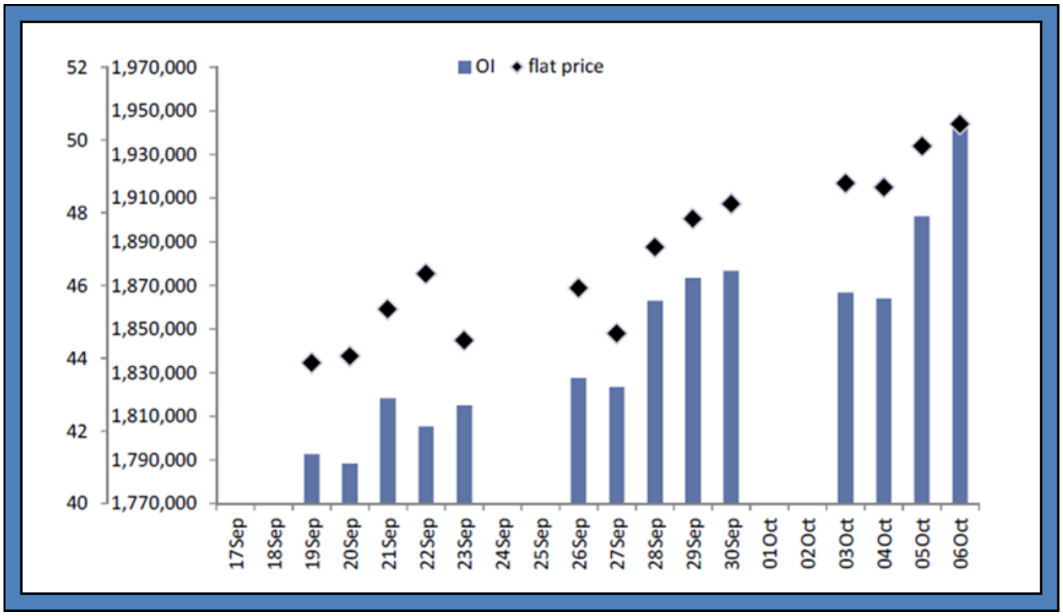
Source of Graph: Ribeiro *et al.* (2009), Chart 2.

Notes on Graph: the crude oil price on the left-hand-side of the graph is in dollars per barrel while the upgrading spread on the right-hand-side is in dollars per metric ton.

Driving Fundamental Behavior

Arguably, hedging opportunities became much more relevant in the crude oil markets with the shale oil revolution. Regarding shale oil, "from a financing perspective, the great bulk of the positive cash flows occurs early in each project's life. This is preferred from a general risk and discounting perspective, but also figures very importantly … [in] hedging efforts, as the oil [derivatives] market … offers liquidity only out about 2 to 3 years or so. So there's a [good] … match between forward market liquidity and the shale oil production profile," as explained by Anderson in Till and Jesse (2016). As a result, one can monitor when there is a sharp pick-up in hedging activity, as shown in Figure 5 on the next page, which would be expected to translate into U.S. rig count additions under this analysis.

Figure 5
Open Interest in West Texas Intermediate (WTI) Oil (LHS, in Contracts) and WTI Flat Price (in $/bbl)



Source of Chart: Goldman Sachs Equity Research (2016), Exhibit 19.

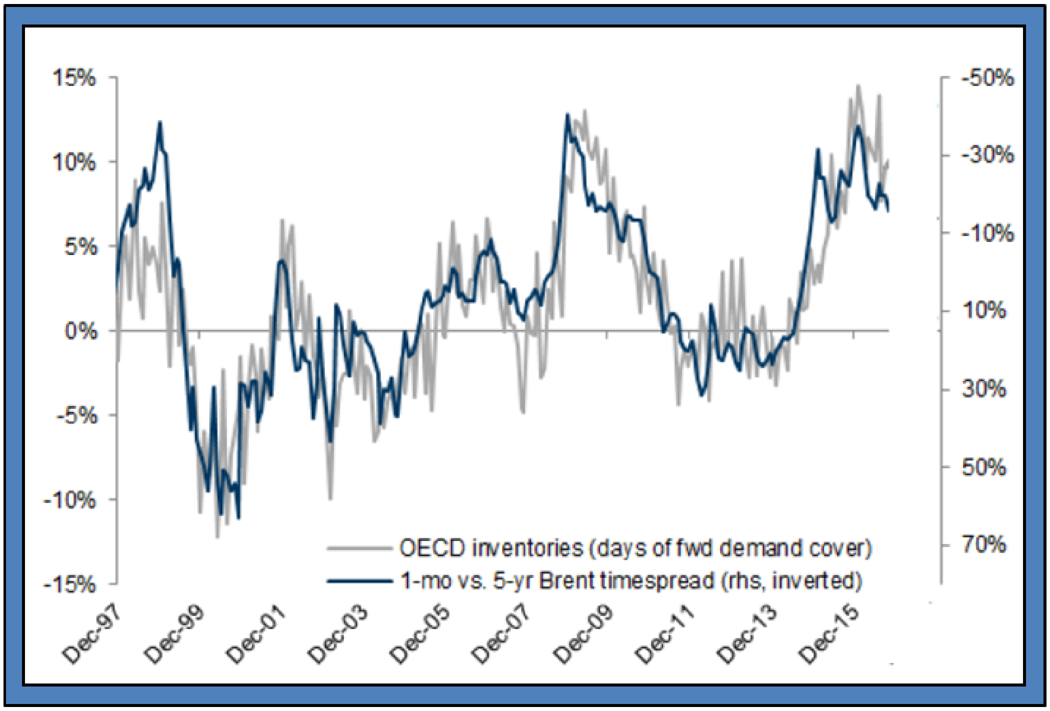
Authors' Data Source: The Bloomberg.

