July 28, 2022

Whither the Oil Markets? A July 27, 2022 Update[1]

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1 OVERVIEW

Beginning in Feb. 2022, I considered developments in the equity and oil markets, as financial markets anticipated and then responded to the outbreak of hostilities in Europe on Feb. 24, 2022 — and, more recently, their concern over inflation and recession in the West. *Inter alia,* perhaps with insufficient remorse, I noted U. S. equity markets ceased to be concerned with the crisis in the Ukraine as early as March 16 — in large part, because these markets turned their attention to the prospects of a recession as the Federal Reserve Board of Governors addressed the level of inflation in the U. S. As demonstrated below, the oil markets ceased expressing heightened concern to the impact of the Ukraine crisis on or about June 15, 2022.

While the equity markets are always of substantial interest, this report focuses on the oil market:

1. The Level of Spot Oil Prices
2. The Futures Curve for Oil Prices
3. Oil Markets — Supply- or Demand-Side Crisis?
4. Near-Term (One-Year Out) Prospects for Oil Prices
5. What About that Refining Spread?

[1]Acknowledgment: I am indebted to J. Glenn Andrews for valuable computing assistance.

6. Spare Oil Capacity in the Persian Gulf

While some of these indicators — such as the spot price of oil — are well-known, this report focuses on the metrics of statistical correlation (between equity and oil prices) and the implied volatilty "skew" to demonstrate the oil markets have proceeded "beyond" the (supply-side) Ukraine crisis and are focusing more on the (demand-side) concerns regarding a possible recession in the U. S. We review the attendant implications for forecasting oil prices one-year out.

2 Spot Crude-Oil Prices

In 2022, WTI oil prices have to date peaked twice: On March 8th, at a level of $123.70; and on June 8th, at $122.11. Since then, prices have declined to the mid-$90's. Fig. 1 displays the price of the WTI prompt-mo. contract — aka, the "spot price of oil" — since the end of 2021. The economic recovery from the pandemic and hostilities in Ukraine have caused an oil-price increase of some $23/bbl. (some 55 cents/gallon).

(PLACE FIG. 1 HERE.)


CL s97.26 98.23 / 98.23 2x1
As of Close 27 Ju Vol 310268 OpenInt 292215
CL1 Comdty 94) Suggested Charts 96) Actions 97) Edit Line Chart
12/15/2021 - 07/27/2022 Mid Px Local CCY Mov Avgs Key Events
1D 3D 1M 6M YTD 1Y 5Y Max Weekly Table + Quick-Add Add Data Edit Chart
Mid Price 98.12
High on 06/10/22 120.57
Average 99.49
Low on 12/17/21 70.64
120
110
100
98.12
90
80
70
Dec 2021
Jan
Feb
Mar
Apr
May
Jun
Jul
2022
Australia 61 2 9777 8600 Brazil 5511 2395 9000 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
Japan 81 3 4565 8900 Singapore 65 6212 1000 U.S. 1 212 318 2000 Copyright 2022 Bloomberg Finance L.P.
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3 The Current Oil Crisis: Supply- or Demand-Side Crisis?

3.1 Correlation(Oil Prices, Equity Prices)

The difficulty in analyzing the current oil market is the confluence of factors affecting prices. On the one hand, it is undeniable we remain impacted by the situation in the Ukraine. On the other, the actions of the Federal Reserve have unavoidably raised the question of a budding recession, and the latter is known to have substantial impact on the price of oil. As shown below, there is a particularly interesting statistic that helps identify whether the current phase of the oil market is driven primarily by supply- or demand-side considerations: The Correlation between Oil Prices and Equity Prices.

In considering the myriad recessions and geopolitical crises the world has passed through the past forty years, we have noted an important empirical regularity/stylized fact:

Type of Crisis	Historical Examples	Corr(Oil Prices, Equity Prices)
Demand-Side: Recession	1. The Great Recession, 2007 – 2009 2. Onset of Global Health Crisis, 2/15/2020	Positive
Supply-Side: Geopolitical Instability	1. "Arab Spring," 2011 2. Onset of Ukraine hostilities, 2/14/2022	Negative

Financial markets do not permit us to observe forward-looking measures of correlation,[2] so Fig. 2 below now presents that 45-day moving-window correlation for 2022. The sign of that correlation switched from a supply-side crisis negative value to a demand-side positive value on May 12, 2022.

(PLACE FIG. 2 HERE.)

[2]Using the methodology of Ronn (2021), "Using Equity, Index and Commodity Options to Obtain Forward-Looking Betas and Conditional-CAPM Expected Crude-Oil Spot Prices," *Journal of Energy Markets,* Dec. 2021, we can obtain forward-looking correlations.

