Commodity Portfolio Monthly

Everything you wanted to know about commodity volatility

Primer

Bank of America Merrill Lynch

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Commodities
Global

In commodities, volatility is connected to physical markets

Commodities are volatile compared to bonds or even equities, but this metric misses the full picture. The correlation of commodities to other asset classes and even within the asset class is low because volatility in oil, agriculture, or metals is closely connected to physical markets. The main driver of volatility in commodities is physical supply and demand, with inventories being a crucial buffer. In general, the higher the level of inventories, the lower the average price volatility. Still, when a commodity is very hard to store (i.e. like a gas or a liquid), vol tends to move higher as storage capacity fills up. This note is a commodity volatility primer that delves into fundamentals, features, and trading strategies in energy, metals, and agriculture volatility markets.

Vol features like skew are unique to each commodity

Storage plays a crucial role in commodity markets, and timespreads are inversely related to inventories for all commodities. Volatility relates to timespreads just as it relates to inventories. Commodity vol tends to spike upwards in response to sharp moves in inventories or market disruption events. But unlike timespreads, the term structure of commodity vol is generally downward-sloping as supply/demand shocks can adjust over time. Commodity vol is also highly seasonal due to fluctuations in supply and demand. In addition, commodity options tend to have a volatility smile due to their fat tail return distributions. Cyclical commodities (oil, base metals) usually show implied vol put skews, due to economic risks and a dominance of producer hedging. In contrast, weather sensitive commodities (grains, nat gas) tend to show call skews due to weather risks.

Diversity of vol market participants creates opportunities

The large volume of non-speculative market participants is a differentiating feature of commodity vol markets. Consumers and producers conduct regular hedging activities and are willing to pay a premium for protection against large adverse price moves. Investors willing to provide this protection can earn a positive risk premium by selling options. This premium, proxied by the spread between implied and subsequent realized volatility, is generally persistent and positive in commodities. Here, we revisit two systematic strategies—call overwriting and delta-hedged strangle (or straddle) selling—and show that a systematic risk premium exists in commodity vol markets. We conclude that short commodity vol strategies can enhance both the performance of a commodity risk premia portfolio as well as the performance of a cross asset short vol portfolio.

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Refer to important disclosures on page 54 to 55.

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1. Commodity vol vs. other asset classes

Commodities are volatile, but low correlation makes them attractive in a portfolio

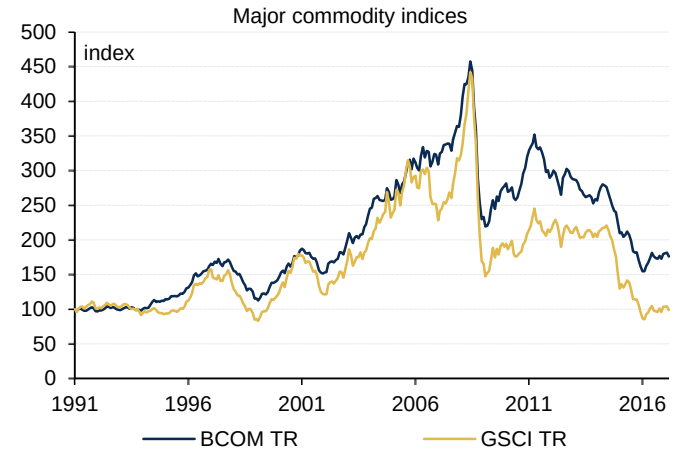
Commodities are often perceived to be a risky asset class because they are volatile compared to fixed income instruments or dividend-yielding stocks. Yet the correlation of commodities to other asset classes is very low. In fact, commodities bear very little, or even negative, correlation to equities and bonds, while generating moderate positive returns over long periods of time. The very negative commodity returns realized in the past couple of years due to the oil price crash stand in stark contrast to historical performance during the preceding five decades. By adding commodity investments to a portfolio composed of traditional asset classes, investors can potentially increase the risk-adjusted returns of the broad basket of investments.

Return on commodities as an asset class

Commodities move in super-cycles, so returns can disappoint at times

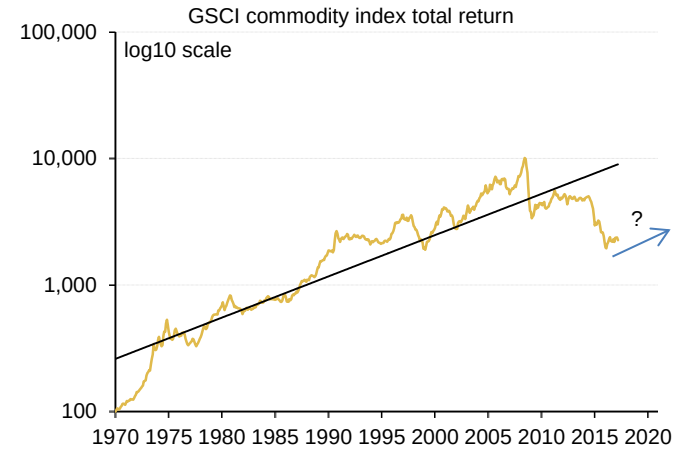
Commodity returns have been rather poor in the past decade and especially since oil prices crashed in mid-2014 (Chart 1). Following the peak in commodity prices in mid-2008 just before the Lehman crash, the GSCI has given back all the gains made in the two decades prior, and is now pretty much flat since its inception in 1992. The BCOM index, which has a slightly lower energy component, is not doing much better. The picture would have looked very different had we taken the same status check five years ago, when both indices were up more than 100% over the preceding decade.
Commodity prices tend to move in super-cycles, and just looking at performance over any five years or any single business cycle does not capture the full picture of how commodities perform over the long run (Chart 2). Over longer periods of time commodity returns have historically been steady and positive (Chart 3 below).

Chart 1: Commodity total returns have been rather poor in the past decade



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 2: Just looking at performance over any five years does not capture the full picture of how commodities perform over the long run

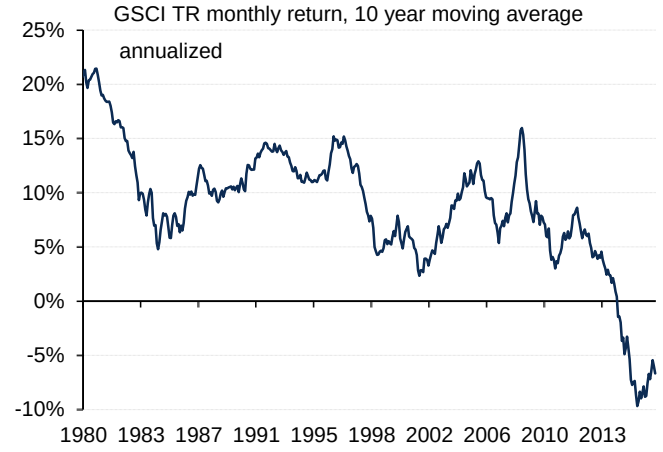


Source: Bloomberg, BofA Merrill Lynch Global Research

The commodity business cycle is different from other asset classes

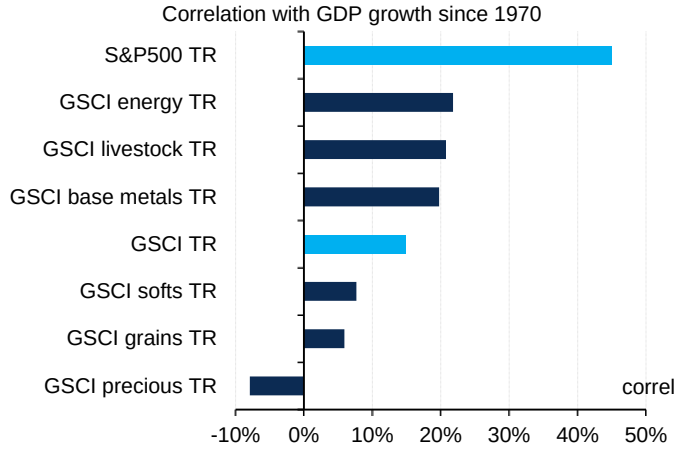
Within the super-cycles, commodities are also affected by much shorter business cycles. Still commodity prices are not very correlated with the business cycle itself, at least not contemporaneously, partly because supply adjusts to changes in demand with a time lag, and partly because demand for many commodities, like grains, is just not very cyclical. Commodity returns are far less correlated with the business cycle than for example equities (Chart 4), and even the cyclical commodities like energy and base metals are less correlated with economic activity than equities. Since most risky assets are rather cyclical, this feature makes commodities valuable diversifiers in a portfolio context.

Chart 3: Over longer periods of time commodity returns have historically been steady and positive



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 4: Commodity returns are far less correlated with the business cycle than, for example, equities



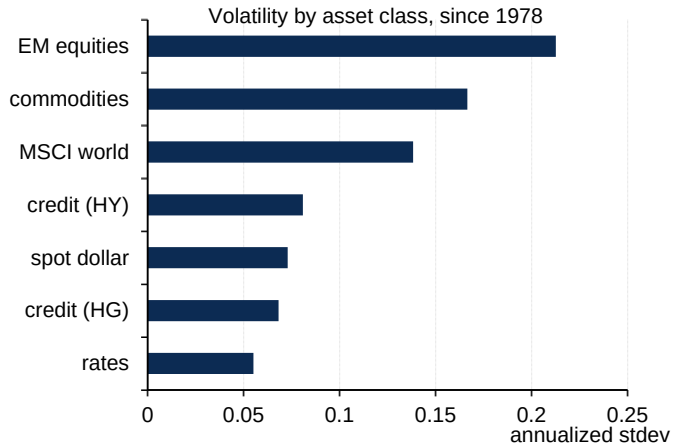
Source: Bloomberg, BofA Merrill Lynch Global Research

Volatility of commodities as an asset class

Commodity index vol is much lower than single commodity vol

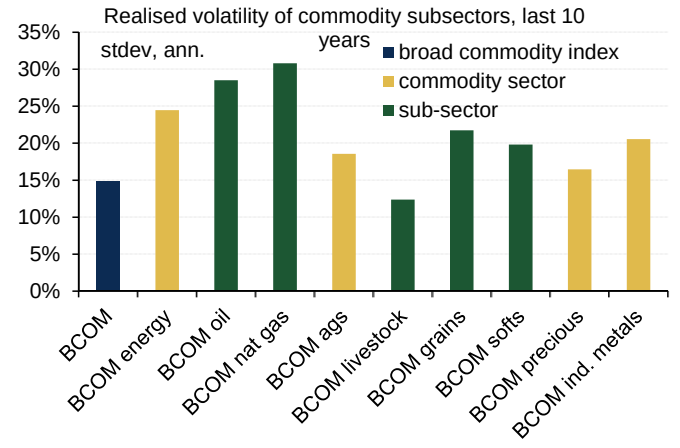
Commodities are volatile compared to other asset classes like credit and rates. On the volatility scale, they rank somewhere between DM and EM equities (Chart 5). Part of the reason for the relative high commodity vol compared to other asset classes is lower diversification of asset-specific risk. Commodity indices like BCOM or GSCI contain just over 20 commodities each while the S&P500 contains, well, 500 individual stocks. Yet commodity sectors like energy or metals are generally uncorrelated to each other. At the micro level the supply and demand fundamentals are a big driver of volatility in the individual commodities. Still, the commodity index vol is much lower than specific single commodity sector vol, because a lot of the commodity-specific supply and demand-driven volatility is diversified away in the index (Chart 6).

Chart 5: Commodities are volatile compared to other asset classes like credit and rates, though not as volatile as EM equities



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 6: Commodity index vol is much lower than specific single commodity sector vol due to low cross-sector correlations



Source: Bloomberg, BofA Merrill Lynch Global Research

Commodity correlation with other asset classes

Commodities have low correlation with other asset classes

Commodity correlations to other asset classes are fairly low and often negative, which makes them good diversifiers in a portfolio comprised of global equities, government and corporate bonds (Table 1). Commodities have the lowest correlation among other asset classes to high-grade credit. After rates, commodities have the lowest correlation among asset classes to world equities, high-yield credit, and EM equities. The

correlation between commodities and a conservative diversified equity & bond portfolio (30% global equities, 35% rates, 35% credit) is also very low historically at just 7% (Table 1), though it has increased considerably to 45% since QE started in late 2008 and all asset classes became more correlated (Table 2).

Table 1: The correlation between commodities and a conservative diversified equity & bond portfolio is also very low historically at just 7%...