Proxying the Physical Market with Futures Spreads

Example from 1997 to 2016

One can also potentially infer aspects of the physical oil market by examining the level of futures calendar spreads. A "calendar spread" consists of taking offsetting positions during the different delivery months of a particular futures contract. There is a considerable amount of evidence that one can proxy the amount of crude oil commercial inventories, at least in Organization for Economic Co-operation and Development (OECD) countries, by reference to the level of crude oil futures spreads. As explained by Longson and Volynsky (2015), "Prompt [term] structure can be a good real-time proxy for the physical [oil] market, and the data proves that out." For example, one can see the direct relationship between OECD commercials stocks and the 1-month-to-5-year ICE Brent crude oil spread in Figure 6 on the next page.

Figure 6
Inventories vs. Brent Time Spreads



Graph Excerpted from Goldman Sachs Commodity Research (2016), Exhibit 7.

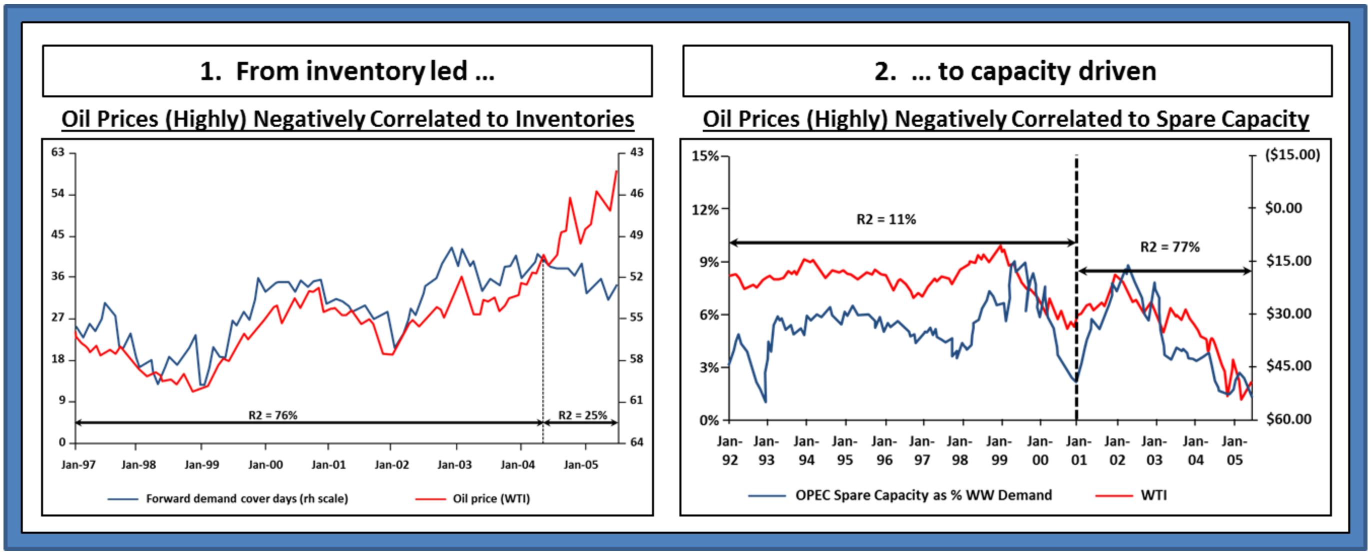
Authors' Data Source: International Energy Agency and Goldman Sachs Global Investment Research.

Notes on Graph: OECD Commercial Stocks (Excluding U.S. NGLs) in Days of OECD Demand Coverage vs. 3-Year Average (LHS) vs. 1-Month to 5-Year Brent Time Spreads (%, RHS, Inverted).

Caveat: Inventories are Only Part of the Picture

There are several caveats on the importance of inventory-related data. The previous figure showed a contemporaneous relationship between futures spreads and inventory data. The historical relationship of inventory data to the outright price of crude oil can be a bit more complicated, which is illustrated in Figure 7 on the next page.

Figure 7



Graphs Excerpted from Hicks and Smith (2006), Slide 5.

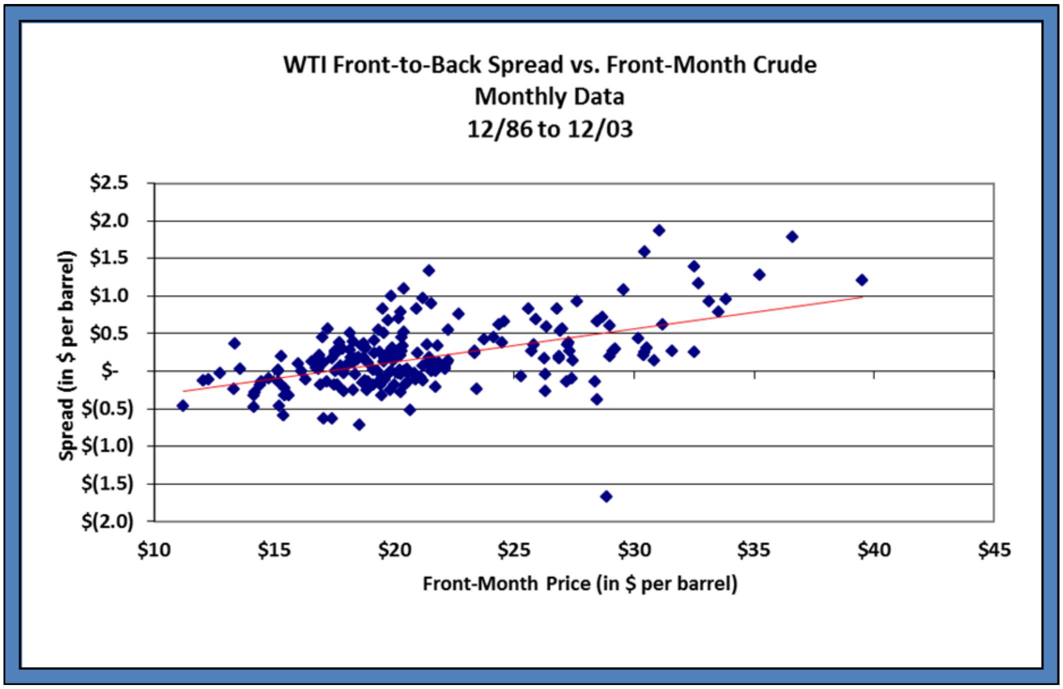
Authors' Data Sources: Smith Barney, Bloomberg, and CIR.

