OPEC Spare Capacity, the Term Structure of Oil Futures Prices, and Oil Futures Returns

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In this article, we are going to look into whether we can explain in simple terms whether holding long futures positions in crude oil is a wise decision or not. It turns out that knowing if OPEC spare capacity is at comfortable levels would have been very helpful in making this decision, at least since the 1990s. But this factor alone is not sufficient. One has to also examine the shape of the crude oil futures curve. The task of this article will be to explain how we came to these conclusions.

Structural Curve Shape of Individual Futures Contracts

We will start our exploration of the key determinants of crude-oil futures returns by posing the following question about all commodity futures contracts. What property seems to have a strong influence on whether an individual futures contract has a positive return over the long run? We will then check if the answer to this question might specifically apply to crude oil futures contracts.

There is comfort in the peer-reviewed literature with treating a commodity futures contract's curve shape as *predictive* of future returns. By futures curve shape, we mean whether a futures contract is trading in backwardation or contango. Futures traders frequently refer to the term structure of a futures contract as a "curve": the futures prices for each maturity are on the y-axis, while the maturity of each contract is plotted on the x-axis, which thereby traces out a "futures price curve." When the front-month price trades at a premium to deferred-delivery contracts, this is known as *backwardation*. Correspondingly, when the front-month price trades at a discount to deferred delivery contracts, this is known as *contango*.

As discussed in Till (2014a), amongst the research covering the determinants of commodity futures returns is the work by Gorton *et al.* (2013). These researchers examine 31 commodity futures over the period, 1971 to 2010. They find that "a portfolio that selects commodities with a relatively high basis …

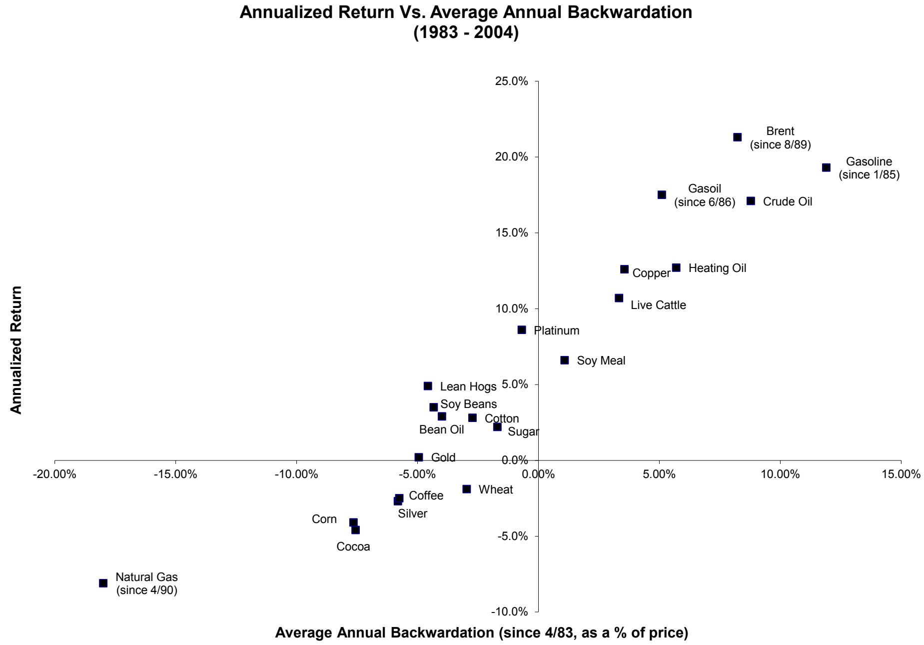

Exhibit 1 Annualized Return vs. Average Annual Backwardation (1983–2004)
Source: Graph based on Nash and Shrayer (2005), Slide 2.

significantly outperforms a portfolio with a low basis …" The authors define "basis" as "the difference between the current spot price and the contemporaneous futures price." In other words, the winning portfolios contain futures contracts that are relatively more backwardated than the losing portfolios. The authors provide a fundamental rationale for their results, linking relatively high-basis futures contracts with relatively low inventories (and correspondingly, relatively more scarcity.)

In related findings, other authors, starting with Nash (2001) and including Gunzberg and Kaplan (2007), have variously shown how the level and frequency of backwardation have determined returns *across individual commodity futures contracts* over approximately 15-to-20-year timeframes. For example, see Exhibit 1. Arnott (2014) demonstrated this linear relationship still held over the period, January 1999 through June 2014.

Separately but related, Feldman and Till (2006) discuss how, over a 50-year-plus timeframe, the returns of three agricultural futures contracts were linearly related to their curve shapes *across time*, clarifying that this result only became apparent at five-year intervals, as shown in Exhibit 2.

The data points that are the outliers in Exhibit 2 illustrate the exception to the curve shape being the long-term driver of returns; and that is when there is a monetary devaluation, as occurred in the 1970 to 1974 timeframe. Therefore, the caveat to the curve shape being the long-term driver is that this assumes overall price stability.