Correlation matrix (monthly returns since 1978)

	Commodities	MSCI world	Rates	Credit (HG)	Credit (HY)	EM equities	Diversified portfolio
commodities	100%	19%	-14%	-3%	13%	24%	0.07
MSCI world	19%	100%	6%	32%	59%	71%	0.78
rates	-14%	6%	100%	84%	-2%	-14%	0.65
credit (HG)	-3%	32%	84%	100%	53%	23%	0.83
credit (HY)	13%	59%	-2%	53%	100%	53%	0.63
EM equities	24%	71%	-14%	23%	53%	100%	0.56
diversified portfolio	0.07	0.78	0.65	0.83	0.63	0.56	1.00

Source: Bloomberg, BofA Merrill Lynch Global Research

Table 2: ...though it has increased considerably to 45% since QE started in late 2008 and all asset classes became more correlated

Correlation matrix (monthly returns since 2009)

	Commodities	MSCI world	Rates	Credit (HG)	Credit (HY)	EM equities	Diversified portfolio
commodities	100%	55%	-22%	18%	38%	57%	0.45
MSCI world	55%	100%	-39%	37%	66%	82%	0.82
rates	-22%	-39%	100%	46%	-24%	-23%	0.16
credit (HG)	18%	37%	46%	100%	62%	46%	0.79
credit (HY)	38%	66%	-24%	62%	100%	70%	0.69
EM equities	57%	82%	-23%	46%	70%	100%	0.76
diversified portfolio	0.45	0.82	0.16	0.79	0.69	0.76	1.00

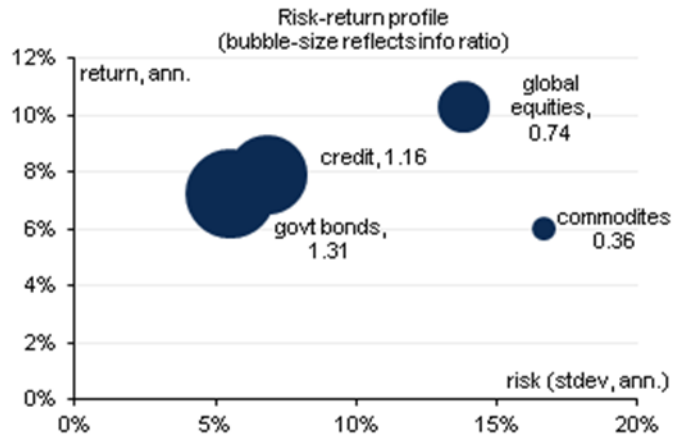
Source: Bloomberg, BofA Merrill Lynch Global Research

Commodity volatility in a portfolio context

Commodities bring diversification benefits in a portfolio context

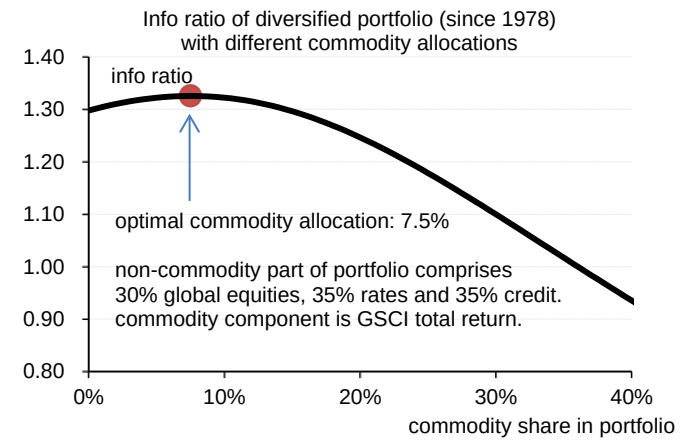
On a standalone basis, commodities do not look so attractive due to relatively low returns and high volatility, which gives them one of the lowest info ratios of all asset classes on a stand-alone basis (Chart 7). So what's the attraction of high vol and relatively low return commodities compared to bonds or stocks? The answer lies in the correlations with other asset classes, which are generally low, making commodities a good diversifier in a portfolio context. Adding 5-10% commodities to a well-diversified portfolio does increase the info ratio due to the low or negative correlations commodities have with other asset classes (Chart 8).

Chart 7: Commodities may not look so attractive due to relatively low returns and high volatility …



Data from Jan 1970 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 8: …but adding 5-10% commodities to a well-diversified portfolio does increase the info ratio

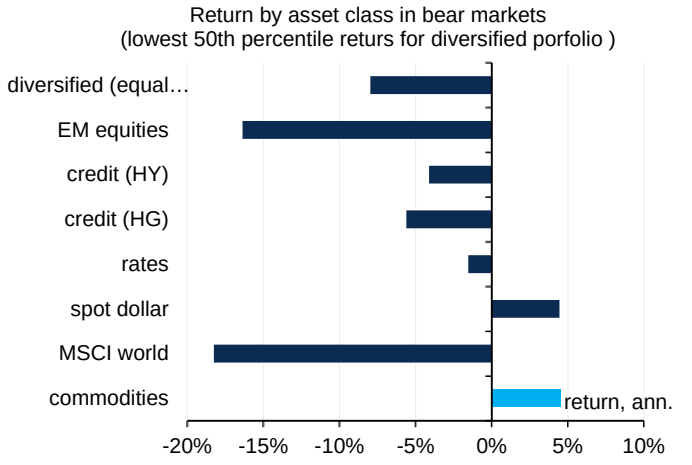


Source: Bloomberg, BofA Merrill Lynch Global Research

And commodities are especially useful as a bear market hedge

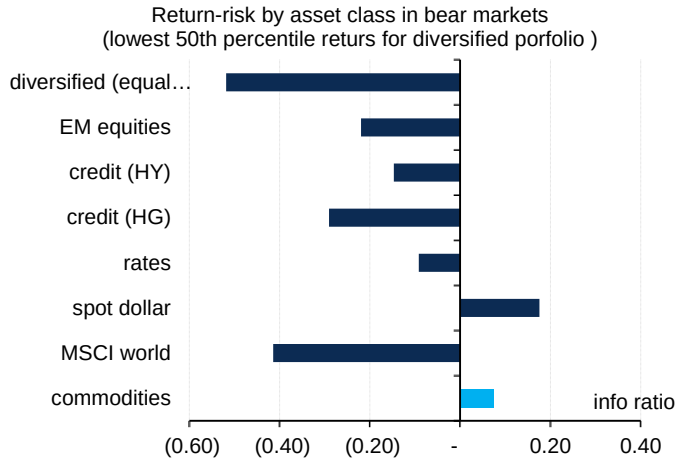
Commodities are especially valuable as a portfolio diversifier in bear markets, due to their somewhat a-cyclical behavior. Looking at the lower half of the return distribution for a well-diversified equity/bond portfolio over the past four decades, commodities have shown positive performance on average when equities and most other asset classes have underperformed (Chart 9). In bear-markets commodities on average tend to outperform most other asset classes both in terms of absolute returns and on a risk-adjusted basis (Chart 10).

Chart 9: Commodities have shown positive performance on average when equities and most other asset classes have underperformed



Data from Jan 1970 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 10: In bear-markets commodities tend to outperform other asset classes both in terms of absolute returns and on a risk-adjusted basis



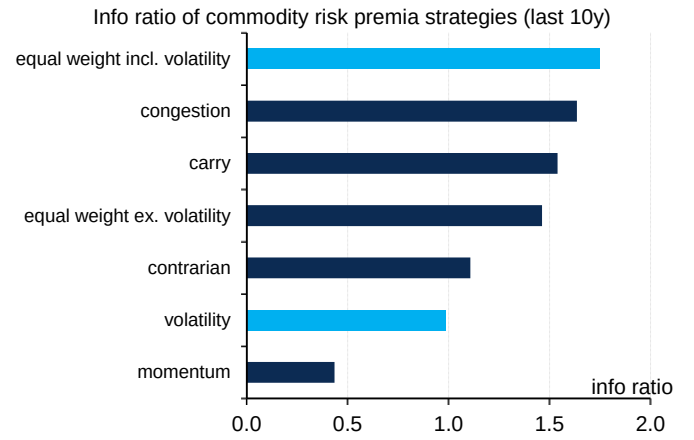
Data from Jan 1970 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Commodity vol improves performance of risk premia portfolios

Commodity volatility itself can also be traded as an asset class. Speculators which provide hedging services to commodity producers and consumers by selling options can systematically earn a positive risk premium by doing so. A systematic commodity vol selling strategy, such as selling of delta hedged straddles on a basket of commodities (see section 4 for details) has stand-alone returns comparable to other commodity risk premia strategies. Moreover such a strategy has weak correlation with other commodity risk premia and hence adding a short vol strategy to a commodity risk premia portfolio systematically improved risk-adjusted performance (Chart 11). Moreover short commodity vol historically has returns similar to short vol strategies in other asset classes, and also here commodity vol

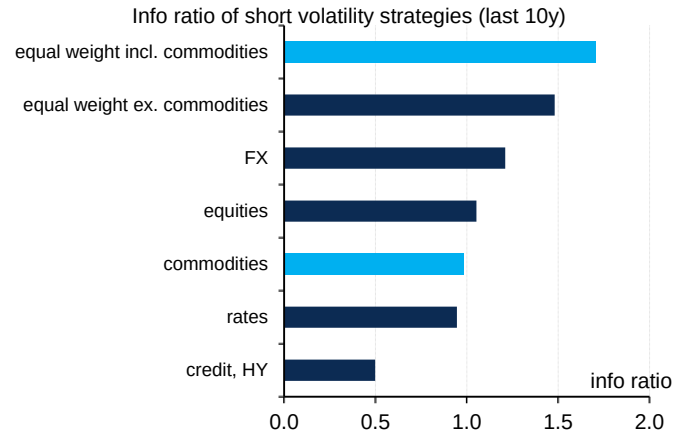
complements other risk premia very well and enhances the risk-adjusted performance of a cross-asset short vol risk premia portfolio (Chart 12).

Chart 11: Adding a short vol strategy to a commodity risk premia portfolio would have systematically improved risk-adjusted performance



Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Jan 2008 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Chart 12: Short commodity vol would have enhanced the risk-adjusted performance of a cross-asset short vol risk premia portfolio



Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Jan 2008 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

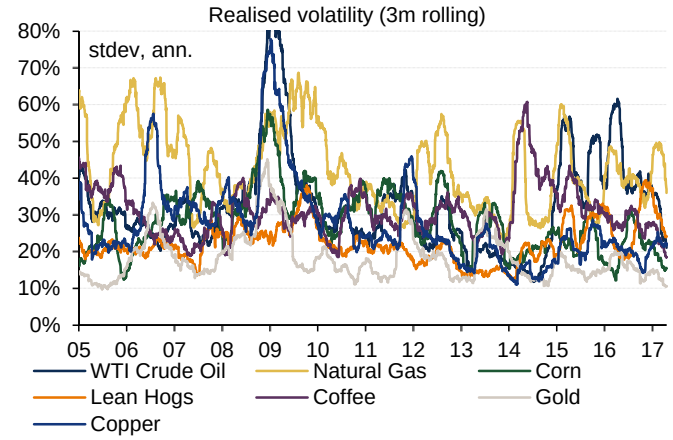
2. Fundamentals of commodity volatility

Commodity volatility and mean-reversion

Commodity vol is mean-reverting and relatively stable over longer horizons

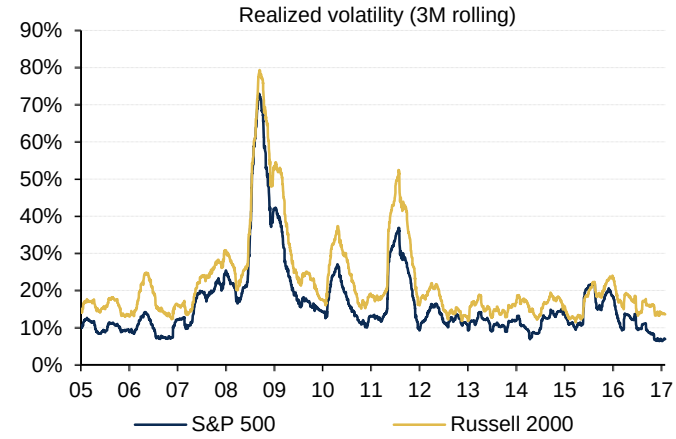
In general, commodity volatility tends to be mean-reverting just like volatility in other asset classes (Chart 13). The longer the period in which volatility is measured, the closer volatility will trend towards its long-term mean. Just as in equities or bonds, commodity volatility cannot be zero and it cannot keep increasing indefinitely (Chart 14). Thus, options traders will constantly consider strategies that exploit the long-run mean-reversion properties of commodity volatility.