On the left-hand-side graph of Figure 7, we can see that the price of oil had been highly negatively correlated to the OECD inventory situation before OPEC spare capacity started becoming an issue in 2004. At that point, the outright price of oil and oil inventories were not very correlated from mid-2004 through the end of 2005. The left-hand-side graph represents OECD industry oil stocks in terms of the number of days covering forward demand. The right-hand-side graph of Figure 7 completes the picture. Once OPEC spare capacity started becoming under pressure, oil prices became highly negatively correlated to spare capacity as a percentage of worldwide (WW) demand. These two graphs are meant to illustrate that inventories are only part of the picture in examining the drivers for the outright price of oil. When OPEC spare capacity had become low, inventories were no longer a significant driver of price, a point covered in Till (2016).

Additional Caveat: Spare Capacity Has Mattered in Interpreting the Oil Futures Curve Shape

Figures 8 and 9 on the next two pages show that the interpretation of the crude oil futures curve has depended on the spare capacity situation.

Figure 8



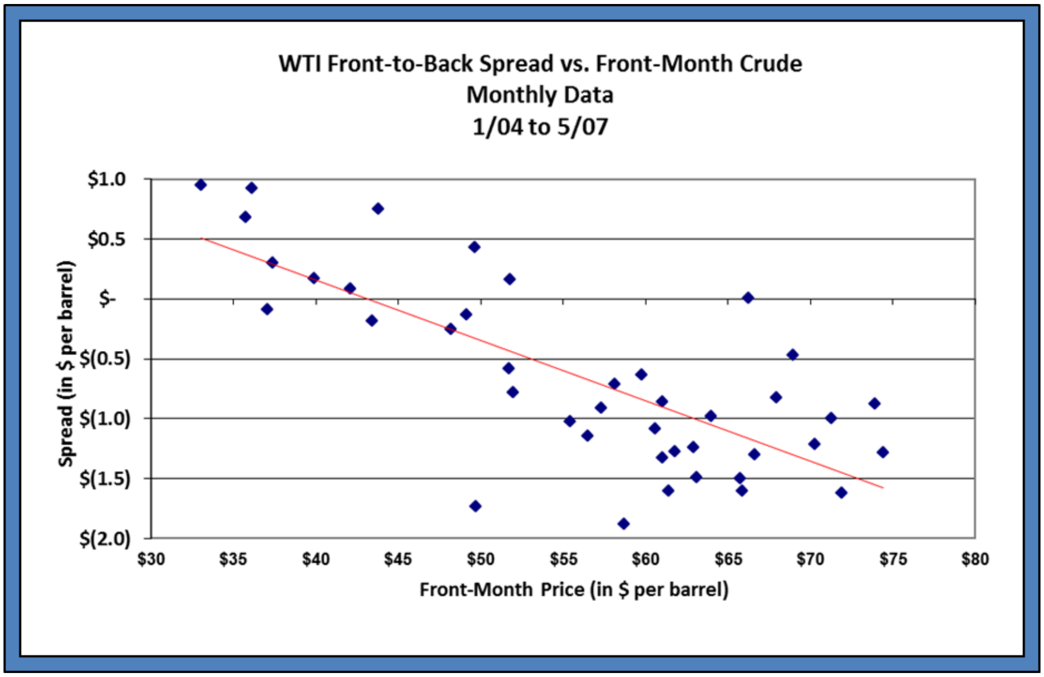
Source: Premia Research LLC.

Data Source: The Bloomberg.

Prior to 2004, if there were scarcity in the crude-oil market, one could expect two outcomes: (1) increasing spot prices; and (2) for the front-month price to trade at an ever larger premium to deferred-delivery contracts. In this state-of-the-world, the market would be encouraging the commodity's immediate use rather than for it to be stored. In this case, the outright price of oil and the front-to-back spread were highly positively correlated, as illustrated in Figure 8. During 2004, OPEC's immediately-deliverable spare capacity collapsed.

When there has been inadequate spare capacity, a futures curve has needed to provide a return for storage since there would be a pressing need to incentivize precautionary stockholdings in oil. In this state-of-the-world, the prompt futures price has traded at ever more of a discount to provide a sufficient return for storage, and the spot price of oil has increased to encourage consumer conservation. In this case, the outright price of oil and the front-to-back spread have been highly negatively correlated as illustrated in Figure 9 on the next page.

Figure 9



Source: Premia Research LLC.