From Geman (2005), we know that spot commodity prices are generally mean-reverting; or as futures traders would say, high prices cure high prices, and low prices cure low prices. How then can an individual futures contract have either long-term positive or negative returns if a commodity's spot price has a tendency to mean-revert? It is when a futures contract also has a tendency to trade at a discount (or premium) to the spot price: this slight benefit (or cost) only adds up meaningfully over long time-horizons; otherwise, a contract's immensely-volatile spot price dominates as the futures contract's source of return. This result is analogous to dividends being a key source of return for equities. This result is only apparent starting at five-year holding periods, as shown by Cochrane (1999).

Structural Curve Shape and the Implications for Crude Oil Futures Contracts

Has the shape of a crude oil futures curve demonstrably mattered for a contract's long-term returns? The short answer is yes. Exhibit 3 shows how *substantial* the return difference is, depending on whether one holds WTI futures contracts unconditionally versus only if the first-month futures price minus the second-month futures price is positive: i.e., if the front-to-back spread is in backwardation. For this latter state-of-the-world, one only held WTI futures contracts if the curve was in backwardation the previous day.

From January 1st, 1987 through August 29th, 2014, the annualized returns for holding and rolling WTI futures contracts were 6.2% over T-bills. Correspondingly, the returns over the same period for only holding WTI futures contract when the contract's front-to-back spread was in backwardation the previous day were 12.8% per year over T-bills.

Commodity Futures Curve Shape and Inventories

We had noted previously that Gorton *et al.* (2013) linked relatively more backwardated futures contracts with relatively low inventories for a commodity. Conversely, when a commodity has relatively more inventories, its commodity futures contracts tend to trade in contango, as will now be explained, drawing from Till (2008). In times of surplus, commodity inventory holders receive a positive return-to-storage, as represented by the size of the contango, since they can buy a commodity for delivery in the near term at a lower price and lock in positive returns to storage by simultaneously selling the higher-priced contract for future delivery. If inventories breach primary storage capacity, a commodity futures curve will trade into deeper contango, so as to provide a return for placing the commodity in more expensive, secondary storage (or eventually, tertiary storage.)

As a consequence, the general relationship is the more of a commodity's stocks that need to be stored, the more the tendency for its futures curve to trade in contango. And correspondingly, the scarcer a commodity is, the more its future curve trades in backwardation, providing no return (and no incentive) for storage.

One should note that these explanations originally date back to 1948 with Holbrook Working's paper, the "Theory of the Inverse Carrying Charge in Futures Markets." Working had studied grain futures prices back to 1884 in order to come up with explanations of futures-contract relationships that are applicable to this day, across commodities and across time.

Special Features of the Crude Oil Markets

Drawing from Harrington (2005), the true buffer against crude oil price shocks should be represented as not just above-ground stocks, *but also* spare production capacity. "Spare capacity refers to production capacity less actual production; it quantifies the possible increase in supply in the short-term," noted Khan (2008). More precisely, the U.S. Energy Information Administration (EIA) has defined "spare capacity as the volume of production that can be brought on within 30 days and sustained for at least 90 days. … OPEC spare capacity provides an indicator of the world oil market's ability to respond to potential crises that reduce oil supplies," according to EIA (2014).

Crude oil markets have been able to tolerate relatively low oil inventories if there was sufficient swing capacity that could be brought on stream relatively quickly in case of any supply disruption or demand shock. Indeed, as confirmed by Abu Al-Soof (2007), it has historically been OPEC's policy to attempt to provide sufficient spare capacity to enhance stability in the oil markets. The IMF (2005) even referred to the "maintenance of adequate spare capacity as a public good" because of the role that spare capacity had played in reducing the volatility of oil prices.

Instead of relying on OPEC spare capacity, why wouldn't more crude oil inventories be held globally? Rowland (1997) explained why:

"From wellheads around the globe to burner tips, the world's oil stocks tie up enormous amounts of oil and capital. The volume of oil has been estimated at some 7-8 billion barrels of inventory, which is the equivalent of over 100 days of global oil output or 2.5 years of production from Saudi Arabia, the world's largest producer and exporter of crude oil. Even at today's low interest rates, annual financial carrying costs tied up in holding these stocks amount to around $10-billion, which is more than the entire net income of the Royal Dutch/Shell Group, the largest private oil company in the world."

At this point, a careful reader may note a particular emphasis on OPEC spare capacity, ignoring non-OPEC producers. According to IMF (2005), "non-OPEC producers do not have the incentive to maintain spare capacity as they individually lack the necessary market power to influence oil prices." If this changes, this article will have to be correspondingly updated.

What Has Happened When OPEC Spare Capacity Has Been Quite Low?