Chart 13: Commodity volatility tends to be mean-reverting, just like volatility in other asset classes



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 14: The longer the period in which volatility is measured, the closer volatility will trend towards its long-term mean, as in equities

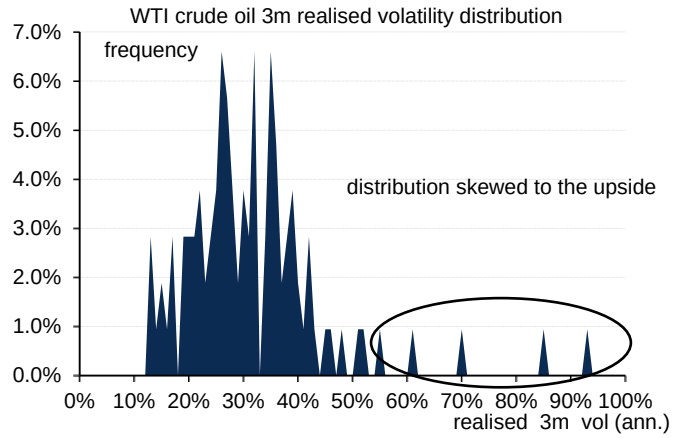


Source: Bloomberg, BofA Merrill Lynch Global Research

In the short term commodity vol can spike, especially to the upside

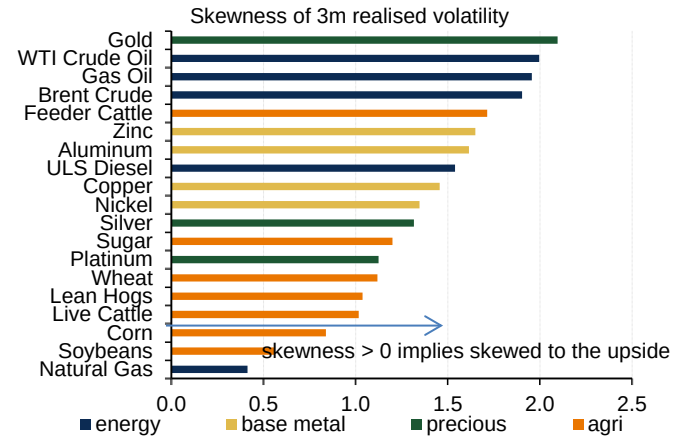
In the short term, commodity volatility may diverge from its long-term mean, constantly adapting to changing market conditions. In fact, commodity volatility tends to spike upwards quite often in response to sharp movements in commodity inventories or market disruption events. As a result, the distribution of commodity volatility is positively skewed, i.e., the probability of volatility jumping up is higher than the probability of volatility jumping down (Chart 15). This suggests that tactical buying of volatility can be highly profitable under certain market conditions. At the same time, volatility sellers can generate income by charging high risk premiums. The distribution of realised volatility is skewed to the upside for virtually all commodities, with oil and gold exhibiting the largest skews (Chart 16). The skew is less positive for base metals and agricultural commodities, but positive nonetheless.

Chart 15: The distribution of commodity volatility is positively skewed, i.e., the probability of vol jumping up is higher than of it jumping down



Data from Jan 1991 to Apr 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 16: The distribution of realized vol is skewed to the upside for virtually all commodities, with oil and gold exhibiting the largest skews



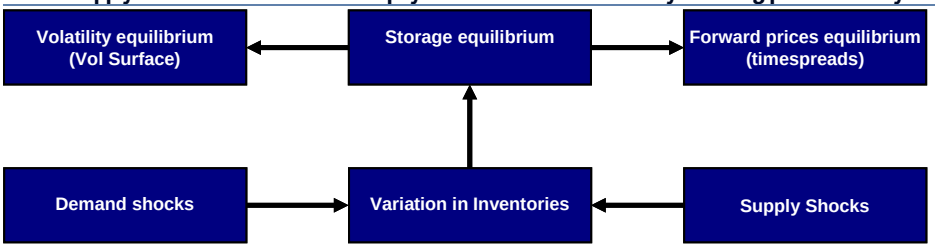
Data from Jan 1991 to Apr 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Physical inventories and commodity volatility

Commodity vol is driven by supply and demand fundamentals

Like everything else in commodity markets, the main driver of volatility is the supply and demand balance of the physical market, with inventories playing a crucial role. Inventory levels link the commodity current and future values as storage is the mechanism through which commodities are carried over time. In effect, commodity inventories can function as a cushion to accommodate demand and supply shocks, varying their levels to absorb supply and demand shocks in the physical market and ultimately reducing price volatility (Exhibit 1).

Exhibit 1: Inventories function as a cushion to accommodate S&D shocks, varying their levels to absorb supply and demand shocks in the physical market and ultimately reducing price volatility

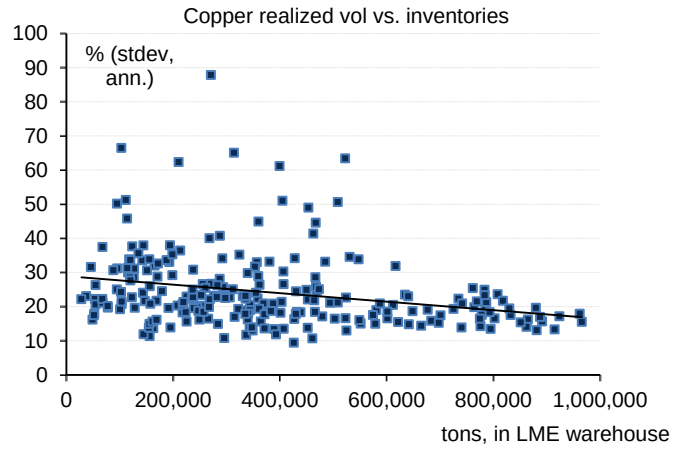


Source: BofA Merrill Lynch Global Research

For easy-to-store commodities, inventories and vol are inversely related

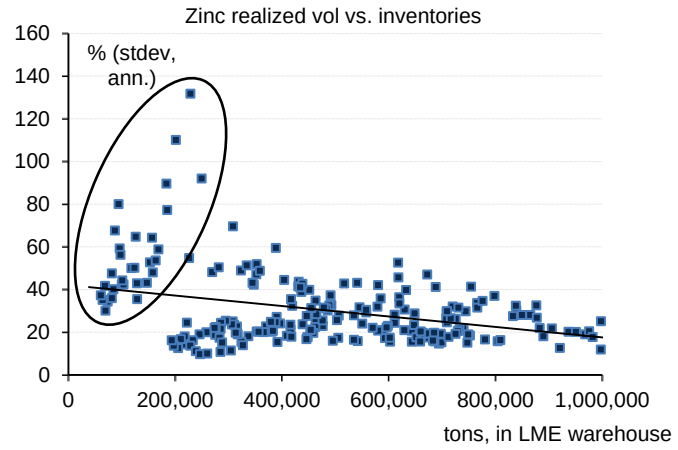
In general the higher the level of inventories, the better the market can cope with temporary market disruptions. Hence the higher the inventory levels, the lower price volatility ought to be. Put differently, sharp price movements become less likely as the inventory buffer grows (Chart 17). When inventories decline below normal levels and stock-outs become a real possibility, positive demand shocks and negative supply shocks can only be accommodated through sharp price movements (price spikes). In these situations, volatility should increase to above normal levels (Chart 18). This inverse relationship between inventories and price volatility is generally the case for commodities which are easy to store – which implies reaching full storage capacity is hardly ever an issue. This is true of most commodities including base metals, precious metals and agricultural products with a long shelf life.

Chart 17: As long as a commodity is easy to store, the higher the inventory levels, the lower the price volatility



Data from Jan 1990 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 18: When inventories decline below normal levels, volatility tends to increase above normal levels



Data from Jan 1990 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

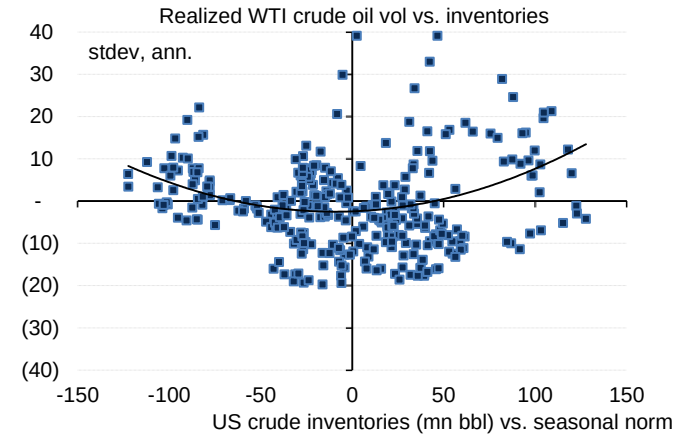
For hard-to-store commodities, stocks and vol have a u-shaped relationship…

For commodities which are harder to store, not only is the risk of stock-outs an issue, but also the risk of reaching full storage capacity. The pattern of positive correlation between inventories and volatility breaks down when inventories are high and come close to reaching full capacity. With limited spare storage capacity, a high level of inventories implies that negative demand shocks or positive supply shocks may have to be accommodated by sharp price movements. In this case, higher inventory levels end up increasing price volatility. This is because the cushion to accommodate supply and demand shocks in the form of spare storage capacity is no longer there. So for hard-to-store commodities vol tends to spike both at very high and very low levels of inventory, which makes for a u-shaped relationship between inventories and volatility.

…and so vol can spike at both very high and very low inventory levels

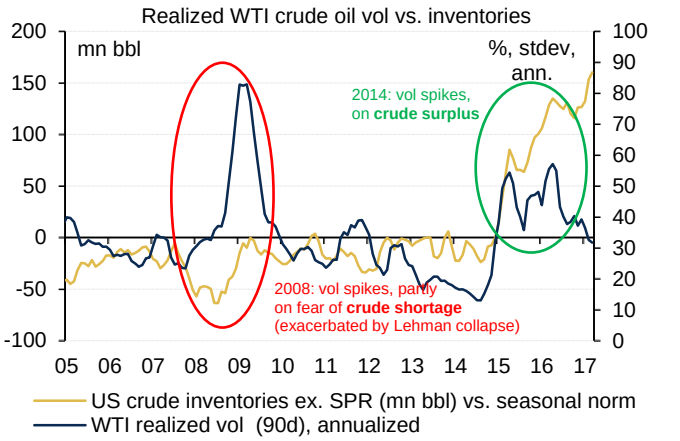
Oil is a case in point for why vol spikes at both very high and very low inventories (Chart 19). In mid-2014 when Saudi changed its longstanding oil supply policy and flooded the market with crude oil to shut out higher-cost US shale producers, volatility soared as prices collapsed on concerns that the world would run out of storage capacity – which it pretty much did, at least for land-based storage in many regions (Chart 20). The converse happened in early 2008 before the Lehman collapse. Crude oil vol rose on falling oil inventories and fear of a stock shortage, which caused vol to spike as prices soared to a peak of $147/bbl in June 2008. Natural gas is another case in point – a hard-to-store commodity that is often on the verge of maxing out or depleting its available storage, which leads to violent spikes in volatility at both storage extremes.

Chart 19: Oil is a case in point for why vol spikes at both very high and very low inventories



Data from Jan 1990 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 20: Volatility soared in mid-2014 as prices collapsed on concerns we would run out of storage capacity



Source: Bloomberg, BofA Merrill Lynch Global Research

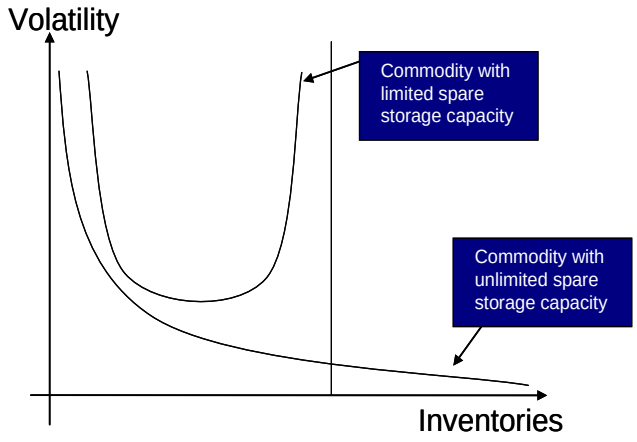
Isolating the storage component of vol shows the inventory-vol relationship

Storage is obviously closely linked to the physical properties of the commodity in question. Hard-to-store commodities are typically liquid (like oil and NGLs) or gaseous ones (like natural gas) because these require specialized storage facilities, which are in limited supply. This stands in stark contrast to base metals, bulks or grains, which often simply need a roof to be kept dry for storage, if that. This means storage capacity can be expanded both quickly and cheaply if needed, and is therefore never really at risk of running out (Exhibit 2).