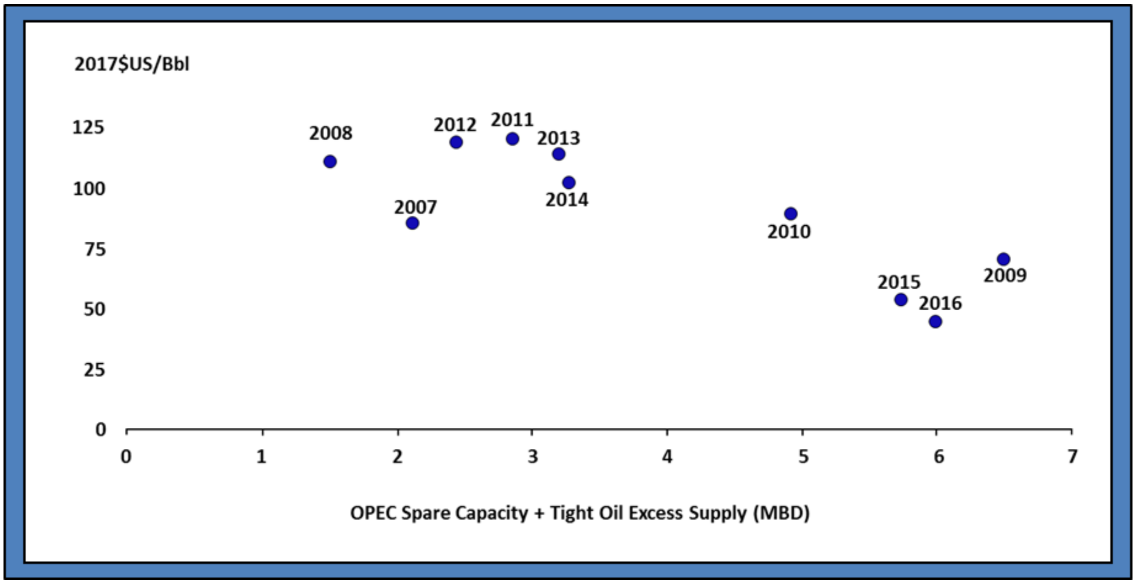
Data Source: The Bloomberg.

Eventually a demand-destroying oil price spike occurred in 2008 at low levels of OPEC spare capacity, followed by a dramatic drop in the price of oil. With the demand destruction that occurred as a result of the price spike, OPEC spare capacity recovered.

A Further Caveat on Spare Capacity

One should note that an analyst now needs to also include U.S. tight oil excess supply and not just OPEC spare capacity, as shown in Figure 10 on the next page, in considering spare productive capacity.

Figure 10
Brent Crude Oil Prices and Spare Productive Capacity (2007 to 2016)



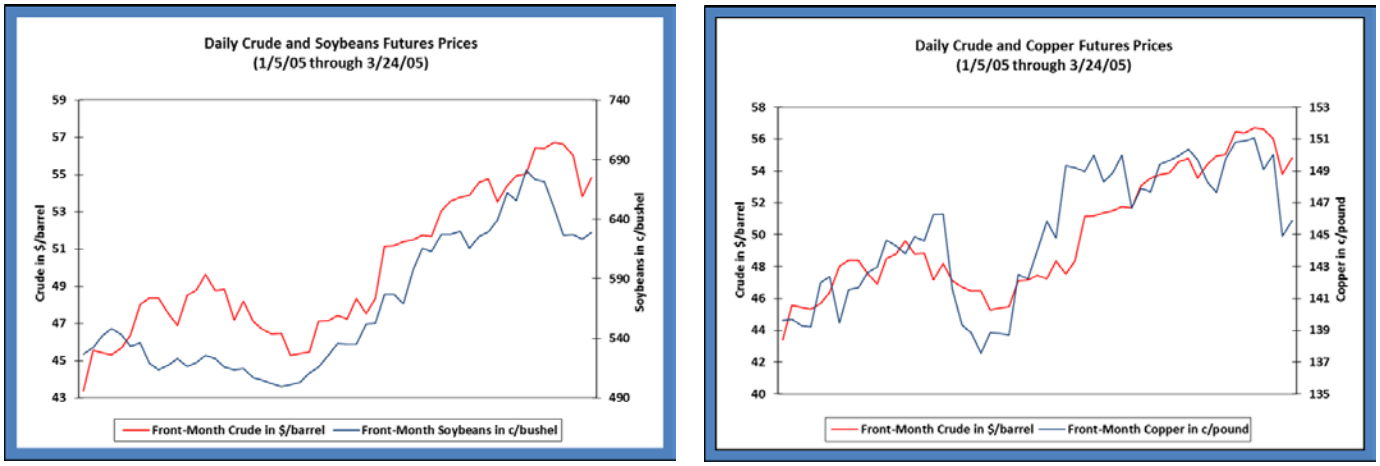
Graph Excerpted from Foreman (2017), Slide 6.

But again, regarding outright prices, as long as surplus capacity has not approached pinch-point levels, inventories have been an important driver of the price of oil.

Understanding Chinese Demand (Through 2008)

Oil futures traders first became aware of *not* solely relying on OECD data to make predictions on the direction of oil-price relationships in 2005. It was at that time that the potential impact of temporarily-concentrated Chinese demand started to reveal itself through various futures-price relationships. Figure 11 on the next page provided an early indication of the structural changes to come in the commodity markets, and particularly, in the oil markets.

Figure 11
Common Waxing and Waning of Commodity Prices around the Chinese New Year's Holiday in 2005