One might expect that if the oil market's excess supply cushion dropped to sufficiently low levels that there would be three resulting market responses: (1) there would be continuously high spot prices to encourage consumer conservation, drawing from Murti *et al.* (2005); (2) the markets would undertake precautionary stock building, which would then lead to persistent contangos in the crude oil futures markets, following from

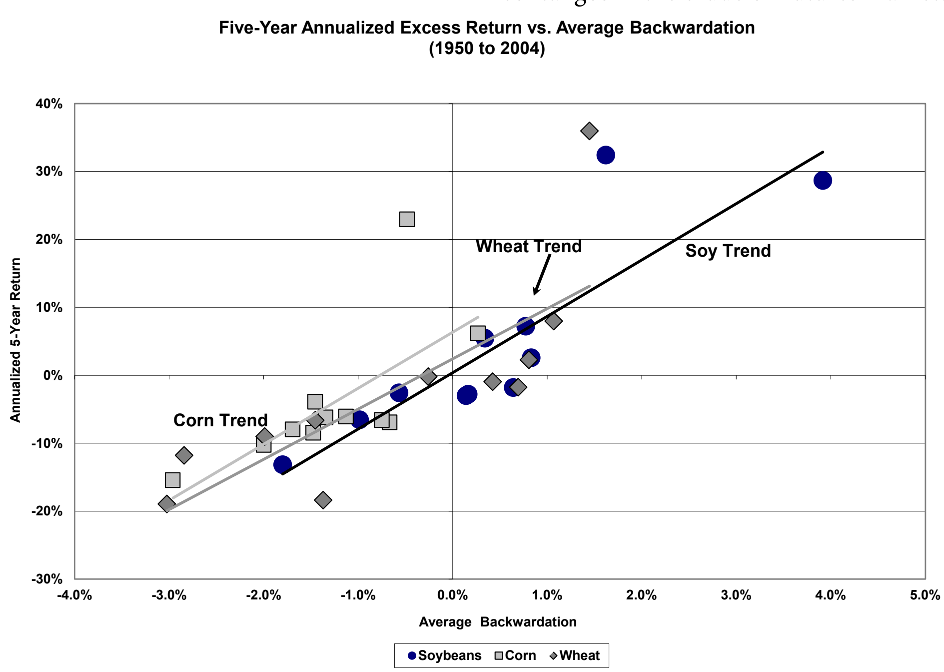

Exhibit 2 Five-Year Annualized Excess Return vs. Average Backwardation (1950 to 2004)
Source: Graph based on research undertaken during the work that led to the article by Feldman and Till (2006).
"Average backwardation" is here defined as the average monthly "percentage of backwardation" for each front-month agricultural futures contract, calculated over five-year time horizons.
"Excess return" refers to the futures-only returns from buying and rolling futures contracts. This return calculation excludes returns from the collateral that would be held in fully collateralizing such a program. Therefore, they are the returns in "excess" of the collateral return.
For further detail on these calculations, please refer to Feldman and Till (2006).

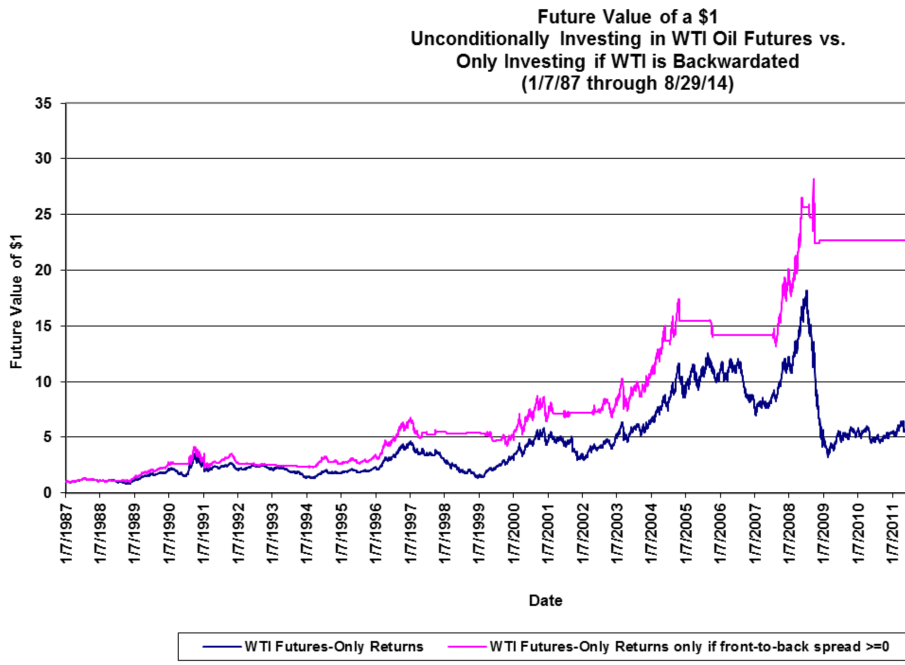

Exhibit 3 Future Value of a $1 Unconditionally Investing in WTI Oil Futures vs Only Investing if WTI is Backwardated (1/7/87 through 8/29/14)
Source: Bloomberg