3.2 The Current Oil Volatility "Skew"

Implied volatility, be it in the equity or oil markets, is concerned with the volatility implicit in option contracts; these implied vols answer the question, "If the market is using Black-Scholes to value observable option prices, what vol is it using?" For a given time to option expiration, the volatility "skew" is concerned with the depiction of oil implied volatility as a function of the option's moneyness, where the latter is defined as the ratio of an option's strike price K to the price of its underlying futures contract F (written mathematically as K/F).

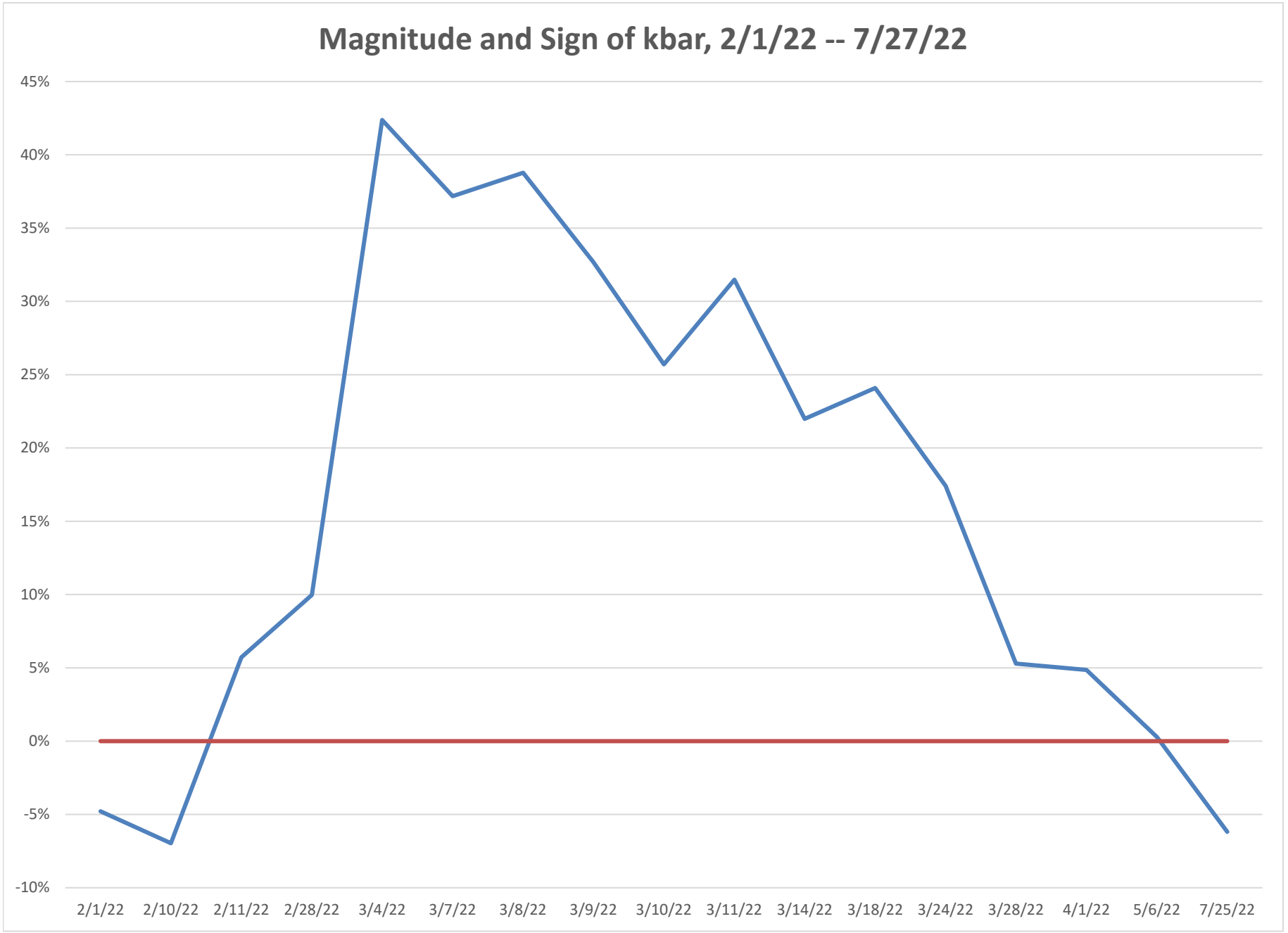
For most of the past 14 years, the oil vol "skew" has been skewed to the left — meaning implied vols for lower strike prices were higher than those for higher strike prices. In assigning a higher implied vol to the lower strike prices, markets were indicating a greater concern with an oil price "crash" than with a "spike."

As an empirical phenomenon, oil prices tend to spike during a geopolitical crisis, one typically, although not currently, emanating from the Middle East. Clearly, oil prices spike if consumers are concerned with the timely delivery of oil from important oil-producing regions. Beginning Feb. 11, the oil vol skews began to be skewed to the right, exhibiting a concern with oil futures prices spiking.