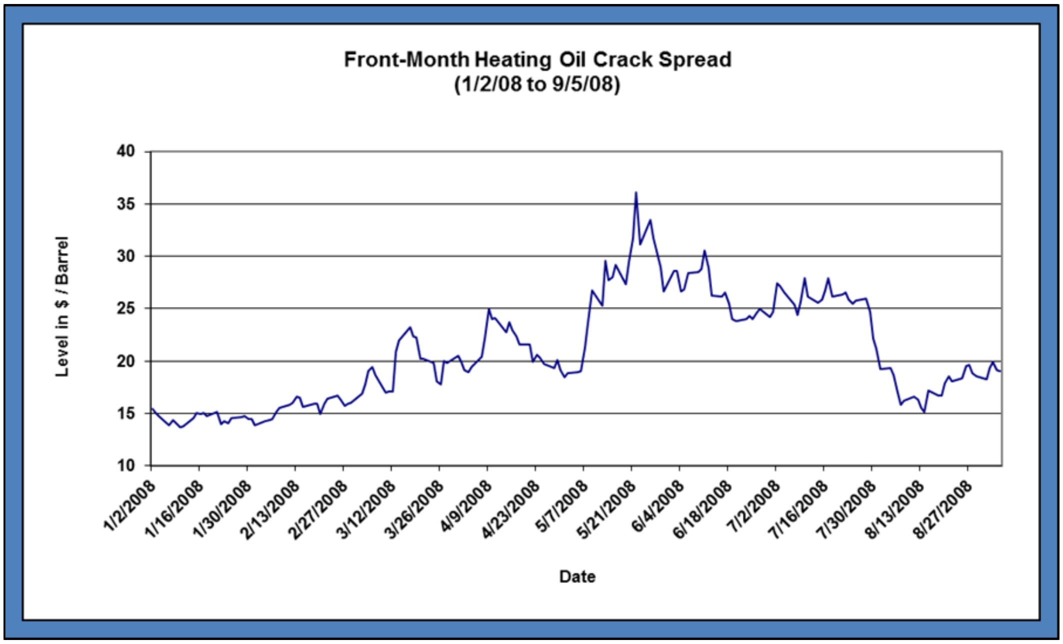
Source of Graph: Till (2008), Figure 8.

Data Source: The Bloomberg.

In this graph, we see a common waxing and waning of prices in crude oil, soybeans, and copper coincident with the Chinese New Year's holiday in 2005, presumably when Chinese demand was temporarily absent. This factor appeared to overwhelm any other factor in these three markets. Stein (2005) wrote that 2005 marked the "first business cycle where Chinese demand is having a global effect on prices, notably of energy and other raw materials."

Later, in the summer of 2008, the heating-oil crack spread indicated extraordinary demand for middle distillates, as shown on the next page in Figure 12. There were no severe weather events, supply disruptions, or large-scale trading blowups in the U.S. or Europe at the time, so it was not immediately apparent why this spread should spike so extraordinarily.

Figure 12



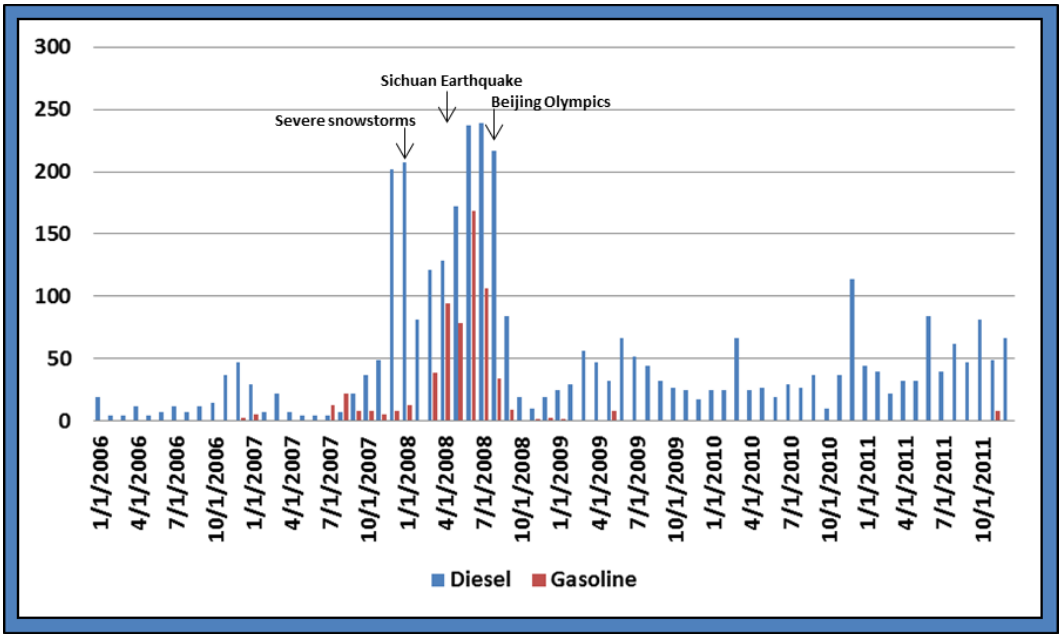
Source of Graph: Till (2008), Figure 13.

Data Source: The Bloomberg.

That is, except for news from China, including the devastating earthquake in China, which damaged power-supply grids, and also pre-Olympic petroleum-product stocking in order to ensure that there would be no shortages during the historic Beijing Olympics. These were amongst the key events in China that drove a spike in diesel and gasoline imports.

In Figure 13 on the next page, one can note that the spike in demand for refined product imports is consistent with the spike in the heating oil crack spread in Figure 12.

Figure 13
Chinese Gasoline and Diesel Imports Surged in 2008 Due to a Number of Key Events in China (Thousands of Barrels per Day)



Graph Based on Fenton (2012), Slide 24.

Data Source: China Customs General Administration and The Bloomberg.

Notes on Data: Bloomberg ticker for Diesel imports: CNIVDF <Index>; Bloomberg ticker for Gasoline imports: CNIVGSOL <Index>. Bloomberg data was converted from monthly tonnes to barrels per day using the CME Group's Conversion Calculator, which was accessed at: http://www.cmegroup.com/tools-information/calc_refined.html on November 27, 2017.