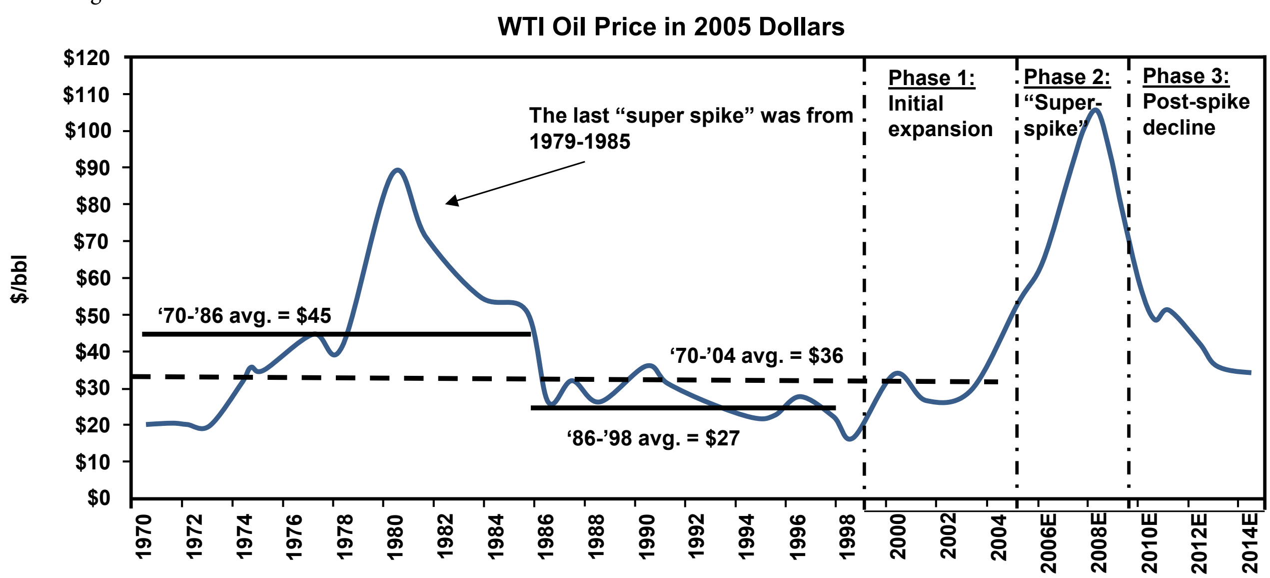

Exhibit 4 WTI Oil Price in 2005 Dollars - Super-Spike Prediction
Source: Graph based on Murti et al. (2005), Exhibit 2

Harrington (2005)'s arguments; and (3) any price super-spike would be temporary, once the price level was discovered that would result in demand destruction, as was essentially argued in Murti *et al.* (2005) and is illustrated in Exhibit 4.

High Spot Prices

Arguably, this is exactly what happened during 2004 through mid-2008. Regarding the first point, Exhibit 5 illustrates how crude oil prices exploded as OPEC spare capacity collapsed.

By July 2008 the excess-capacity cushion became exceptionally small relative to the risk of supply disruptions due to naturally-occurring weather events as well as due to well-telegraphed-and-perhaps-well-rehearsed geopolitical confrontations. At that point, the role of the spot price of oil was arguably to find a level that would bring about sufficient demand destruction to increase spare capacity, which did occur quite dramatically, starting in the summer of 2008, after which the spot price of oil spectacularly dropped by about $100 per barrel by the end of 2008, confirming Exhibit 4's prediction. Exhibit 6, which is drawn from work by researchers at the Federal Reserve Bank of Dallas, is consistent with this narrative.

There were a number of plausible fundamental explanations that arose from any number of incidental factors that came into play to reduce OPEC spare capacity, culminating in the 2008 oil price spike. As covered by Amenc *et al.* (2008), these incidental factors included: (1) a temporary spike in diesel imports by China in advance of the Beijing Olympics; (2) purchases of light sweet crude by the U.S. Department of Energy for the Strategic Petroleum Reserve; (3) instability in Nigeria; and (4) tightening environmental requirements in Europe.