In my research, I have quantitatively addressed this issue by employing a model able to establish quantitatively a vol "skew": In Murphy and Ronn (2014), we calibrated a Merton (1976) Jump-Diffusion Model, which usefully gives rise to a parameter explicitly quantifying whether the oil options market is currently concerned with spikes or crashes in prices.[3] Fig. 3 below presents the magnitude of the kbar parameter over the period Feb. 1, 2022 through July 27, 2022: A positive value signifies concern over price spikes, whereas a negative value reflects a crash concern. Fig. 4 presents the actual vol skews on the dates of June 14 and 17th, at which time the transition from spike concern to crash concern occurred last month.

(PLACE FIGS. 3 AND 4 HERE.)

[3]Murphy, Finbarr and Ehud I. Ronn, "The Valuation and Informational Content of Options on Crude-Oil Futures Contracts," *Review of Derivatives Research,* 2014.


Magnitude and Sign of kbar, 2/1/22 -- 7/27/22
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
-5%
-10%
2/1/22
2/10/22
2/11/22
2/28/22
3/4/22
3/7/22
3/8/22
3/9/22
3/10/22
3/11/22
3/14/22
3/18/22
3/24/22
3/28/22
4/1/22
5/6/22
7/25/22

Click a volatility point for details

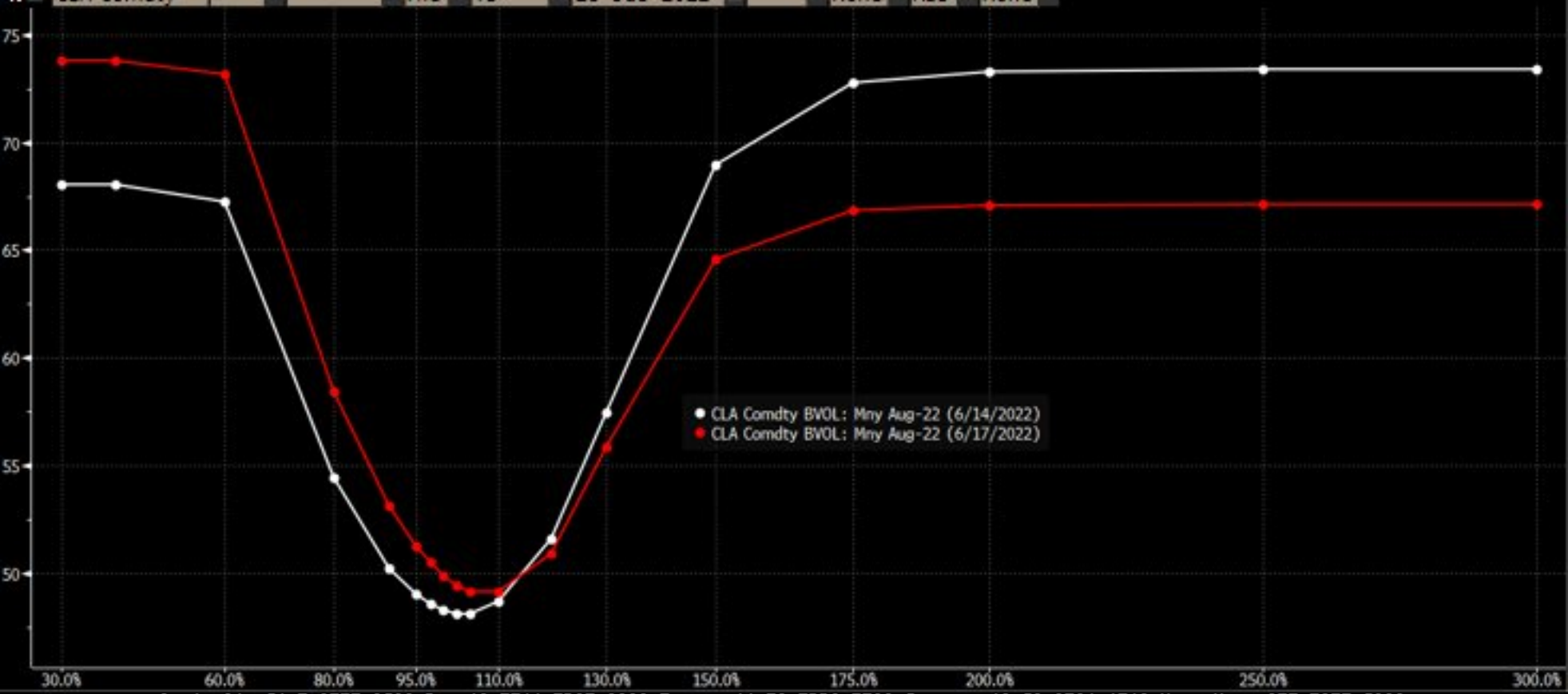
CLA Comdty | 90) Asset | 91) Actions | 92) Views | 93) Settings | Volatility Surface