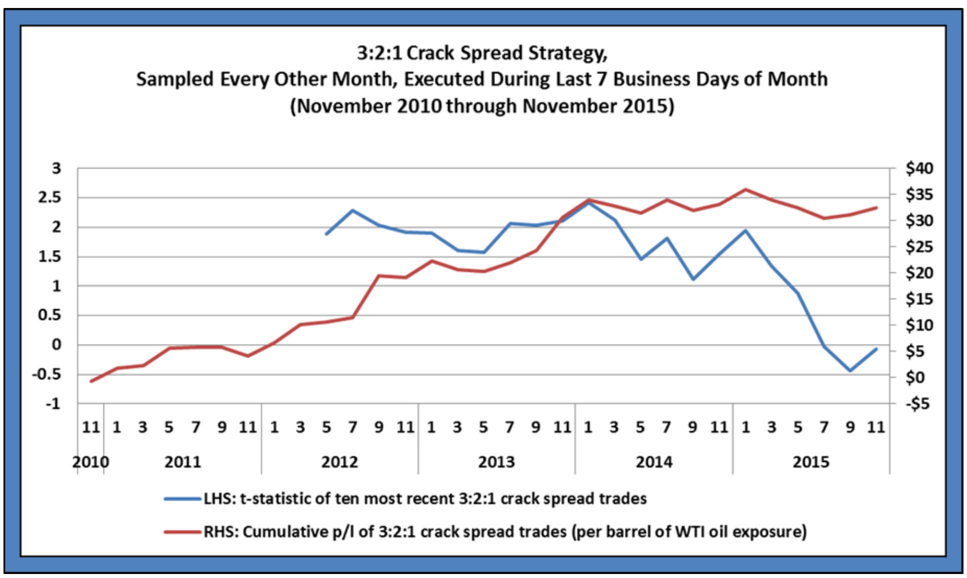
As discussed in the *Financial Times*' Alphaville section (2013), "[i]n oil market analyses, it is essential that refined products are also taken into account, as it is misleading to solely look at crude prices, crude inventory, and crude supply … in isolation," which we can also conclude from this article's earlier section on upgrading spreads. One should also add that we are now in a different market environment than in 2008; since that time, there have been both additions in refinery capacity and a surplus in light sweet crude oil from the post-shale environment. Therefore, the type of dramatic price impact discussed in this section, resulting from a Chinese product import surge, is currently unlikely.

In understanding past Chinese-related demand through price signals, one can also draw from Kaufmann and Ullman (2009). These researchers investigated "where changes in the price of crude oil originate and how they spread …" Their paper did so "by examining causal relationships among prices for crude oils from North America, Europe, Africa, and the Middle East." The authors looked into where "innovations in world oil prices enter the market," using price data from a variety of grades of oil from both OPEC and non-OPEC nations from 1987 through March 2008. One of their results was that the spot price for Dubai-Fateh oil had been a "'gateway' for innovations to crude oil prices." "A large fraction of the crude oil shipped to Asian nations from the Middle East (more than 10 … [million barrels per day]) uses the spot price for Dubai-Fateh as a benchmark … As such, innovations in the spot price for Dubai-Fateh may [have] reflect[ed] increasing demand [over time] in Asia," inferred Kaufmann and Ullman (2009).

Managing the Domestic U.S. Crude Oil Surplus (2011 through 2013)

At the end of 2013, alert futures traders had an early signal that, as phrased by J.P. Morgan Commodity Research (2013), "the boom in … [domestic oil] production ha[d] been well absorbed by existing U.S. infrastructure." Refinery margins no longer needed to consistently rally at the end of each month to provide an extraordinary return for transporting domestic crude oil, in whatever way possible, to U.S. refineries. This observation is illustrated in Figure 14, which shows the degradation in performance of a bullish refining-margin trading strategy, starting in late 2013. This graph displays the cumulative performance of entering into futures spread trades that represented near-month refinery margins from the end of 2010 through the end of 2015.

Figure 14



Source of Graph: Premia Research LLC.

Data Source: The Bloomberg.

Notes on Graph: "A 3:2:1 crack spread reflects gasoline and distillate production revenues from the U.S. refining industry, which generally produces roughly 2 barrels of gasoline for every barrel of distillate. The 3:2:1 crack spread is calculated by subtracting the price of 3 barrels of oil from the price of 2 barrels of gasoline and 1 barrel of distillate," as noted in https://www.eia.gov/todayinenergy/detail.php?id=1630, accessed on October 12, 2017. Here, the 3:2:1 crack spread was calculated using these proportions, but then the total was divided by 3, thereby expressing the spread as per one barrel of crude oil. Further, the spread was calculated with the gasoline and heating oil nearby futures contracts and also with the WTI crude oil second nearby futures contract.