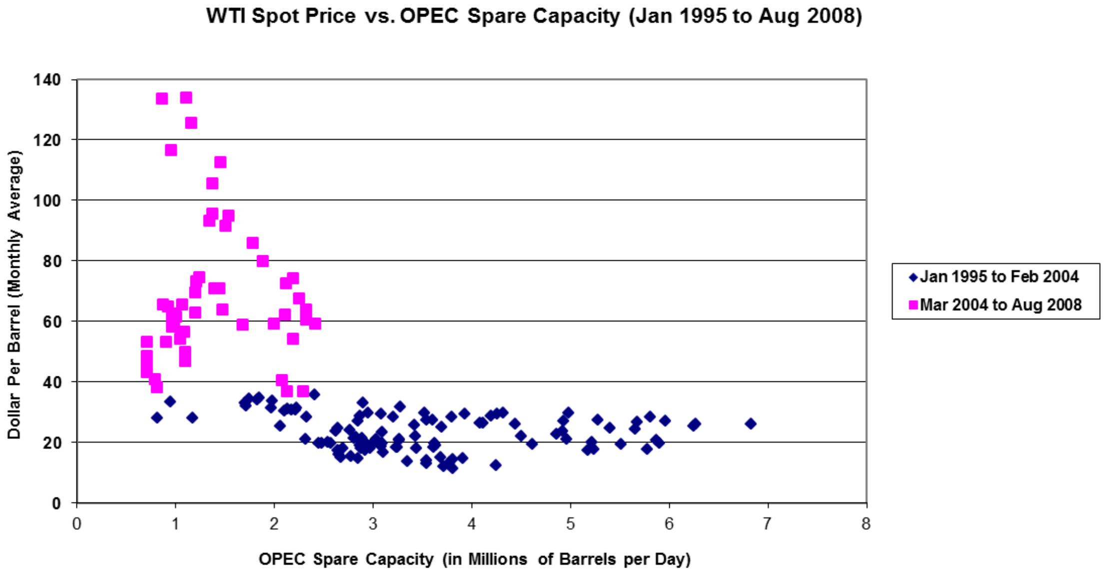

Exhibit 5 WTI Spot Price vs. OPEC Spare Capacity (January 1995 to August 2008)
Source: The WTI Spot Price is the "Bloomberg West Texas Intermediate Cushing Crude Oil Spot Price," accessible from Bloomberg using the following ticker: "USCRWTIC <index>".
The OPEC Spare Capacity data is from the U.S. Energy Information Administration's website.
Presenting data in this fashion is based on Büyükşahin et al. (2008), Exhibit 10, which has a similar, but not identical, graph. Their graph, instead, shows "Non-Saudi crude oil spare production capacity" on the x-axis. In Büyükşahin (2011), Slide 49, the energy researcher shows that this relationship structurally changed after January 2009.

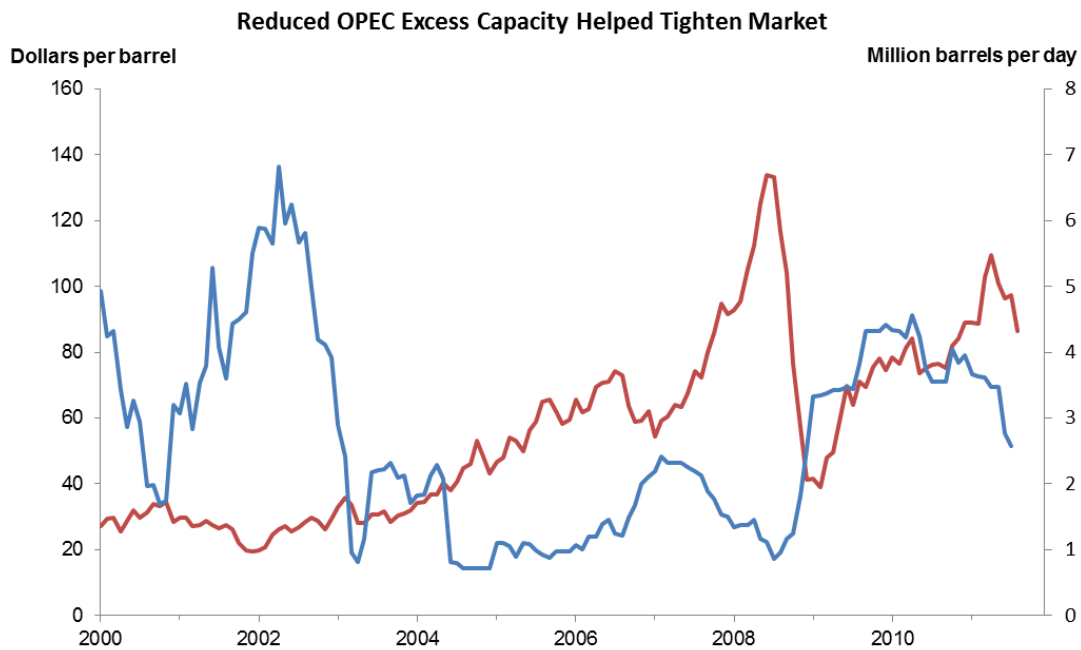

Exhibit 6 Reduced OPEC Excess Capacity Helped Tighten Market
Sources: U.S. Energy Information Administration; Wall Street Journal."
Graph based on Plante and Yücel (2011), Chart 2.

Precautionary Stock Building

Data Problems

Our second point had been that at sufficiently low levels of OPEC spare capacity, the markets would undertake precautionary stock building, which would then lead to persistent contangos in the crude oil futures markets. At this point, our narrative is admittedly, but necessarily, speculative. A perceptive reader of crude-oil narratives would note that U.S. crude oil inventories actually declined prior to mid-2008 (although floating storage did increase from March through May 2008), as noted by Plante and Yücel (2011).

Here is the problem. "Reliable inventory data outside the OECD is often absent. … This is worrying because it is the non-OECD that currently provides almost all demand growth globally. The data is worst where it is needed most," explained McCracken (2014). In summary, there is not reliable data for *global* crude oil inventories.