Default rate curves will migrate to RFR on 11 Aug. More »

Moneyness

1) Vol Table | 2) 3D Surface | 3) Term | 4) Skew | 6) Prices | 7) Correlation

	Security	Data Series			Surface as of		Comparison		Mkt Vol
1.	CLA Comdty	BVOL	Aug-22	Mid	Custom	14-Jun-2022	None	Abs	None
2.	CLA Comdty	BVOL	Aug-22	Mid	Custom	17-Jun-2022	None	Abs	None
3.	CLA Comdty			Mid	TD	28-Jul-2022	None	Abs	None
4.	CLA Comdty			Mid	TD	28-Jul-2022	None	Abs	None



3.3 OVX: The Level of Implied Vol in the Oil Markets

Before proceeding, it is useful to present in Fig. 5 a graph of the time-series of OVX, the implied oil volatility index that is the oil analogue to the 30-day S&P 500 implied volatility index, VIX. For calendar-year 2022 to date, OVX peaked at 78.91% on March 7th, with the onset of hostilities in Ukraine. The current level of 48.99% is substantially above the mid-30% value of OVX in normal times; the spread of 25.7% to the equity VIX remains elevated relative to normal times. In brief, while the market is not as uncertain about the prospects of oil prices as it was during the height of the crisis, its concerns remain elevated relative to "normalcy."

(PLACE FIG. 5 HERE.)


OVX ↑ 48.99 +1.18
At 17:00 d 0 47.15 H 52.90 L 46.96 Pre 47.81
OVX Index Suggested Charts Actions Edit Line Chart
12/31/2021 - 07/27/2022 Last Px Local CCY Mov Avgs Key Events
1D 3D 1M 6M YTD 1Y 5Y Max Daily Table + Quick-Add Add Data Edit Chart
Last Price 48.99
High on 03/07/22 78.91
Average 51.42
Low on 01/11/22 34.31
80
70
60
48.99
40
Jan
Feb
Mar
Apr
2022
May
Jun
Jul
Australia 61 2 9777 8600 Brazil 5511 2395 9000 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
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SN 556779 BRT GMT-3:00 H222-7453-171 27-Jul-2022 17:22:34

4 Near-Term (One-Year Out) Prospects for Oil Prices: The Oil Futures Curve and One-Year Expected Spot Prices

4.1 The Futures Curve

As is well-known, the oil futures curve depicts the prices of crude-oil futures contracts by maturity, going out as far as Feb. 2033 (although with much diminished liquidity in the out years). While that downward-sloping curve is depicted in Fig. 6 below,[4] of greater interest at this time is the slope of that curve. That slope is presented in Fig. 7 as the difference between the price of the contract closest to maturity (aka, the "prompt-month contract") and the one exactly twelve months from delivery.

(PLACE FIGS. 6 AND 7 HERE.)

[4] A downward-sloping futures curve is described by the term "backwardation."

CLU2 ≤94.70 95.01 / 95.20 1 × 1
As of Close 22 Jul Vol 294067 OpenInt 296398
CLA Comdty 1) Actions 3) View Table Commodity Curve Analysis


CL 98.30 +3.32 ic98.30/98.31 2x1 Pre 94.98
At 16:49d Vol 306299 Op 95.60 Hi 98.59 Lo 94.30 OpenIn 292215
Buy CL13 COMB Co Sell CL1 COMB Com 96) Actions 97) Edit Spread Analysis
Data Last Price Data Last Price 08/02/2002 - 07/27/2022 Regression Corr 120
Mult 1.0 Const 0.0 Mult 1.0 Const 0.0 Normalize by Factor 100.0 Calc % Local
1D 3D 1M 6M YTD 1Y 5Y Max Weekly Table Add Studies or Events Edit Chart
Hi: 145.29 Hi: 145.87
Low: 23.19
Low: 16.94
Last Price
CL13 Comdty 84.52
CL1 Comdty 98.30
266.24%
246.11%
98.30
84.52
140
120
60
40
20
Hi: 22.59
CL13 Comdty - CL1 Comdty -13.78
Low: -25.61
20
10
0
-10
-13.78
-20
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023
Australia 61 2 9777 8600 Brazil 5511 2395 9000 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
Japan 81 3 4565 8900 Singapore 65 6212 1000 U.S. 1 212 318 2000 Copyright 2022 Bloomberg Finance L.P.
SN 556779 BRT GMT-3:00 H222-7453-171 27-Jul-2022 16:59:21

What is clearly noteworthy about the current futures curve is how steeply downward-sloping it is: In terms of where the market is pricing a futures curve one year out, it has been as much as $25 below and is currently more than $13 below the spot price, at about $84.52. Although not easily "proven," I suspect the steepness of the slope has to do with the current elevated spot price of oil, due to events in Europe.