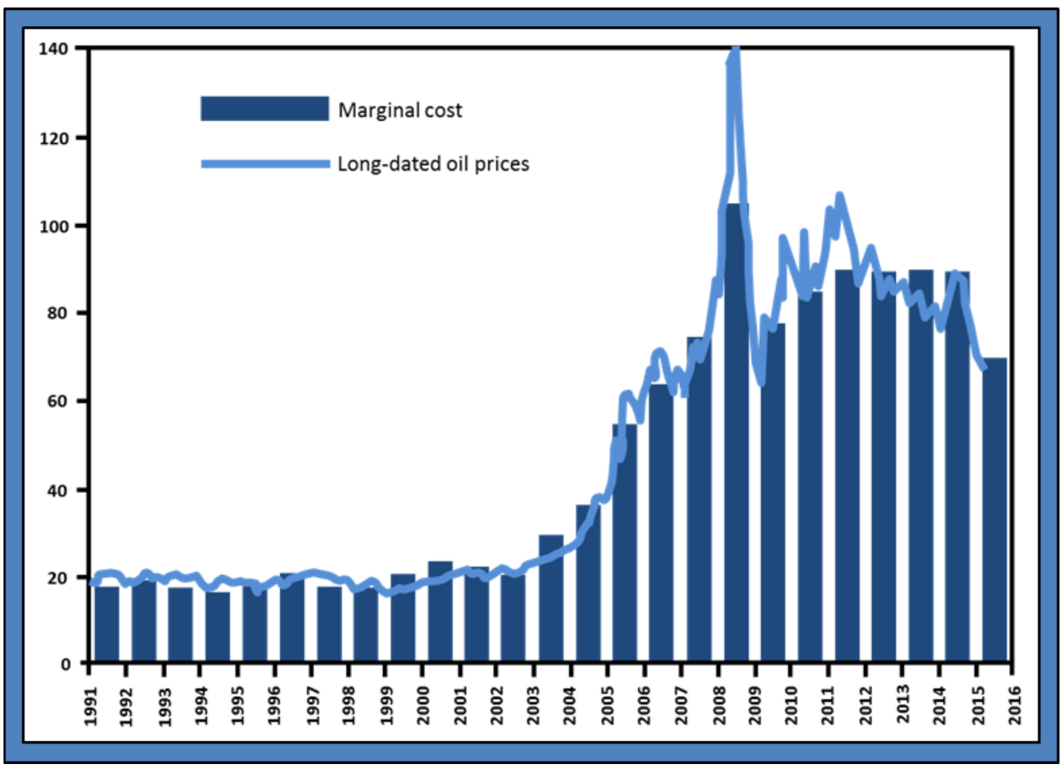
Figure 14 specifically shows (a) how the cumulative performance of the bullish refining-margin strategy leveled off at the end of 2013, and (b) how, as of the end of 2013, the rolling t-statistic for this trade began falling off. At that time, the markets no longer needed to incentivize extraordinary profits for transporting and refining burgeoning domestic crude oil supplies.

The Marginal Cost of Production for Crude Oil

As a final note on what futures prices can potentially reveal about petroleum-complex fundamentals, Figure 15 illustrates the market's perception of the then-current marginal cost of oil production: through the examination of the five-year futures price. Explained Goldman Sachs Economic Research (2015): "[T]he long-dated commodity price … [is usually] a reflection of [a] … commodit[y's] marginal cost of production …"

Figure 15

Marginal Cost (Defined as the Average of the Highest Cost (or Bottom Quartile) Producers) vs. 5-Year WTI Futures Price in $/Bbl



Source of Graph: Goldman Sachs Economic Research (2015), Exhibit 2.

Anderson (2017b), though, cautions that one should perform a more precise analysis of long-run variable costs than simply inspecting five-year forward market prices.

Caveats on the Use of Price Data

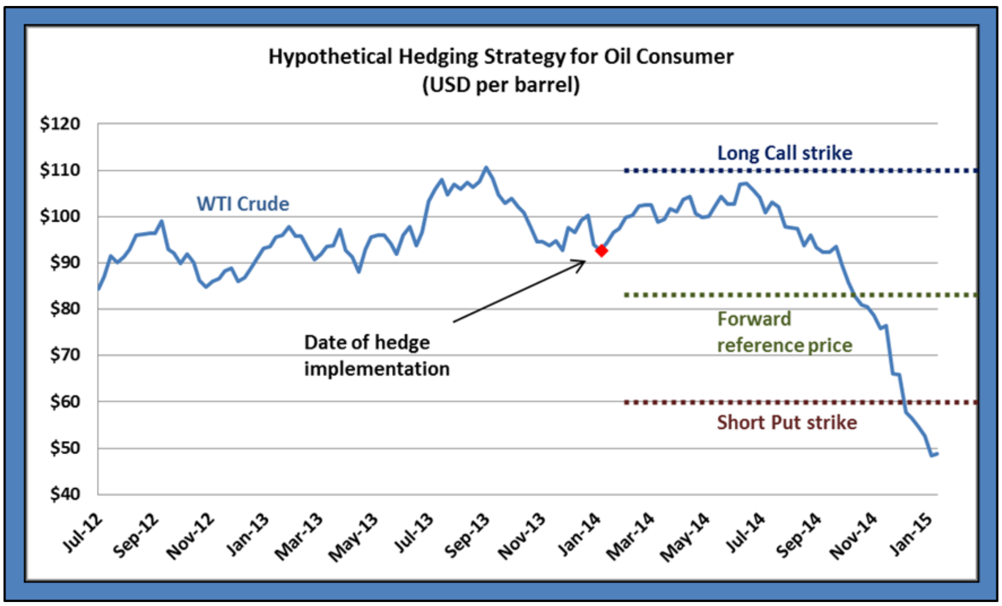
This paper will conclude with some caveats on the use of price data, namely that prices can be driven by purely technical effects and that forward prices are not predictions.

Purely Technical Effects

Dynamic Hedging

One purely technical effect is the temporary impact on futures prices from the hedging of option deals. Figure 16 illustrates a hypothetical hedging strategy of an oil consumer (like an airline) buying an out-of-the-money call option, financed by selling an out-of-the-money put option in 2014. As the price of oil became closer to the put option strike, the consumer may have decided to close out this hedge.