Oil requires specialized storage tanks, though at a cost these can be built over a period of months if needed. We saw this for example in 2010 when a temporary glut of crude oil is Cushing, Oklahoma, caused a major build out in storage facilities which ultimately mitigated the price decline in WTI crude oil (delivered at Cushing) and the spike in its volatility. Natural gas storage is more difficult to expand, as most storage takes place in depleted salt caverns that are limited by their natural occurrence. This means storage capacity is relatively fixed over long periods of time. Electricity is an extreme example of a commodity which cannot be stored in its pure form (though its inputs can, like coal, gas or hydro reservoirs), and despite recent advancements in battery technology, electricity is still extremely costly and in most cases not cost-effective to store at all. This makes for some extreme vol spikes when the electricity market is either over or under supplied in any one period.

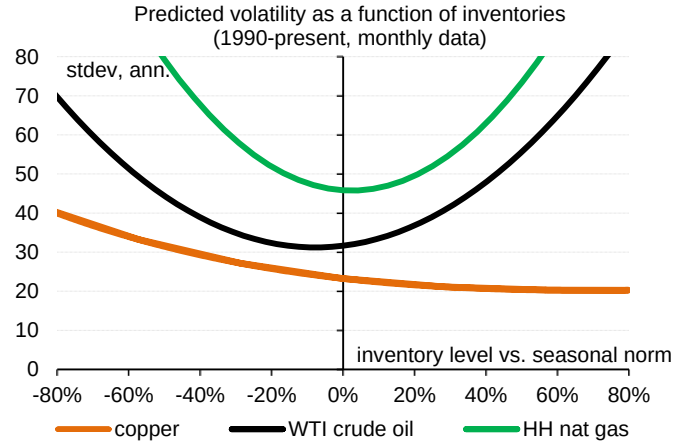
Looking at a scatter plot for WTI crude oil inventories and volatility (see Chart 19 above), we can vaguely see how vol is a u-shaped function of inventories. Vol, however, is affected by many other things than inventories. Macro conditions and seasonality are also important drivers of vol in commodities. Conditioning volatility and inventories on general market volatility (proxied by the VIX), trend and seasonal factors, we isolate the all-else-equal impact of inventories on vol. Here we see quite clearly the u-shaped relationship between inventories and vol for hard-to-store commodities like oil and natural gas (Chart 21), in stark contrast to an easy-to-store commodity like copper whose vol is monotonically decreasing in inventories as there are no upper storage constraints.

Exhibit 2: The inventory-vol relationship for hard-to-store liquid and gaseous commodities stands in stark contrast to metals and bulks



Source: BofA Merrill Lynch Global Research

Chart 21: Isolating the impact of inventories on vol we see clearly the u-shaped relationship for hard-to-store commodities

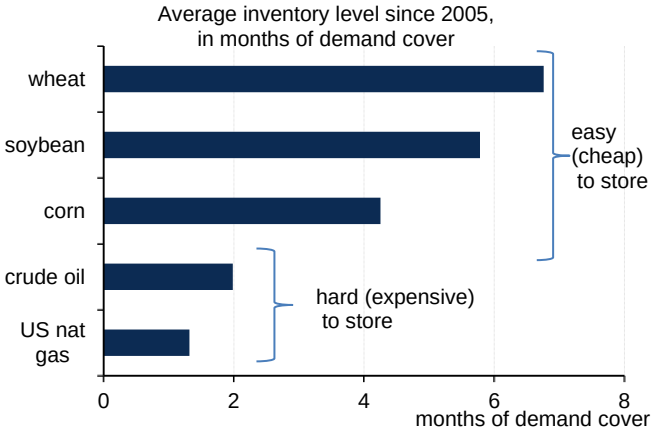


Source: Bloomberg, BofA Merrill Lynch Global Research

Hard-to-store commodities have higher levels of volatility on average

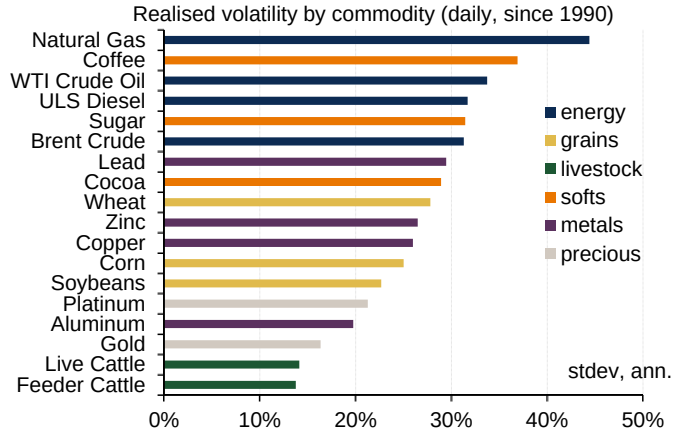
Naturally the average level of volatility, not just its relationship to inventories, also differs across commodities. In general, commodities that are easy to store tend to have a lower average level of volatility. If the cost of storing a commodity is low because its storage facilities are cheap, it is generally optimal to keep more inventories as a buffer to smooth supply-demand shocks across time (Chart 22). This means volatility on average is lower as supply and demand shocks can be smoothed out over a longer horizon by building or drawing inventories. Industrial and precious metals are examples of such commodities which are cheap to store and have low levels of volatility (Chart 23). Agricultural products, at least those that have a long shelf life like grains and oilseeds, also have low storage costs and relatively low volatility despite being subject to sometimes severe weather supply shocks.

Chart 22: If the cost of storing a commodity is low because storage is cheap, it is generally optimal to keep more inventories as a buffer



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 23: Industrial and precious metals are examples of such commodities with relatively low levels of volatility



Source: Bloomberg, BofA Merrill Lynch Global Research

Weather and commodity volatility

Commodities sensitive to weather tend to have higher volatility

The other major factor that determines relative volatility across commodities is the standard deviation of supply and demand for each particular market. For instance, soft commodities like sugar, coffee, cocoa and cotton are relatively easy to store. Yet because their supply is concentrated in relatively few producing regions, their prices tend to be more volatile than other ags. In effect, production concentration makes them sensitive to country-specific weather shocks. Energy commodities are the hardest to

store, and face volatile demand for heating, which makes them very volatile. In addition, realized volatility can have seasonal features linked both to the fundamental features of each commodity market, which mainly comes down to the seasonal distribution of weather shocks.

3. Features of commodity volatility

Forward commodity prices and volatility

Timespreads are determined by storage costs and the "convenience yield"

Inventory levels link the commodity current and expected future prices. Storage after all is the mechanism by which commodities are carried over time. A simple arbitrage condition guarantees that the cost of physical storage for any given commodity has to be equal to the difference between forward and spot prices.

Forward price – spot price =

cost of financing the purchase

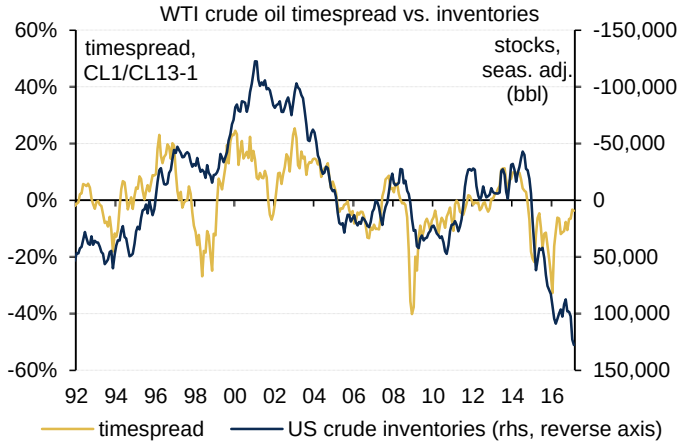
+ cost of storing the commodity

- benefit of owning the commodity

If the net cost of physically storing a commodity — i.e., the cost of financing the purchase of the physical commodity and storing it, minus the benefit of holding the physical commodity — is higher than the difference between spot and forward prices, owners of the physical commodity would rather sell the commodity on the spot market and buy it forward than store it. That movement would bring spot prices down and forward prices up. If the net cost of physically storing a commodity is lower than the difference between spot and forward prices, then an investor could buy the commodity on the spot market, store it and sell it forward at a profit. Hence, the relative value of storage helps to determine the time value of the commodity, ie, it helps to determine timespreads (Chart 24). As a result, timespreads as a % of the spot price are closely interlinked with inventories, regardless of the spot price level (Chart 25).

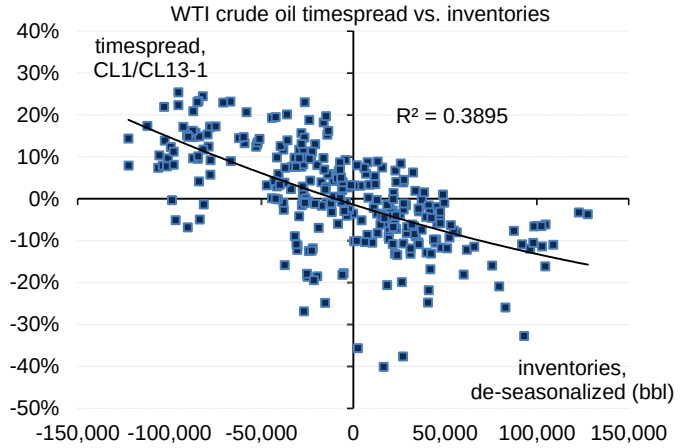
While evaluating the cost of financing the purchase and the cost of storage is relatively straightforward, the same cannot be said about the benefit of owning the physical commodity. Refineries, utility companies, industrial producers and other consumers purchase commodities for consumption and are often willing to pay a premium for the convenience of having the physical ownership. This premium when expressed as a percentage of the spot prices is called the *convenience yield*. The magnitude of the convenience yield, together with interest rates and storage costs, then helps to determine the relationship between forward and spot prices, i.e., it helps to determine the equilibrium forward curve. Thus, inventories have a simultaneous impact on the shape of the forward curve and on the level of price volatility.

Chart 24: The relative value of storage helps to determine the time value of the commodity, ie, it helps to determine timespreads



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 25: Timespreads as a % of the spot price are closely interlinked with inventories, regardless of the spot price level

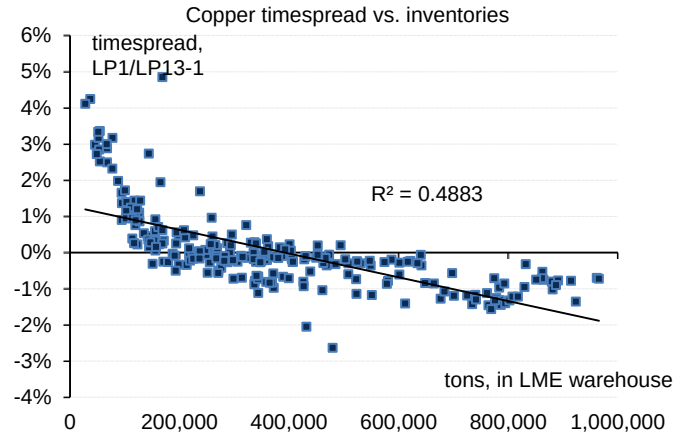


Data from Jan 1990 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Timespreads are inversely related to inventories for all commodities...