4.2 Analysts' Price Forecasts

While a steeply downward-sloping futures curve would appear to augur lower spot prices in the future, it is imperative on us to recognize the risk premium embedded in futures prices. Such a risk premium can be negative — as it was during the beginning of the Ukraine supply-side crisis in Feb. — or it can be positive if we are primarily concerned with a demand-side recession. In the latter case, futures prices are below their forecast ("expected") levels.

To see both of these effects, consider Figs. 8 and 9 below: These figures present analytsts' price forecasts relative to the concurrent futures prices. Back in March, futures prices were elevated more than $20 due to then supply-side crisis of Ukraine; currently, futures prices are below their one-year-ahead forecast levels by about $6 due to a demand-side concern about recession.Stated differently, if the recession does not occur, analysts are expecting prices to increase by that $6 spread.

(PLACE FIGS. 8 AND 9 HERE.)

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NYMEX WTI $/BBL | Browse | As Of 03/08/22 | Ticker Type Actual

Quarterly Forecast | Yearly Forecast

Overview | Curve Analysis | Ranking

Firms Standard | Custom | Rank All | Updated Last 6 Months

Consensus	Spot	As Of	Q1 22	Q2 22	Q3 22	Q4 22	Q1 23	Q2 23
Median		03/03/22	83.00	77.00	75.00	74.20	73.75	72.00
Mean		03/03/22	82.87	80.58	77.11	75.98	76.89	76.26
High		03/03/22	98.00	98.00	93.00	102.10	111.40	117.00
Low		03/03/22	72.50	65.00	65.00	60.00	61.00	61.00
Forward	123.70	03/08/22	103.18	112.03	102.12	97.28	92.23	89.98
Diff (Median - Curr)			-20.18	-35.03	-27.12	-23.08	-18.48	-17.98
Firm	**Rank**	**As Of↓**	**Q1 22**	**Q2 22**	**Q3 22**	**Q4 22**	**Q1 23**	**Q2 23**
Landesbank Baden-Wuerttemberg		03/03/22	98.00	98.00	93.00	88.00	83.00	78.00
Capital Economics Ltd	3	03/02/22	92.67	97.00	89.50	80.00	76.13	72.38
Goldman Sachs Group Inc/The		02/28/22	127.00	127.00	127.00	127.00	110.00	110.00
Banco Santander SA		02/21/22	86.32	82.44	78.56	74.68		
Commerzbank AG		02/15/22	87.00	82.00	77.00	77.00	72.00	72.00
Westpac Banking Corp		02/07/22	85.43	87.38	80.91	71.20	64.72	61.17
MUFG Bank	2	02/01/22	85.10	94.70	87.80	102.10	111.40	117.00
Rabobank International		02/01/22	89.28	89.55	90.00	90.48	91.08	91.38
Emirates NBD PJSC		01/28/22	72.50	70.00	65.00	60.00		
Intesa Sanpaolo SpA	5	01/24/22	73.00	65.00	66.00	68.00	68.00	68.00
Market Risk Advisory Co Ltd		01/06/22	73.00	70.50	69.00	71.50	70.40	70.70
MPS Capital Services Banca per...		12/27/21	77.00	70.00	67.00	66.00		
Natixis SA		12/13/21	77.50	74.50	72.50	72.50	72.50	69.50
Australia & New Zealand Bankin...		10/25/21	81.20	75.60	73.40	74.20	77.40	82.00
BNP Paribas SA		10/19/21	83.00	75.00	75.00	77.00	75.00	72.00
ABN AMRO Bank NV		10/14/21	82.00	77.00	72.00	67.00	61.00	61.00
Deutsche Bank AG		07/29/21	67.00	57.00	62.00	62.00		
Toronto-Dominion Bank/Toronto		03/30/21	62.00	62.00	64.00	64.00		
Barclays PLC	1	03/22/21	69.00	63.00	68.00	71.00		
CIMB		03/12/21	60.00					

(Last Price: Most Recent Forecast, Prior Forecast, Excluded From Consensus)

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NYMEX WTI $/BBL | Browse | As Of 07/27/22 | Ticker Type Actual