Figure 16



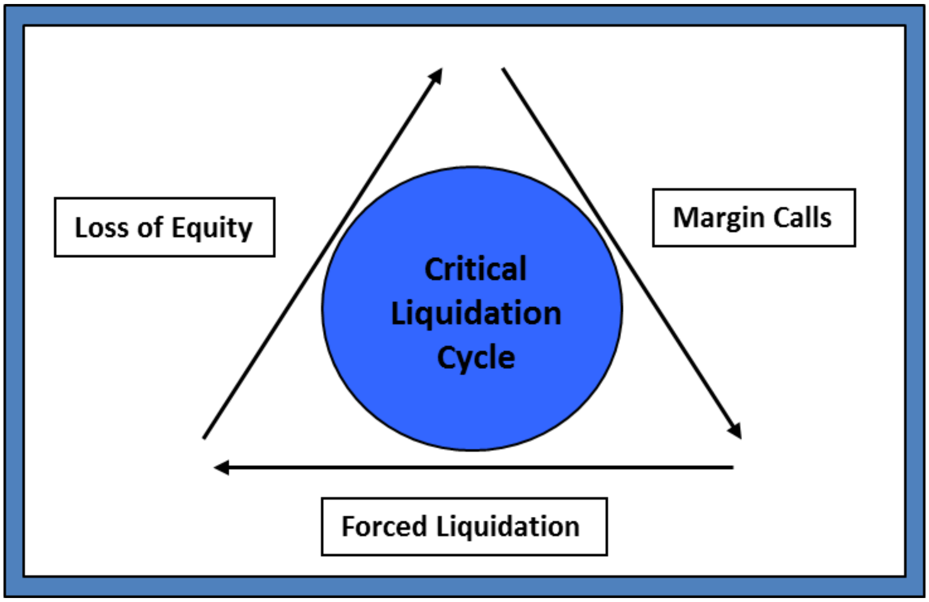
Source of Graph: Cembalest (2015).

Cembalest (2015) wrote that "the speed and magnitude of the oil price decline [in the fall of 2014] [reflected] the impact of hedging unwinds." At the time, "Wall Street banks … scrambled … to neutralize their exposure to big oil options trades, adding to the downward spiral in crude prices as they s[old] futures contracts to offset options deals that … [became] unexpectedly in the money," as reported by Ngai (2014).

Liquidation Pressure

Another purely technical factor is the temporary effect of liquidation pressure. Futures traders are aware that when traders have to liquidate large positions that this can be a temporary, but meaningful, driver of price. Figure 17 illustrates how a highly leveraged fund can enter into a "critical liquidation cycle," whereby once a fund crosses a threshold of losses, a cycle of investor redemptions can occur and/or the fund's credit providers may demand the reduction of leverage, and the value of a fund's holdings would thereby decline precipitously as the fund would sell off holdings in a distressed fashion.

Figure 17
Critical Liquidation Cycle



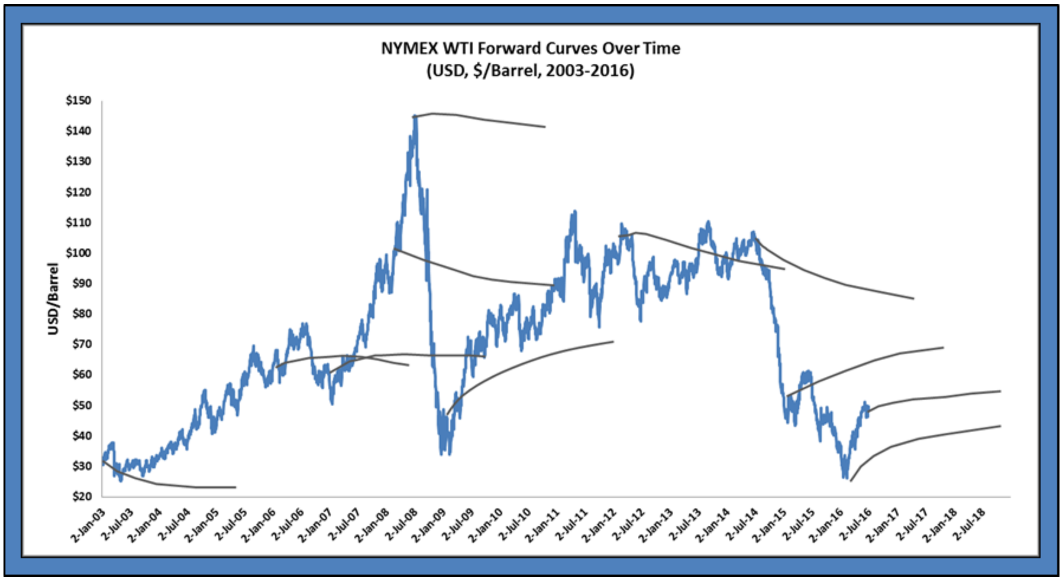
Source of Graph: de Souza and Smirnov (2004).

Both of the technical factors mentioned in this section can cause a temporary overshooting of prices.

<u>Not Predictions</u>

Finally, a futures market is not a forecasting agency; it facilitates risk sharing and the efficient allocation of resources. To expect futures prices to only reflect predictions of future prices ignores its other functions. Figure 18 on the next page shows how the "forward curve [for oil has] not [been] a good price predictor, but still functions well for hedging storage costs and requirements," citing a Center for Strategic and International Studies (CSIS) presentation.

Figure 18
Nymex WTI Forward Curves over Time Overlaid Against Crude Oil Front-Month Futures Price Realizations



Source of Chart: CSIS and Citi Research.

Conclusion

Instead of asking whether the fundamentals justify the oil price, this paper adopted the view of a veteran oil futures trader and asked the opposite question: what is the price telling me about fundamentals? The reason for this outlook is as follows: the market imposes sufficient discipline to prevent a trader from ignoring price except for a very short space of time!

Endnotes

Ms. Hilary Till, the co-author of this article, presented this paper at the 7th International Trading Conference, which was co-organized by the Ulsan National Institute of Science and Technology (UNIST) in South Korea on October 24, 2017. Research assistance from Katherine Farren, CAIA, of Premia Risk Consultancy, Inc. is gratefully acknowledged. The paper also benefitted from helpful research from Hendrik Schwarz and Jan-Hein Jesse. Please note, though, that the ideas and opinions expressed in this article are the sole responsibility of the authors.

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