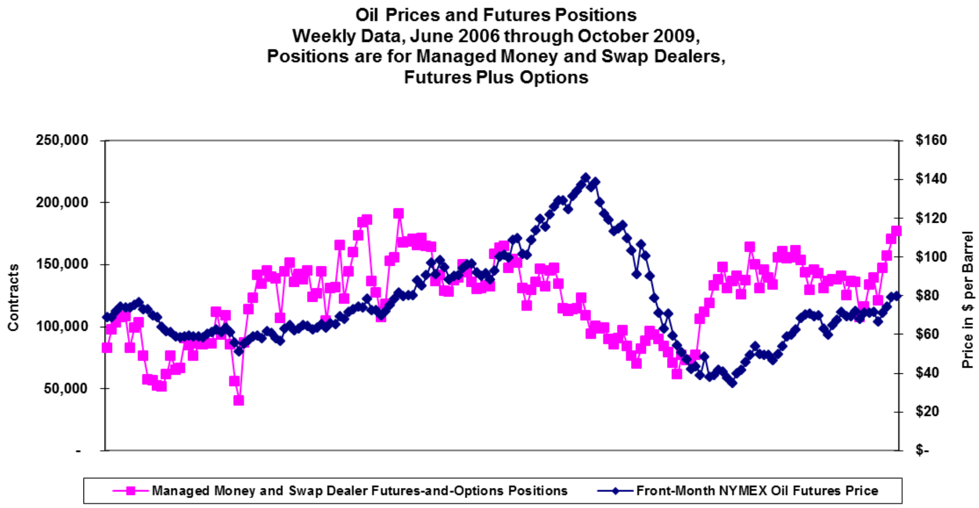

Exhibit 7 Oil Prices and Futures Positions, June 2006 through October 2009, weekly data
Positions are for Managed Money and Swap Dealers, Futures Plus Options
Source: Graph based on Ribeiro *et al.* (2009), Chart 1.

Persistent Contangos

But thankfully, given the transparent commodity futures markets, we can examine whether there were persistent contangos in the crude oil futures curves during 2004 through mid-2008. From 3/1/04 to 7/31/08, the WTI front-to-back spread averaged -44c, while the Brent front-to-back spread averaged -30c. During this time period, the WTI front-to-back spread traded in contango 68% of the time while the Brent front-to-back spread traded in contango 65% of the time. Each crude oil futures market provided persistent, but not continuous, opportunities for earning a return-for-storage.

Structural Deficiencies

In hindsight, we can point out the structural deficiencies in 2008's (temporary) crude oil bull market. The ultimately bearish factors were as listed above: (a) a diminishing of OPEC spare capacity, and (b) a persistence in oil futures contract contangos, which historically had been inconsistent with strong returns.

It is plausible that there were perceptive crude oil traders who were aware of the structural deficiencies in the 2008 oil price spike. As evidence, Exhibit 7 shows that according to Commodity Futures Trading Commission (CFTC) data, market participants who were classified as "managed money" and "swap dealers" *did* reduce their positions in the oil market in the months preceding the July 2008 price peak. For these two classes of traders, one advantage of having reduced their positions, as the market was dramatically rallying, is that one could not logically refer to their trading strategies as "predatory."

Finally, we would note that the third point above, that the price super-spike would be temporary was, in fact, what occurred.

The Link Between OPEC Spare Capacity and the Crude Oil Futures Curve Shape

In reviewing the above, we are essentially arguing that the amount of OPEC spare capacity has been a plausible determinant of the shape of the crude oil futures curve, particularly if a crude oil futures contract does not have local logistical bottlenecks and is therefore seamlessly connected to the global marketplace. With sufficient OPEC oil spare capacity, there would not be a need for prohibitively expensive precautionary inventories. And with sufficiently low inventories, we would expect that an oil market's futures curve would trade in backwardation.

Brent Futures (Excess) Returns
February 1999 through January 2015
Based on Monthly Data

	Unconditional Monthly Returns	Conditional on Previous Month's OPEC Spare Capacity > 1.8 mbd Monthly Returns	Conditional on Previous Month's OPEC Spare Capacity <= 1.8 mbd Monthly Returns
Arithemtic Average:	1.2%	1.7%	-.2%
Skew:	-.018	0.42	-0.88
Minimum:	-34%	-19%	-34%

Exhibit 8 Brent Futures (Excess) Returns February 1999 through January 2015, Based on Monthly Data
Source: Till (2015a), Slide 20.
Source of Brent Futures Data: Bloomberg. The Bloomberg ticker used for calculating Brent Futures-Only Returns is "SPGSBRP <index>".
Source of OPEC Spare Capacity Data: EIA (2015), Table 3c.
Explanation of Abbreviation: "mpd" stands for million barrels per day.
Necessary Caveats: These results would only be appropriate for trading or investment purposes if (a) the EIA's monthly data has not required substantial revisions after publication; and (b) if the state-of-the-world represented by an empirical analysis over the period, 1999-through-the present, continues to be the case. Both assumptions cannot be guaranteed.