Quarterly Forecast | Yearly Forecast

Overview | Curve Analysis | Ranking

Firms Standard | Custom | Rank All | Updated Last 6 Months

Consensus	Spot	As Of	Q3 22	Q4 22	Q1 23	Q2 23	Q3 23	Q4 23
Median		07/27/22	107.00	95.00	95.50	90.00	88.00	84.00
Mean		07/27/22	108.32	100.00	97.03	91.95	91.28	82.67
High		07/27/22	137.00	130.33	128.48	127.05	126.45	110.00
Low		07/27/22	89.50	80.00	75.00	69.00	68.63	64.88
Forward	98.38	07/27/22	95.81	89.77	86.20	83.99	82.13	80.59
Diff (Median - Curr)			+11.19	+5.23	+9.30	+6.01	+5.87	+3.41

Firm	Rank	As Of↓	Q3 22	Q4 22	Q1 23	Q2 23	Q3 23	Q4 23
Banco Santander SA		07/22/22	96.00	88.01	81.80	78.95	77.05	74.20
Citigroup Inc		07/22/22	95.00	81.00	75.00	69.00	74.00	71.00
Goldman Sachs Group Inc/The		07/21/22	137.00	125.00	125.00	125.00	120.00	110.00
Commerzbank AG		07/11/22	97.00	92.00	92.00	87.00	87.00	87.00
Deutsche Bank AG		07/05/22	107.00	107.00	107.00	93.00	88.00	88.00
Market Risk Advisory Co Ltd		07/01/22	96.33	92.67	70.40	70.70	71.00	
Intesa Sanpaolo SpA	5	06/09/22	115.00	104.00	99.00	96.00	92.00	88.00
MPS Capital Services Banca per…		05/20/22	97.00	91.00				
Westpac Banking Corp		04/22/22	113.00	108.00	104.00	99.00	91.00	84.00
Natixis SA	4	04/07/22	110.00	95.00	87.00	83.00	82.00	77.00
MUFG Bank		04/01/22	136.00	108.00	106.00	95.00	98.00	
Rabobank International		03/23/22	127.92	130.33	128.48	127.05	126.45	
Emirates NBD PJSC		03/23/22	115.00	110.00				
Landesbank Baden-Wuerttemberg		03/03/22	93.00	88.00	83.00	78.00		
Capital Economics Ltd		03/02/22	89.50	80.00	76.13	72.38	68.63	64.88
Australia & New Zealand Bankin…	1	10/25/21	73.40	74.20	77.40	82.00	81.00	83.20

(Last Price: Most Recent Forecast, Prior Forecast, Excluded From Consensus)

4.3 Using the CAPM to Predict One-Year Ahead Oil Prices

In my research, I adopted the Capital Asset Pricing Model (the CAPM) to generate oil-price forecasts. The Appendix to this document presents the "theory" of that approach. What that Appendix demonstrates is that, when Correl(Oil Prices, Equity Prices) < 0 — say, because of a geopolitical crisis — the resulting futures price is greater than the expected (forecast) price, reflecting the intuitive notion of a risk premium attributable to concerns over oil supplies reaching consumer markets.

The appendix demonstrates the computation of an oil-price risk premium (i.e., "Annualized Expected Futures Price Change") and the dollar risk premium (i.e., expected price − futures price) are given by

$$\begin{pmatrix} \text{Annualized Expected} \\ \text{Futures Price Change} \end{pmatrix} \equiv \begin{pmatrix} \text{Correl-} \\ \text{ation} \end{pmatrix} \begin{pmatrix} \text{Implied} \\ \text{Vol} \end{pmatrix} \begin{pmatrix} \text{Stock Market} \\ \text{Sharpe Ratio} \end{pmatrix} \tag{1}$$

$$\begin{pmatrix} \text{Expected} \\ \text{Price} \end{pmatrix} - \begin{pmatrix} \text{Futures} \\ \text{Price} \end{pmatrix} = \text{Risk Premium} \times \text{Futures Price} \tag{2}$$

In order to compute the risk premium and the price forecast for $T = 1$ yr. out, we require these data inputs:

Description	Datum
Futures Price	\$88.00
Correlation Coefficient	0.1127
Futures Implied Vol	46.15%
Sharpe Ratio	0.45

Based on eq. (1), the annualized risk premium is given by the product $0.1127 \times 0.4615 \times 0.45 = 2.34\%$. In the dollar terms of eq. (2), the expected price exceeds the futures price by $88.00 \times 0.0234 = \$2.06$. This estimate is lower than the \$6 reported by analysts forecasts, but recall the correlation coefficient used here is a backward-, not forward-looking, one.

5 The Refining Spread in 2022

There is one, albeit imperfect, measure of the U. S. refining spread: The difference between refined gasoline in New York harbor and the price of crude oil at Cushing, OK. The measure is a biased one, since the price of crude in New York harbor has been greater than that of Cushing for the past eleven years, due to the increased crude-oil production in the Continental U. S. causing the price at Cushing to trade at a discount. The magnitude of that discount is currently about $9.20.