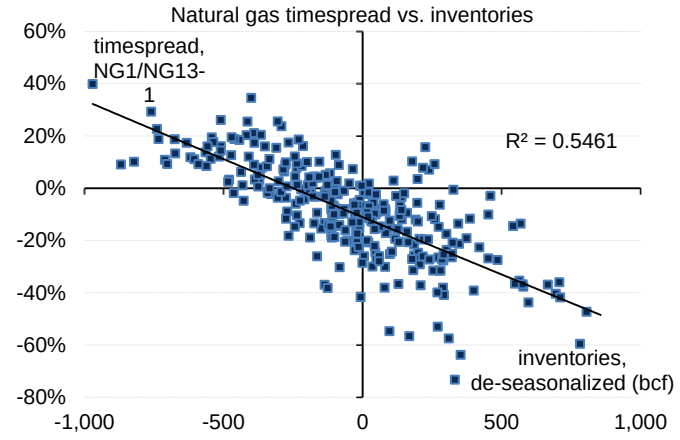
It is worth emphasizing that the negative correlation between inventories and timespreads holds universally for all commodities, regardless of whether these are easy or hard to store. For easy-to-store commodities like copper the relationship is very strongly negative at very low inventory levels when stock-out risks are high, and the relationship is weaker at high inventory levels albeit always negative (Chart 26). For hard-to-store commodities like crude and natural gas the timespread-inventory relationship is strongly negative both at high, normal and low inventory levels (Chart 27).

Chart 26: For easy-to-store commodities like copper the relationship is very strongly negative at very low inventory levels



Data from Jan 1990 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 27: For hard-to-store commodities like crude and natural gas the timespread-inventory relationship is universally strongly negative



Data from Jan 1990 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

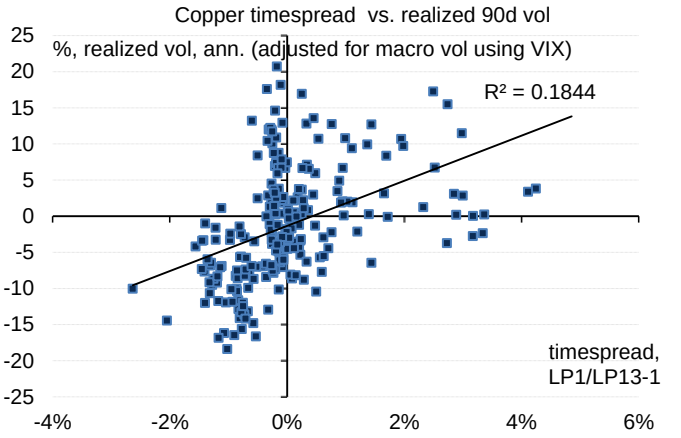
...and volatility relates to timespreads just as it relates to inventories

The monotonically decreasing relationship between timespreads and inventories for all commodities implies that vol and timespreads have a similar relationship to that of vol and inventories: u-shaped for hard-to-store commodities, and monotonically increasing for easy-to-store commodities[1]. When inventories reach very low levels and the probability of stock outs increases, volatility goes up and the forward curve goes into backwardation i.e. timespreads rise as immediate ownership of the physical commodity is priced at a premium. Hence, volatility levels and the degree of backwardation are typically positively correlated for easy-to-store commodities like metals or grains (Chart

[1] As the timespread-inventories relationship is negative and vol-inventories is negative, vol-timespreads is positive for easy-to-store commodities.

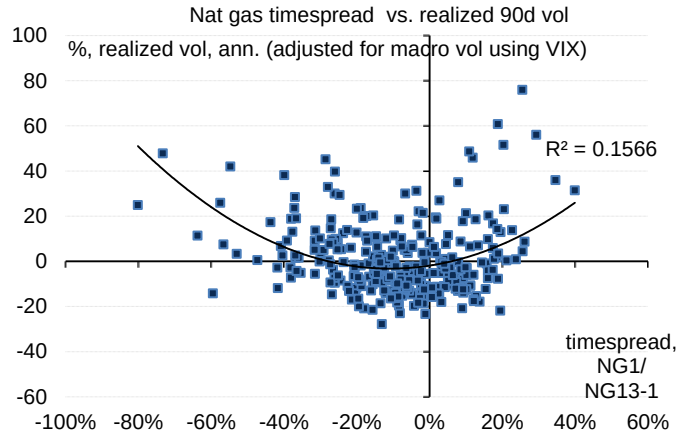
28). At high timespread levels (low inventory levels) the same positive correlation between timespreads and vol applies to hard-to-store commodities (Chart 28), yet at low timespread levels (high inventory levels) the correlation becomes negative as the risk of running out of storage capacity sends vol spiking as timespreads collapse. So for hard-to-store commodities like oil and natural gas we observe a u-shaped relationship between timespreads and vol, just like that between inventories and vol (Chart 29).

Chart 28: Volatility levels and the degree of backwardation are typically positively correlated for easy-to-store commodities



Data from Jan 1990 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 29: For hard to store commodities like oil and natural gas we observe a u-shaped relationship between timespreads and vol



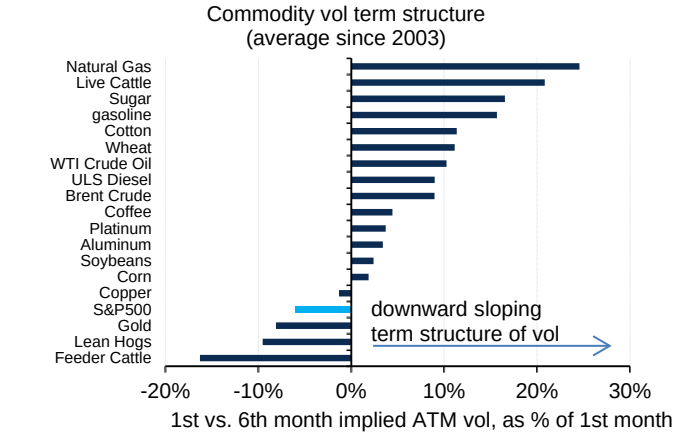
Data from Jan 1990 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Term structure of commodity volatility

The term structure of commodity vol is generally downward-sloping

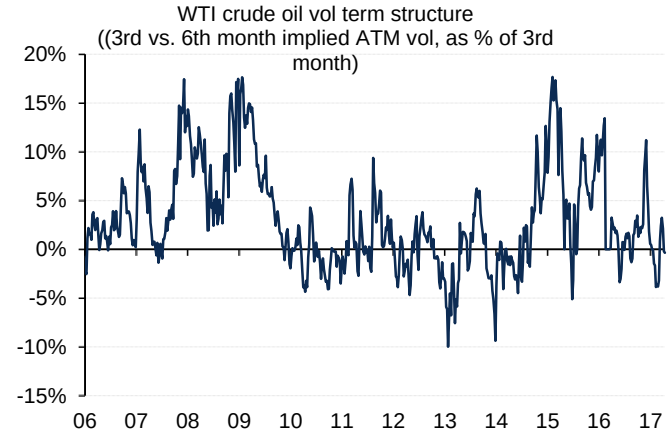
For a given distribution of shocks, prices should respond more when demand and/or supply are less price-elastic. In the long-run, demand and supply can typically adapt to new circumstances and become more price-elastic than in the short run. As a result, near-dated options tend to be relatively more expensive than longer-dated options from a volatility standpoint in commodity markets (Chart 30). This is in contrast to other asset classes such as equities, which tend to have an upward-sloping term structure of implied volatility, because there is generally less uncertainty about the near term than the longer term. In commodities, however, physical market fundamentals justify that long-term volatility trades lower than short-term volatility, especially when the shocks are perceived by market participants to be temporary. In the short term, however, the term structure can be positive or negative depending on prevailing market conditions (Chart 31).

Chart 30: Near-dated options tend to be relatively more expensive than longer-dated options from a pure volatility standpoint



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 31: In the short term, however, the term structure can be positive or negative depending on prevailing market conditions

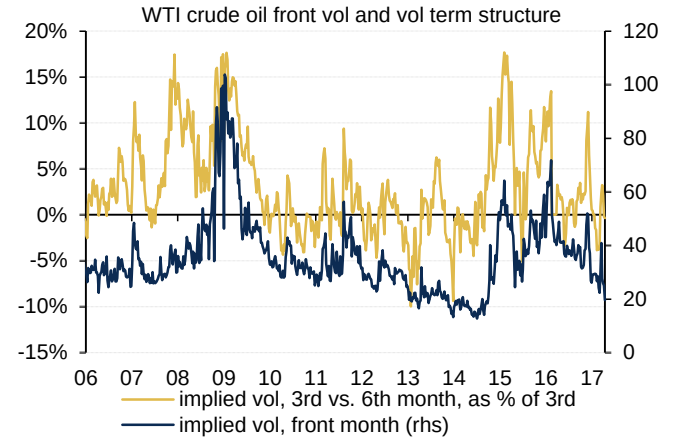


Source: Bloomberg, BofA Merrill Lynch Global Research

The term structure of vol is highly correlated to front vol levels

Volatility is generally more stable the further we move out on the term structure, hence just like for the term structure of prices, the term structure of vol is highly positively correlated with vol in the front of the curve (Chart 32). The level of volatility in the front and the term structure of vol move in the same direction on commodity specific supply and demand shocks. The level of vol, however, is also affected by many other factors unrelated to inventories. So the term structure of commodity vol can often give a clearer signal about the inventory situation than the level of vol, as the term structure is relatively more affected by the supply & demand fundamentals and relatively less by macro factors compared to the vol level.

Chart 32: Just like for the term structure of prices, the term structure of vol is highly positively correlated with vol in the front of the curve

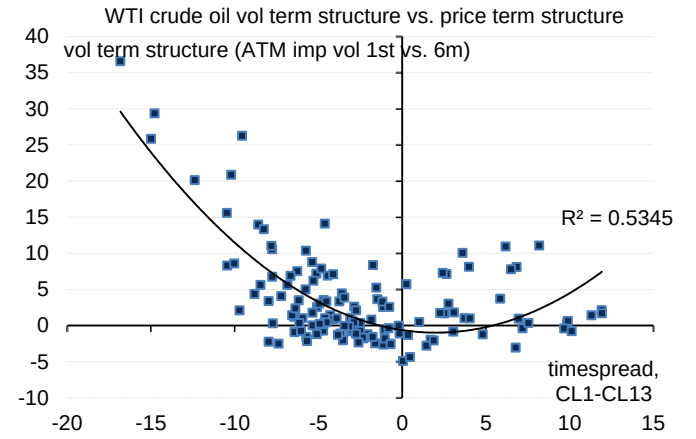


Source: Bloomberg, BofA Merrill Lynch Global Research

Term structure and vol level changes are also linked to inventories

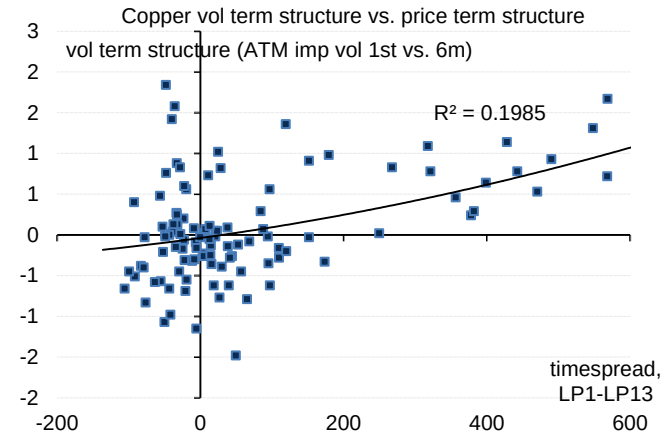
So when looking at volatility unconditionally (i.e. not conditioned on macro and other factors) we see the relationship with inventories/timespreads much more strongly in the term structure of vol than in the level of front vol. This is the case for hard-to-store commodities like crude oil where the relationship is u-shaped just like the relationship between the level of vol and inventories/timespreads (Chart 33), and for easy-to-store commodities like copper where the term structure of vol rises in falling inventories (rising timespreads) and the relationship is strongest when inventories are unusually low (timespreads unusually high) low (Chart 34).