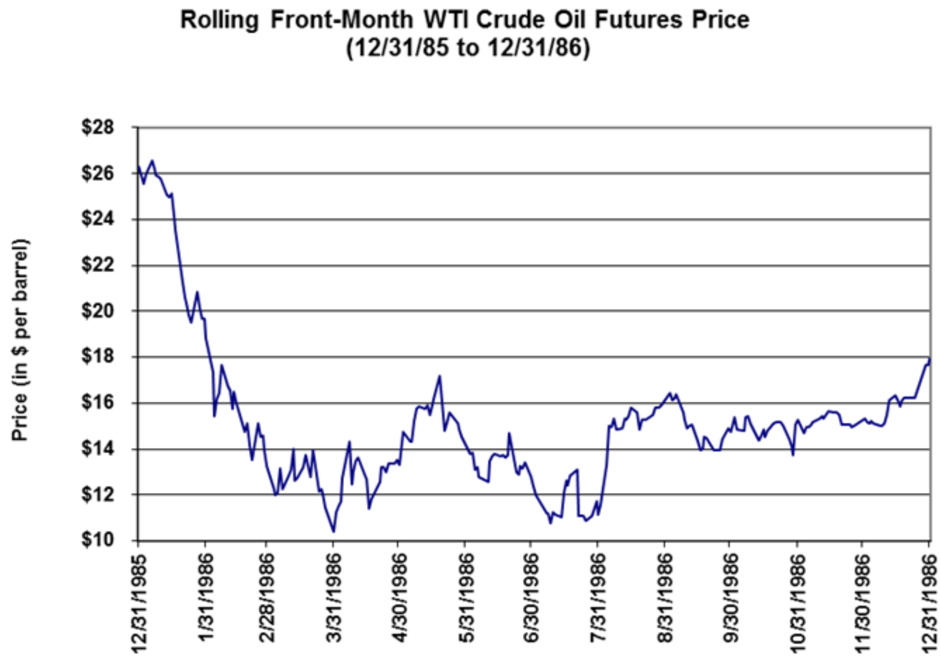

Exhibit 9 Rolling Front-Month WTI Crude Oil Futures Price (12/31/85 to 12/31/86)
Source: Bloomberg

Is there direct empirical support for linking the amount of OPEC spare capacity to the structural shape of a crude oil futures curve? The short answer is yes, but with a couple of caveats.

First of all, official reporting agencies and professional oil analysts use different definitions of OPEC spare capacity, including what precisely "effective" spare capacity actually is. Therefore, we will need to precisely note the source of our OPEC spare capacity data so that oil-market aficionados can determine whether our results are credible or not.

Secondly, for a longer term study of this issue, we need to focus on the Brent crude oil futures markets. At this point, it has only been the Brent contract that has been consistently connected to the global oil market. As discussed by Blas (2011), "From time to time, the [WTI] contract [had] disconnect[ed] from the global oil market due to logistical troubles at its landlocked point of delivery in Cushing, Oklahoma." This had meant that as compared to the Brent futures contract, the WTI futures contract had a greater propensity to trade in contango, as surplus inventories built up in the U.S. That said, due to the "ingenuity of logistical engineers," the WTI oil futures market has now effectively reconnected to the global oil marketplace, quoting *Platts* (2013). Essentially, noted Fenton *et al.* (2013), "the boom in … [domestic oil] production has [now] been well absorbed by existing U.S. infrastructure … [T]ruck, rail, and barge have all served to move the large increase in domestic crude supplies to U.S. refineries," whom, in turn, can export petroleum *products* abroad.Because the WTI market is now reconnected to the global oil marketplace, we expect that our Brent results would now apply to WTI as well.

The empirical results on linking OPEC spare capacity to an oil futures curve are as follows. Using EIA monthly data since 1995, we find that once OPEC spare capacity became lower than 1.8 million barrels per day for longer than a quarter, then the Brent front-to-back spread has traded in contango, on average, for the next two years. Till (2014a) includes additional back-tested work that is consistent with these results. That said, one must be very careful with back-tested results in making future predictions, but at least these historical results add evidence to our line of argument. To be complete, one caveat with these results is that there are month-to-month transient factors that also influence a crude oil futures contract's shape, as covered in Till (2014b).

We should note that we are not the first to link OPEC spare capacity to a crude oil futures curve's shape. Building on past work, Haigh and Dannesboe (2014), for example, found a statistically significant relationship through cointegration methods. Of note, though, we have focused on Brent futures contract front-to-back spreads while Haigh and Dannesboe (2014) mainly focused on the spread between the WTI nearby futures contract versus the 12th-month contract maturity.

The Link Between OPEC Spare Capacity and the Crude Oil Futures Returns

In Till (2015a), we take this line of argument one step further. If insufficient spare capacity generally leads to the crude oil futures curve trading in contango, wouldn't long-term crude oil futures returns be improved by avoiding positions in crude oil contracts when spare capacity is insufficient? The answer is yes, at least historically. Over the period, February 1999 through January 2015, if one unconditionally bought and rolled Brent futures contracts, the returns were 1.2% per month and were negatively skewed. These results exclude the returns from fully collateralizing one's futures contract holdings. But if one only held Brent futures contracts when OPEC spare capacity was greater than 1.8 million barrels per day, the returns became 1.7% per month and the returns were positively skewed, as shown in Exhibit 8. With this strategy, one only held crude oil futures contracts 73% of the time, and the returns shown in the middle column of Exhibit 8 were only calculated when this spare-capacity condition held.