Back in 2006, Congress directed the Commodity Futures Trading Commission to investigate whether the prices of gasoline products after Hurricanes Katrina and Rita "resulted from market manipulation or price gouging practices in the sale of gasoline." At that time, the measured refining spread difference peaked at $36/bbl.

As Fig. 10 shows below, back on June 3rd the measure refning spread peaked at over $60/bbl. and subsequently declined to $32. According to businessinsider.com,

> "The reasoning behind such large spreads is, ironically, largely to do with the rebound in crude supply. The global release of crude oil from countries' strategic reserves have helped ease the supply-demand imbalance that plagued energy markets in early 2022. Yet only a small fraction of the release was of refined products, and that only took place in Europe. The rest of the world is desperate for gasoline and other petroleum products, not the crude released by the US and its allies.
>
> "The release has also created a new supply-chain bottleneck. Refiners are working at full tilt to process crude into final products, but overall refining capacity has been on the decline since the start of the pandemic. The onset of virus-related lockdowns forced many plants to shut their doors, and that's left the industry unable to service the boom in demand for crude processing. Total US refinery capacity is currently the second-lowest its been since late 2014, according to the Energy Information Administration."

(PLACE FIG. 10 HERE.)

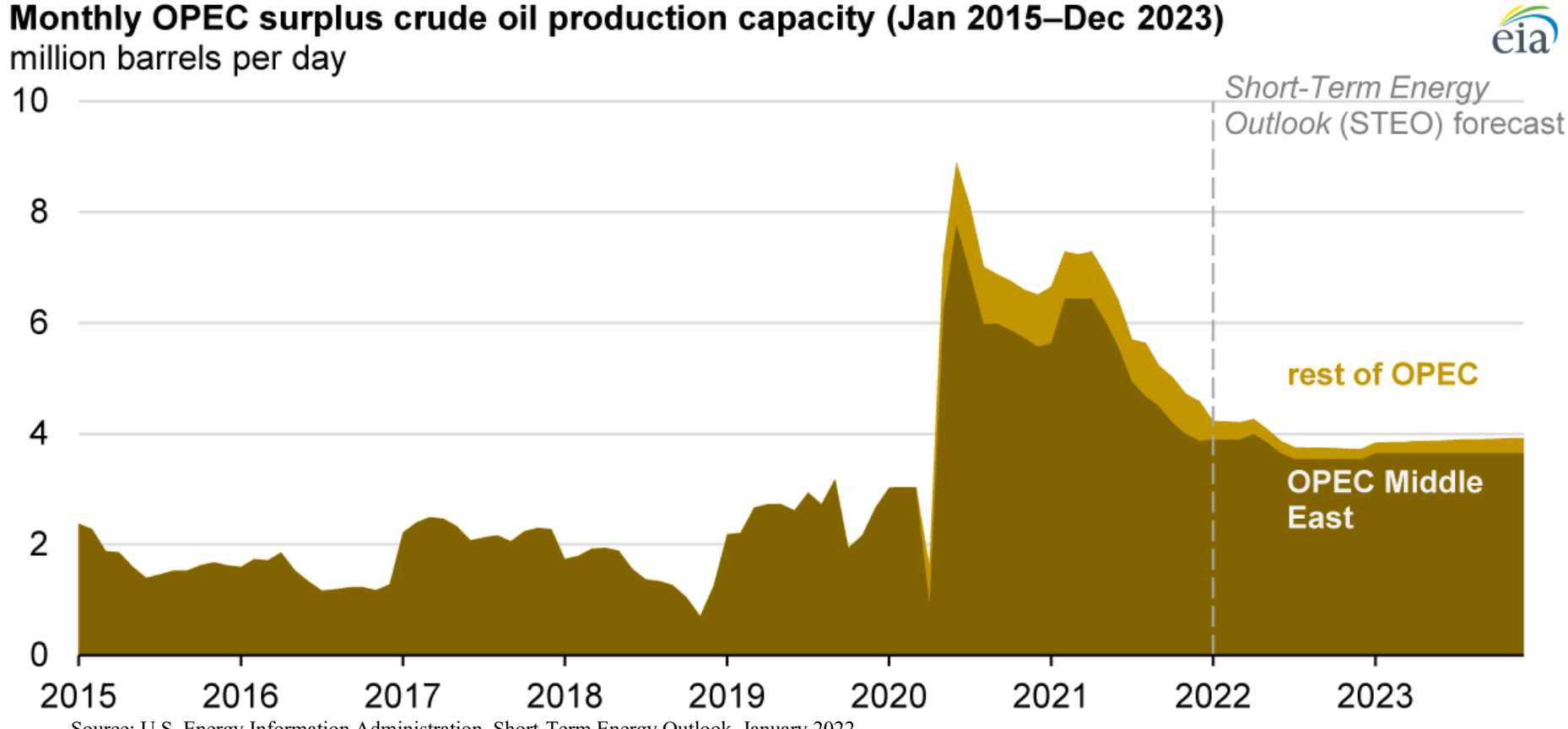

HUCL1 32.036 +2.708 -- / --
At 7/22 d Op 29.465 Hi 32.777 Lo 27.626 Prev 29.328 Vol 0
HUCL1 Index 94 Suggested Charts 98) Actions 97) Edit Line Chart
02/15/2020 - 07/22/2022 Mid Px Local CCY Mov Avgs Key Events
1D 3D 1M 6M YTD 1Y 5Y Max Daily Table + Quick-Add Add Data Edit Chart
Mid Price 32.036
High on 06/03/22 60.634
Average 19.648
Low on 03/24/20 -2.734
60
50
40
32.036
30
20
10
0
Mar Jun Sep Dec Mar Jun Sep Dec Mar Jun
2020 2021 2022
Australia 61 2 9777 8600 Brazil 5511 2395 9000 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
Japan 81 3 4565 8900 Singapore 65 6212 1000 U.S. 1 212 318 2000 Copyright 2022 Bloomberg Finance L.P.
SN 556779 BRT GMT-3:00 G683-2409-173 24-Jul-2022 13:47:55

6 Spare Oil Capacity in the Persian Gulf

In anticipation of the American president's travel to the Middle East earlier this month, there was debate on whether the large Persian Gulf oil producers had surplus capacity to increase oil production. As is well-known, estimation of Persian Gulf oil producers' spare capacity is hindered by the caution with which they share such information. It would require experts on the Middle East to comment on whether these recent meetings entailed discussion of increasing oil production.