Chart 33: For hard-to-store commodities like crude oil, the vol to timespread relationship is u-shaped



Data from Jan 1990 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 34: For easy-to-store commodities like copper, the term structure of vol falls on rising timespreads



Data from Jan 1990 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Seasonality and commodity price volatility

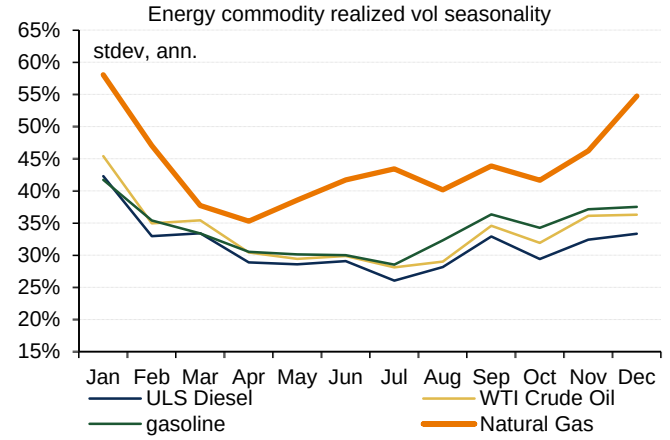
Commodity vol is highly seasonal due to seasonal supply and demand fluctuations

Seasonality is a feature that clearly distinguishes commodities from other asset classes. In some commodity markets the distribution of supply and demand shocks changes throughout the year according to seasonal patterns, and weather is usually the reason for seasonal variations in supply and demand shocks, and hence in price volatility. Throughout the year, the value of storage needs to take into account the risk of potential supply/demand shocks affecting prices in different seasons. As a consequence, seasonality patterns are an important factor determining the equilibrium level of inventories, timespreads, and volatility on a broad range of commodity markets.

Energy and agricultural products exhibit the most seasonality of vol

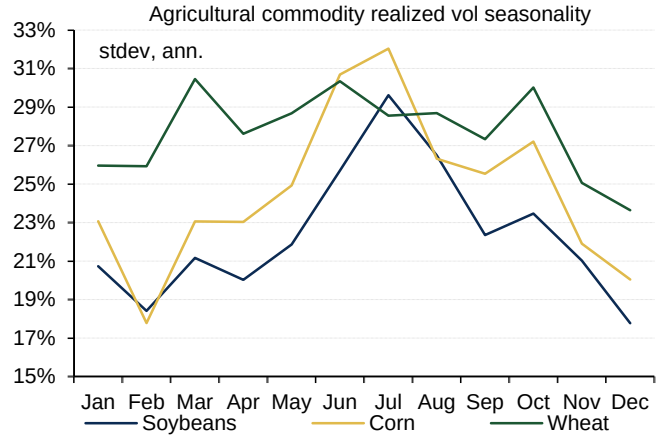
Natural gas and oil are most volatile during the winter months because this is when demand can vary in a more pronounced manner. This is due to high variation in winter weather and by extension in heating oil demand (Chart 35). Even though summer demand for gasoline is on average higher than winter demand for heating oil, heating demand is much more volatile than driving demand, and therefore both crude and the entire oil products complex are generally more volatile in the winter than in the summer. In contrast, agricultural products like corn and soybeans have the highest seasonal volatility in the summer when the crops are maturing. This is when supply is especially sensitive to weather including either too much or too little rainfall (Chart 36).

Chart 35: Natural gas and oil are most volatile during the winter months because this is when demand for heating is most volatile



Data from Jan 1991 to Apr 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 36: Agricultural products like corn and soybeans have the highest seasonal volatility in the summer due to weather



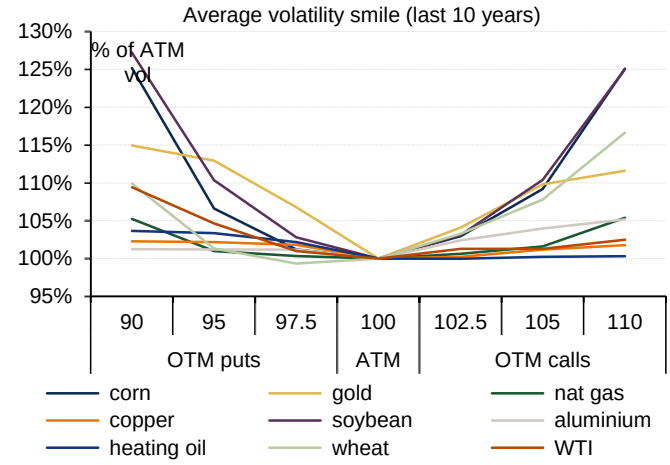
Data from Jan 1991 to Apr 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

The volatility smile in commodity markets

Commodities tend to have a volatility smile due to fat tail return distribution

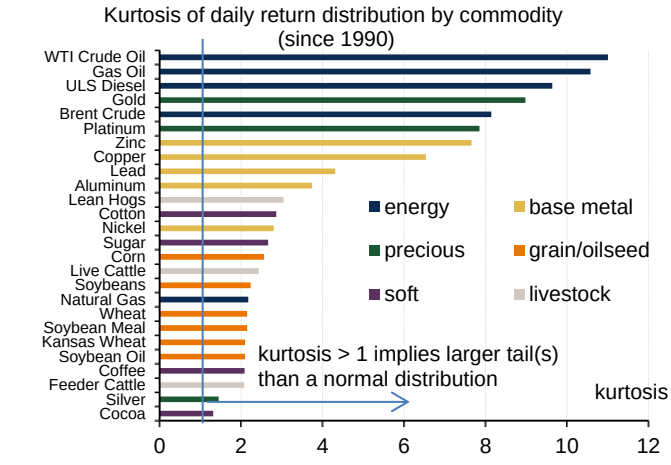
Broadly speaking, derivatives markets tend to price in greater volatility premiums on out-of-the-money (OTM) options relative to at-the-money (ATM) options (Chart 37). The difference in the implied volatility embedded in ATM and OTM options is loosely referred to as the volatility smile. In effect, buyers of protection are usually willing to pay significant premiums for protection against extreme events. The market's view on the likely distribution of sharp price movements will ultimately determine the relative value between OTM puts and calls, and ATM options. Commodities generally have fat tail distributions meaning extreme moves are more likely than in a normal distribution (Chart 38). The distribution of supply and demand shocks will help determine the shape of volatility smiles for any given maturity. Broadly speaking the fatter the perceived tails of the return distribution the larger the volatility smile.

Chart 37: Derivatives markets tend to price in greater volatility premiums on OTM options relative to ATM options



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 38: Commodities generally have fat tail distributions, meaning extreme moves are more likely than in a normal distribution



Source: Bloomberg, BofA Merrill Lynch Global Research

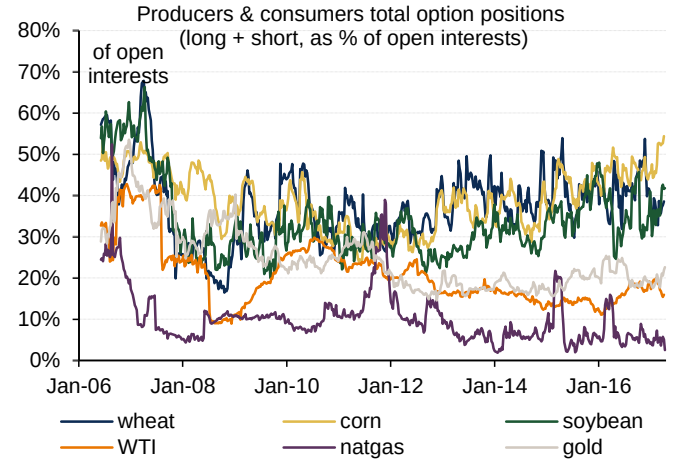
The smile is affected by the relative supply and demand for hedging

The perceived distribution of returns is not the only thing that matters for the implied volatility smile. Crucially the supply and demand for options themselves also matters in determining the price of options, which is reflected in the level of implied vol both at the money and away from the money (i.e. the smile). Consumers and producers buy options to hedge their natural positions – consumers such as airlines typically buy OTM

calls to hedge against price increases, and producers buy OTM puts to hedge against price falls (see Appendix for details on common option strategies). Both are long options and thus long vol, and the premium paid on these options depends on the demand for hedging from producers/consumers relative to the supply of protection from speculators willing to take the other side of the position (i.e. go short vol).

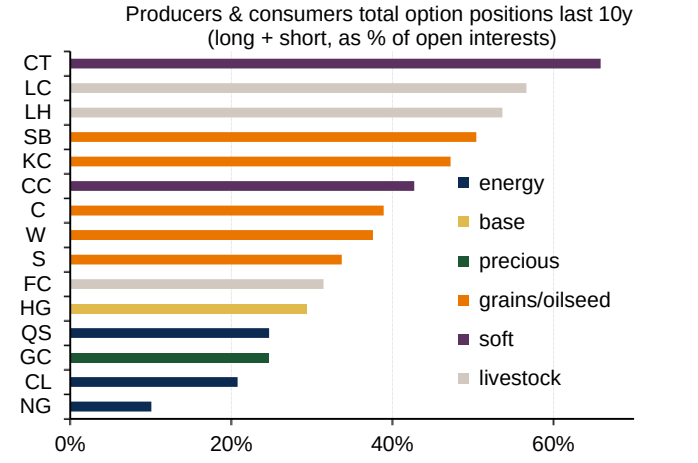
Agricultural markets show some of the largest implied vol smiles despite having the least fat tailed distributions among commodities (Chart 38 above). The reason for this is relatively poor supply of protection from speculators willing to take the risk off producers. In contrast, energy smiles are smaller, despite energy having more fat tailed empirical distributions than agriculture. Looking at the CFTC positions data for options we see that for ags producers and consumers hold a relatively large share of total open option interests in options, which implies that there is an overweight of natural buyers of protection relative to other markets including energy, precious and base metals (Chart 39 and Chart 40).

Chart 39: Ags show some of the largest implied vol smiles despite having the least fat tailed distributions among commodities



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 40: Producers and consumers hold a relatively large share of total open option interests in ags, indicating a lack of sellers of protection

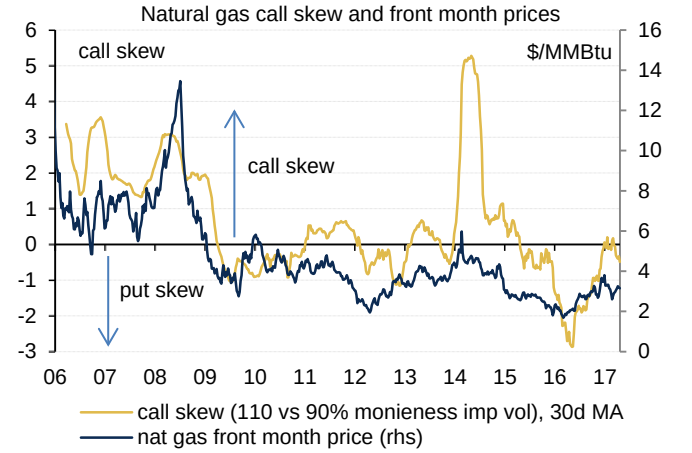


Source: Bloomberg, BofA Merrill Lynch Global Research

The volatility smile fluctuates with market perception of risk

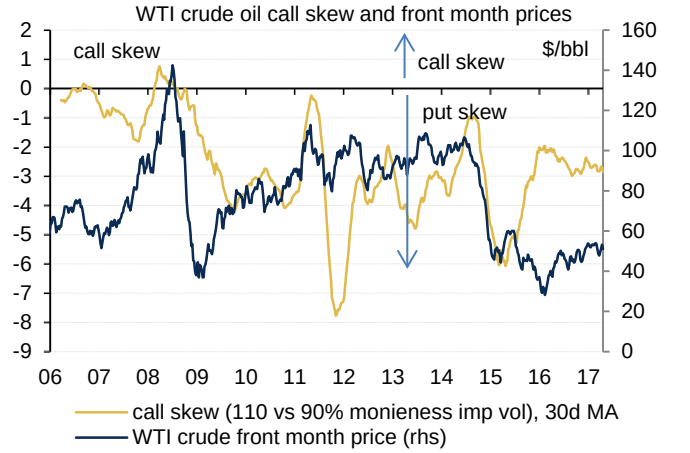
Whenever upward price movements are viewed as more likely than price falls of the same magnitude – i.e. the perceived distribution of returns has a fatter right tail than left tail – options markets tend to develop a call skew, a situation when OTM calls are relatively more expensive than OTM puts. On the other hand, when the reverse is true, commodity markets will typically develop a put skew because protection against price falls becomes more expensive. For instance, US natural gas volatility smiles will oscillate between having a call skew and a put skew depending on the market perception of risk and forward prices (Chart 41). On the other hand, WTI crude oil volatility smiles almost always show a put-skew (Chart 42).