Current Environment

As discussed in Till (2015b), spare-capacity figures have been helpful in deciding upon structural holdings in crude oil futures contracts *when combined with curve-shape data*. In other words, the spare-capacity situation is necessary, but not sufficient, for deciding upon whether to enter into crude-oil futures contract positions. Spare capacity has to be sufficient, but the curve shape of crude oil futures contracts also has to be supportive, ie., in backwardation.

While insufficient spare capacity has historically led to the crude oil futures curve trading in contango, this is not the only factor that can lead to a crude oil futures curve trading in contango. If there is sufficient spare capacity *and* ample supply, then the crude oil futures curve will also trade in contango. This is apparently the situation that we are in now: OPEC Gulf producers have shaken off their traditional role of balancing the oil market. Saudi Arabia and other Gulf oil producers had until recently acted as the central banker of the oil market and had essentially provided a free put to the marketplace in preventing a free fall in oil prices, even in the face of new oil production, particularly from the United States. Arguably, one might compare the current price environment to 1986 when Saudi Arabia and other Gulf producers apparently decided upon prioritizing market share, according to Gately (1986). Exhibit 9 shows the price path of crude oil in 1986. Drawing on Fattouh (2014), there was also ample OPEC spare capacity at the time.

How did holdings in oil futures contracts perform in 1986, both unconditionally and when using a curve-shape toggle? If one passively held and rolled WTI futures contracts, one would have lost -25.5% in 1986. Correspondingly, during that time, if one only held WTI futures contracts if the contract was backwardated, then the losses were significantly lower at -8.8%, again demonstrating the importance of curve shape as a signal.

Spare Capacity and Curve Shape

While the 1986 results may be interesting, one data point by itself is not very persuasive. In Till (2015a), we examine the historical returns of entering into crude oil futures contracts when space capacity is sufficient *and* when the curve shape is supportive; please see Exhibit 10.

This strategy, conditional on both ample spare capacity *and* the Brent futures curve trading in backwardation, is positively skewed with its worst monthly return being -15%. In this case, one only held crude oil futures contracts 45% of the time, and the returns shown in the right-hand column of Exhibit 10 were only calculated when both conditions held. When including the curve-shape toggle, the downside risk was, at least historically, further constrained, as compared to solely examining spare capacity. One could conclude that the addition of the curve toggle is advisable.

Conclusion

This article pursues the following line of logic:

(a) Over sufficiently long timeframes, it is the structural shape of a futures curve that has had a strong relationship with a commodity futures contract's returns.

(b) What is one fundamental feature of the oil futures markets that has led to the market trading in contango? Answer: Insufficient OPEC spare capacity. Therefore, it might not be wise to enter into structural positions in crude oil futures contracts when spare capacity is at pinch-point levels.

(c) Is examining the level of spare capacity sufficient for deciding upon structural positions in the oil futures markets? The answer is no: one should also directly examine the curve shape as well.

One caveat with this article is that it analyzed the crude oil futures markets using historical data. The conclusions in the article are only useful if the states-of-the-world that occurred historically continue to be the case going forward.

Endnotes

This article is updated from the lecture, "Oil Futures Prices and OPEC's Spare Capacity," which, in turn, was delivered at the University of Colorado Denver Business School's J.P. Morgan Center for Commodities on September 18, 2014 as part of the Center's Encana Distinguished Lecture Series. (The slides for this lecture are available at: http://www.edhec-risk.com/events/other_events/Event.2014-09-02.1535/attachments/Till_JPMCC_Lecture_180914.pdf.)

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	Conditional Solely on Previous Month's OPEC Space Capacity> 1.8 mbd	Brent Futures (Excess) Returns February 1999 through January 2015	Conditional on Previous Month's OPEC Space Capacity> 1.8 mbd AND Brent Front-to-Back Spread>0
	Monthly Returns	Based on Monthly Data	Monthly Returns
Arithmetic Average:	1.7%	Arithmetic Average:	2.0%
Skew:	.42	Skew:	.12
Minimum:	-19%	Minimum:	-15%

Exhibit 10 Brent Futures (Excess) Returns, February 1999 through January 2015, with Conditional Provisions
Source of Brent Futures Data: Bloomberg. The Bloomberg ticker used for calculating Brent Futures-Only Returns is "SPGSBRP <index>".
Source of OPEC Spare Capacity Data: EIA (2015), Table 3c.
Explanation of Abbreviation: "mpd" stands for million barrels per day.
Necessary Caveats: These results would only be appropriate for trading or investment purposes if (a) the EIA's monthly data has not required substantial revisions after publication; and (b) if the state-of-the-world represented by an empirical analysis over the period, 1999-through-the-present, continues to be the case. Both assumptions cannot be guaranteed.

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Premia Research LLC starts with the premise that all markets can become fundamentally overstretched. Accordingly, an index should either include natural hedges because of the potential of a market crash, or it should dynamically allocate out of a market during extremes in valuation. The design of the firm's indices reflects these beliefs.