Fig. 11 below documents what the U. S. Energy Information Administration has shared regarding their own estimates of OPEC's surplus capacity.

(PLACE FIG. 11 HERE.)



Source: U.S. Energy Information Administration, Short-Term Energy Outlook, January 2022
Note: Crude oil production totals do not include condensate.

Principal contributor: Sean Hill

7 Conclusions

With the standard caveat regarding uncertainty in equity and oil markets, as well as geopolitical and economic developments,

1. A recovery from the pandemic economy would doubtless have elevated oil prices. While in a very real sense oil and equity markets have signaled thay have "moved on" from a predominant and immediate concern about the situation in Ukraine and its implications for oil prices, it would appear prices are currently elevated by some $15 relative to where they would be if the post-pandemic situation had not been accompanied by that profound geopolitical crisis.

2. Absent a significant improvement in the international situation and/or a deeper-than-expected recession, spot wholesale prices are expected to decline from their current $97 to approx. $88 in one-year's time.

3. If, as expected, more refining capacity comes on line, retail gasoline prices may decline further than indicated by their wholesale-price counterparts.

A Appendix — A CAPM Approach to Forecasting Oil Prices

- Let

  μ_T = Expected return on maturity T
  μ_M = Expected return on the market portfolio
  r = Riskfree rate of interest
  β_T = Market beta of oil futures contract of maturity T
  ρ_T = Corr(R_M, R_T)
  F_{0T} = Current time 0 price of futures contract for maturity T
  S_T = Spot price of oil at date T; at time 0 (today), that price is unknown
  λ = Equity market's Sharpe Ratio

Then

$$\begin{aligned}
\mu_T &= \beta_T (\mu_M - r) = \frac{\text{Cov}(R_T,\, R_M)}{\text{Var}(R_M)} (\mu_M - r) \\
&= \frac{\rho_T \sigma_T \sigma_M}{\sigma_M^2} (\mu_M - r) = \frac{\rho_T \sigma_T}{\sigma_M} (\mu_M - r) \\
&= \rho_T \sigma_T \frac{\mu_M - r}{\sigma_M} \qquad (3)
\end{aligned}$$

- With respect to futures contract of maturity T,

$$\begin{aligned}
E(S_T) &\equiv F_{0T} \exp\{\mu_T T\} \\
&= F_{0T} \exp\{\rho_T \sigma_T \lambda T\} \\
\Longrightarrow \frac{1}{T} \ln\left[\frac{E(S_T)}{F_{0T}}\right] &= \rho_T \sigma_T \lambda \\
\begin{array}{c}\text{Annualized Expected} \\ \text{Futures Price Change}\end{array} &\equiv \rho_T \left(\begin{array}{c}\text{Current CL}_T \\ \text{Implied Vol}\end{array}\right)\left(\begin{array}{c}\text{Current Stock Market} \\ \text{Sharpe Ratio}\end{array}\right)
\end{aligned}$$

- Implication: When $\rho_T < 0$ — say, because of a geopolitical crisis — the resulting $F_{0T} > E(S_T)$ reflects the intuitive notion of a risk premium attributable to concerns over oil supplies reaching consumer markets