Chart 41: US natural gas volatility smiles will oscillate between having a call skew and a put skew depending on the market perception of risk



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 42: On the other hand, WTI crude oil volatility smiles almost always show a put-skew

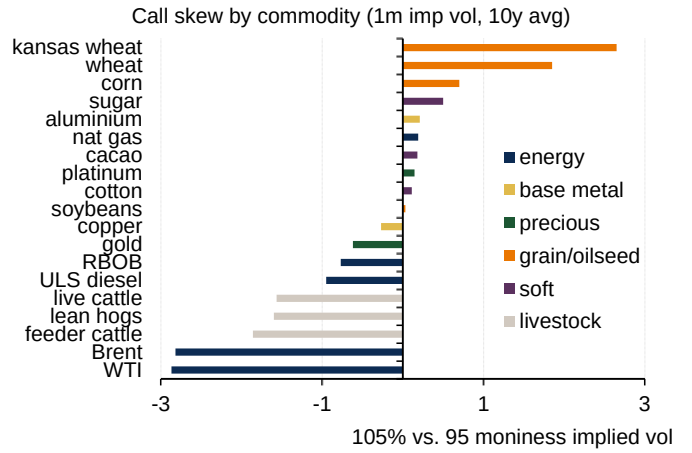


Source: Bloomberg, BofA Merrill Lynch Global Research

On average most commodities tend to show a put skew

In general, though, most commodities show a put skew most of the time (Chart 43). The reason for this is twofold. First, most commodities' return distribution is negatively skewed, so options price greater risk of large downside moves than upside moves. Second, producers, naturally long the commodity, tend to hedge more than consumers, who are naturally short the commodity, which means there is often greater demand for downside protection (OTM puts) than upside protection (OTM calls). This adds to the put skew in the implied volatility. The put skew is most pronounced for oil and livestock, while the grains tend to have a strong call skew. Natural gas and gold also show a call skew on average. Most of the variation in skew across commodities comes down to the distribution of supply and demand shocks, which are largely driven by weather and cyclicality.

Chart 43: Most commodities show a put skew most of the time, and the put skew is especially pronounced for oil and livestock



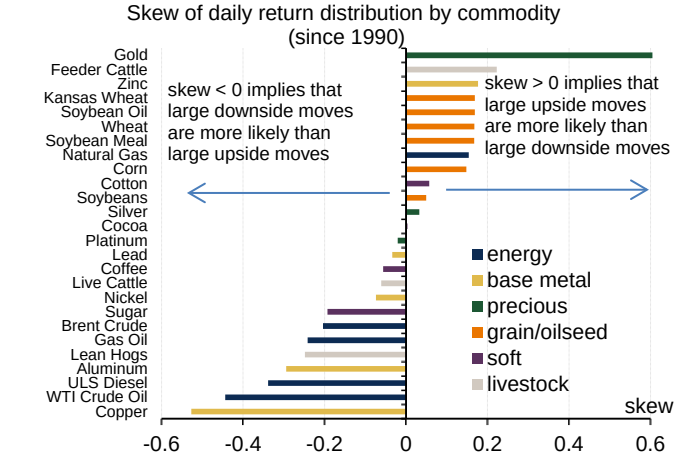
Source: Bloomberg, BofA Merrill Lynch Global Research

Cyclical commodities tend to have a put skew

It is not surprising that the options market is pricing a higher risk of large downside moves than upside moves in the crude oil and products – this matches the historically observed distribution of returns. Historical returns of the oil commodities have a strong negatively skewed distribution (Chart 44), as do other cyclical commodities including industrial metals. Demand for these commodities is highly cyclical and the negative skew in economic activity, e.g. as measured by industrial production or PMIs, translates into a negative skew in oil demand and thus in price returns (Chart 45). Sure, oil is also

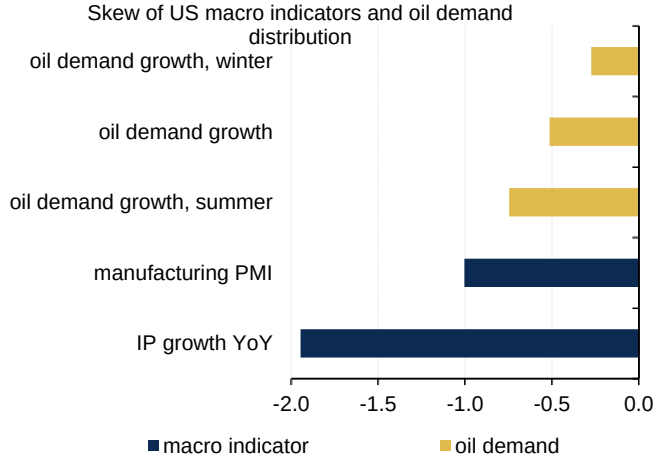
affected by weather in the winter, and weather events' impact on oil demand tends to be skewed the other way – to the upside, as a typical cold winter increases heating demand more than what is lost during a warm winter. Yet at the end of the day only 15% of oil is used for heating these days and hence cyclical effects tend to dominate extreme moves in oil demand and prices, and the distribution of oil returns has a distinct negative skew. The distribution is slightly less negative in winter when weather shocks are more common.

Chart 44: Historical returns of the oil commodities have a strong negatively skewed distribution



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 45: Demand for these commodities is highly cyclical and the negative skew in economic activity causes a negative skew in oil demand



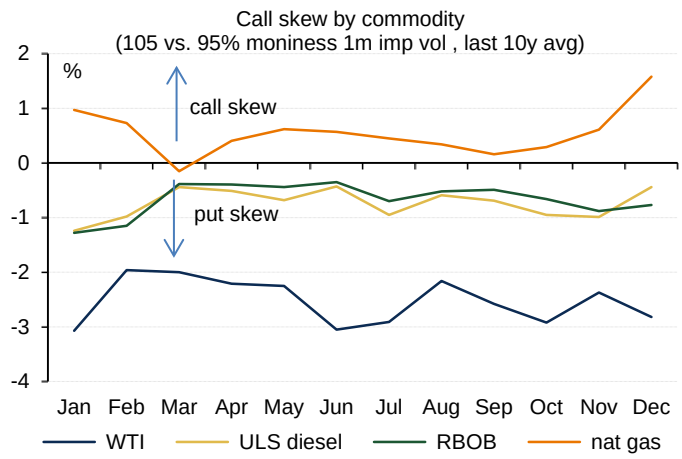
Data from Jan 1991 to Mar 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Highly weather-sensitive commodities tend to have a call skew

Natural gas, in contrast to oil, is mostly used for heating and thus less sensitive to cyclicality and more sensitive to weather[2]. So the historical distribution of natural gas has a distinct positive skew, which is exacerbated in the winter. This translates directly into a volatility call skew which rises in winter when returns are more positively skewed (Chart 46). The grains also have a positively skewed historical return distribution, caused by weather impacts on supply. Once the crops are planted, the production that year depends mostly on weather. Adverse weather shocks, such as too much or too little rain during the growing season, tend to have larger adverse effects on the yield (production per acre) than beneficial weather shocks – a drought at the wrong time can almost wipe out an entire crop. So the grains have a strongly positively skewed return distribution, which is exacerbated in the summer just before harvest when the crops are especially sensitive to weather shocks. This explains the strong call skew in ags which is exacerbated over summer (Chart 47).

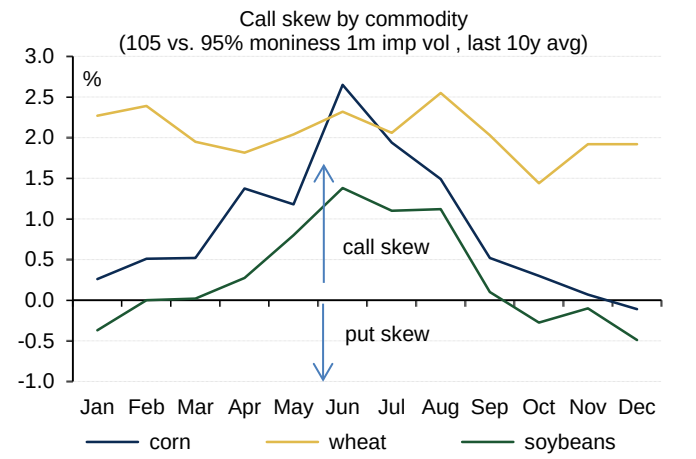
[2] Two thirds of US natural gas is used for heating either directly or indirectly via electricity generation, and less than 1/3 of demand is cyclical industrial demand.

Chart 46: The distribution of natural gas has a distinct positive skew, exacerbated in the winter, and also reflected in the volatility call skew



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 47: The grains have a strongly positively skewed return distribution which is exacerbated in the summer just before the harvest



Source: Bloomberg, BofA Merrill Lynch Global Research

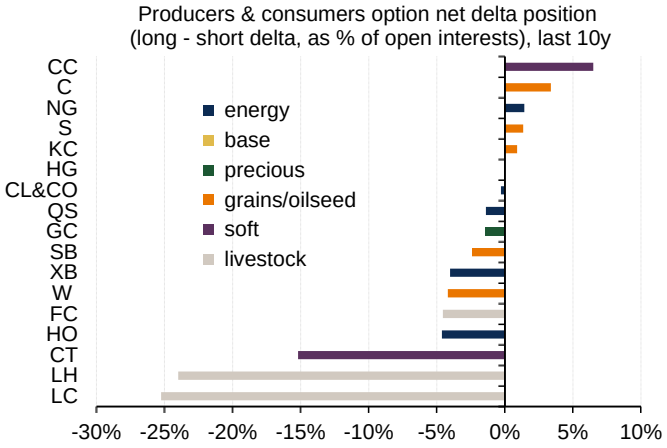
Relative consumer and producer demand for hedging also affects the skew

Relative consumer and producer demand for hedging also affects the volatility skew. If there are more natural buyers of downside protection (producers) than buyers of upside protection (consumers), OTM puts are bid up relative to OTM calls, which contributes to a volatility put skew. This is the case for most commodity markets. Producers tend to hedge more than consumers because most commodity producers are specialists whose entire earnings are often driven by a single commodity like oil for an E&P or say corn for a farmer in the US Corn Belt. So producers tend to hedge e.g. by buying options to lock in earnings over their cost planning horizon. Demand is much more fragmented than supply; each of us consume a little oil, gas and wheat every day, yet it is only a small part of our total consumption and hence not practical nor cost-effective to hedge. There are exceptions of course: airlines and some trucking companies are big oil consumers and do tend to systematically hedge by buying forward.

Positioning data indicates more producer than consumer hedgers

In general though, consumers tend to hedge much less than producers. And this is reflected in the CFTC positioning data for options positions (Chart 48). Positioning shows a net negative delta for the sum of consumer and producer positions, which indicates there are more buyers of puts (negative delta) than buyers of calls (positive delta) in the producer/consumer category. Livestock shows a very strong producer hedging bias. The picture is mixed for the grains, possibly because while most grain-producing farmers hedge part of their harvest forward (negative delta), livestock-producing farmers consume grains for feed and tend to hedge that consumption forward (positive delta). Natural gas shows on average a small positive net delta, which is not surprising given that 1/3 of gas demand is used for power generation and commercial power generators often hedge forward their consumption.

Chart 48: Consumers tend to hedge much less than producers, and this is reflected in the CFTC data for options positions



Source: Bloomberg, BofA Merrill Lynch Global Research

The spread between implied & realized volatility

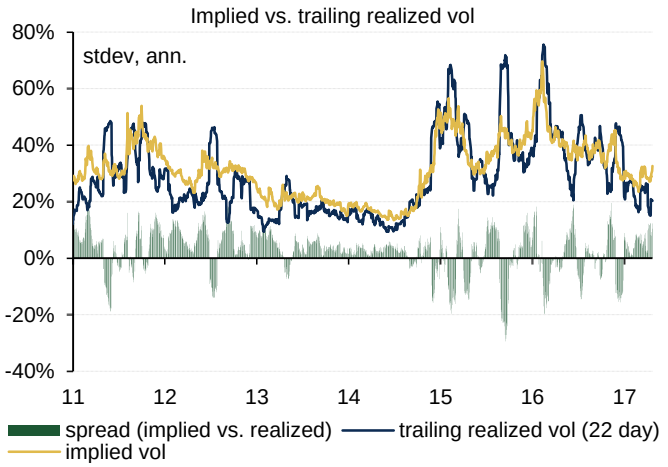
Implied vs. subsequent realized is a proxy for risk premium on selling vol

Taking advantage of differences between implied volatility and the subsequently realized volatility of the option's underlying is a common strategy among hedge-fund investors. This type of arbitrage is normally used to take advantage of the embedded risk premium paid by buyers of protection (or volatility buyers) in the options markets, but other factors may also come into play. For instance, the gap between implied and realized volatility may widen due to an unusually uncertain market environment. Over the holding period, a volatility seller will realize a profit on the trade if the subsequently realized volatility is below the implied volatility at which he sold the option. The profit is extracted by continuously re-hedging the short-option position to keep it delta-neutral.

Implied vs. trailing realized can be useful in identifying tactical opportunities

Understanding how the implied vs. realized volatility spread behaves over time is key to identifying trading opportunities. Of course subsequent realized vol is only available in hindsight, and when viewing the market in real time investors often look to the spread between the forward looking implied vol and the backward looking trailing realized vol available at the time (Chart 49). This spread widens when implied vol rises for example on a supply/demand or macro shock. This can be a good time to tactically short vol if one expects the shock to be short lived and implied vol to mean revert soon. In contrast, if the shock is expected to persist and implied vol can continue to rise, it may make sense to go tactically long vol.

Chart 49: When viewing the market in real time, investors often look to the spread between implied vol and the trailing realized vol



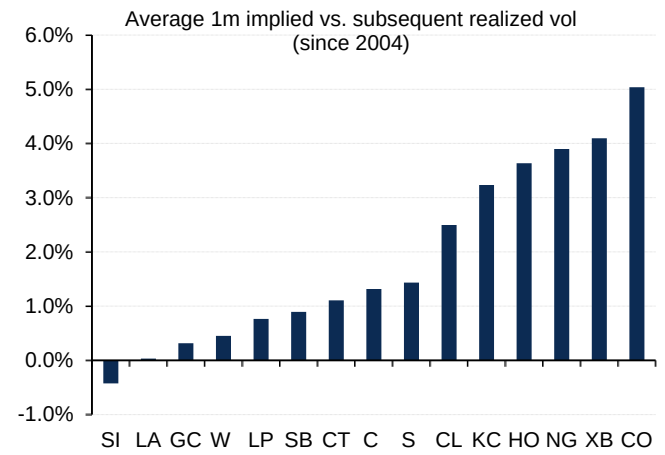
Source: Bloomberg, BofA Merrill Lynch Global Research

Implied generally trades at a premium to subsequent realized vol

For most commodities, implied volatility has historically traded at a premium to subsequent realized volatility (Chart 50). This is because risk-averse market participants are willing to pay a high premium for buying protection against large price moves. At the same time, volatility sellers charge a risk premium to bear the risk of upside spikes in implied volatility. In fact, the origin of the implied volatility premium has been the subject of intense academic debate. We observe that the implied vs. subsequent realized vol spread has been positive for most commodities in most years since 2004 (Chart 51) despite fluctuating levels of general macro vol, proxied for example by the VIX, and also after the end of QE in late 2014, which depressed vol in all asset classes.

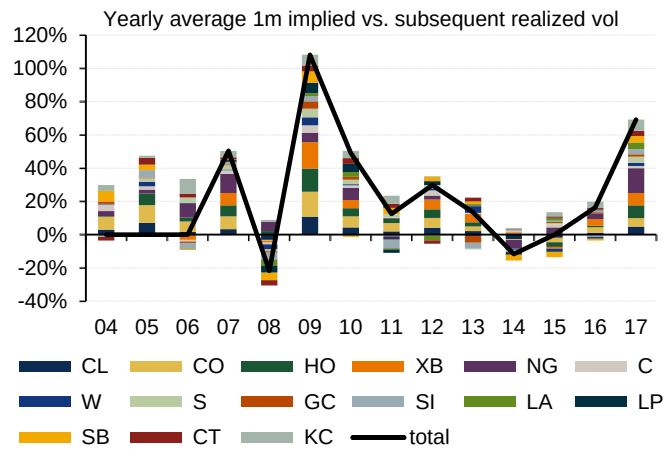
In the short run, however, the spread can be negative when subsequent realized vol surprises to the upside. There are two key examples of this. First, the Lehman collapse in 2008 caused an unexpected massive spike in vol in all markets including most commodities. The second example is 2014, when OPEC changed its 20 year+ standing oil policy and stopped balancing the market, which caused a massive and unexpected spike in volatility as the market digested and came to terms with the implications of the new oil market regime.

Chart 50: For most commodities, implied volatility typically trades at a premium to subsequent realized volatility



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 51: We observe that the implied vs. subsequent realized vol spread is positive for most commodities in most years since 2004



Source: Bloomberg, BofA Merrill Lynch Global Research

Implied vs. subsequent realized spreads are higher further out the forward curve…

The distribution of risk across the forward curve also amplifies the implied volatility premium in certain cases with the spread being wider on the part of the curve where protection is most sought (Chart 52 and Chart 53). This is despite the fact that the term structure of implied vol for commodities is generally downward sloping (see Chart 30 in section 2). The reason the term structure of implied vs. subsequent realized vol is upward sloping in commodities is that the term structure of realized vol is more steeply downward sloping than that of implied vol. This contrasts with financial assets like equities, which typically have an upward sloping term structure of implied vol and a flat term structure of realized vol – shocks shift the entire forward curve of financial assets equally as there is usually no physical benefit to holding the asset compared to a forward contract on it.

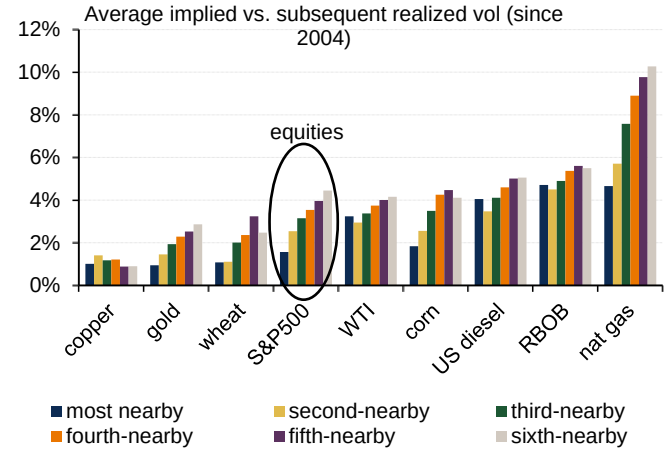
…because the term structure of realized vol is more downward sloping than implied

The physical nature of commodity markets and the fact that supply and demand have to balance in each period means that long dated futures contracts have lower realized and implied volatility than near dated, as supply and demand shocks can better be corrected over longer periods of time. This is especially the case for hard-to-store commodities like oil or natural gas, while shocks to easy-to-store gold and copper are propagated more evenly along the future curve as it is generally optimal to holder larger inventory buffers of these cheap-to-store commodities.

Gold is special as it behaves more like a financial asset

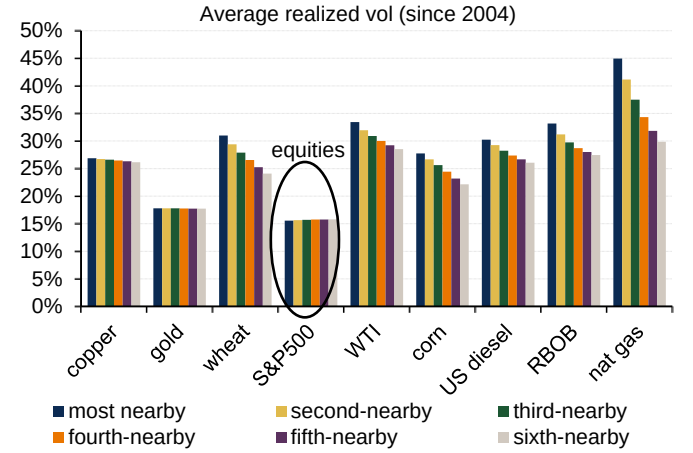
The larger the inventory buffer, the more closely the term structure of realized vol resembles the flat term structure of financial assets. Gold is a special commodity in that it behaves more like a financial asset than a commodity, with a completely flat term structure of realized vol, like equities. This is because gold is not consumed, apart from a few minor industrial uses, and 90%+ of all the gold ever produced sits in inventory, which makes physical shortages virtually impossible. Gold has an upward sloping implied vs. subsequent realized term structure like other commodities, because it, like equities and in contrast to most commodities, has an upward sloping implied vol term structure (see Chart 30 in section 2).

Chart 52: The reason the term structure of implied vs. subsequent realized vol is upward sloping in commodities…



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 53: …is because the term structure of realized vol is more steeply downward sloping than that of implied vol



Source: Bloomberg, BofA Merrill Lynch Global Research

How far out in curve to short vol? A question of liquidity

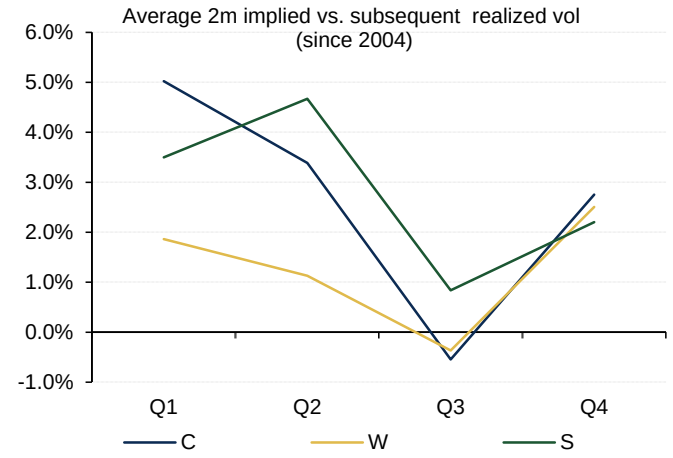
For investors that systematically want to capture the implied vol premium over subsequent realized, e.g. by systematically shorting volatility by selling options, shorting vol further out on the curve might enhance the risk premium earned due to the widening implied vs. realized spread across the term structure. This should be weighted up against liquidity considerations and transactions costs though. Systematically shorting vol beyond a few months out on the forward often runs into liquidity constraints which increases transaction costs and erodes away the higher premium on implied vol further out the curve.

Agricultural commodities have tighter implied-realized spread in summer

There is also a distinct seasonal patterns in the implied vs. subsequent realized spread for many commodities. In grain and oilseed markets, the implied vs. subsequent realized vol spread falls during the summer when adverse weather risks to supply are greatest and realized vol tends to spike (Chart 54). Farmers don't mind upside price spikes, and as price spikes tend to be skewed to the upside in summer, grain producers are less willing to pay a premium on downside protection when there isn't as much downside as upside risk over summer. So the premium earned by sellers of vol to farmers is lower in the summer. When the harvest comes in the fall, farmers can sell spot and hence there is no need to hedge, so the implied vol premium typically collapses in 3Q.

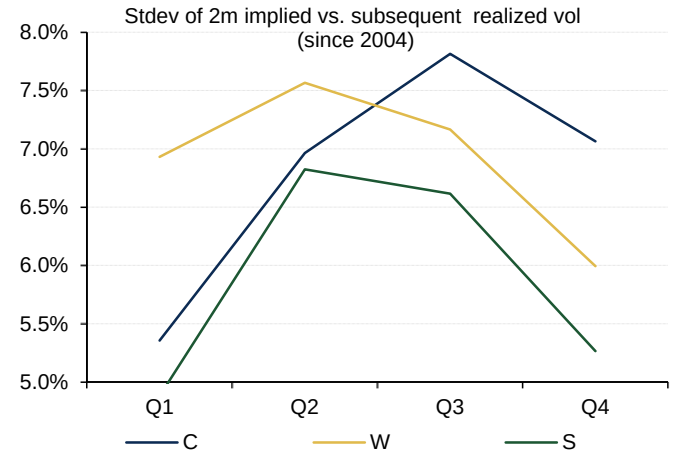
Moreover the variance of this premium, as proxied by the variance of the implied vs. subsequent realized spread, is also higher in the summer (Chart 55). These two observations combined indicate that someone systematically selling vol might want to reduce exposure to the short vol position during the summer relative to the winter months, as the risk premium earned from systematically being short vol in summer is both lower and more volatile.

Chart 54: In grains and oilseed markets, the implied vs. subsequent realized vol spread falls during the summer



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 55: The variance of the implied vs. realized spread is also higher in the summer



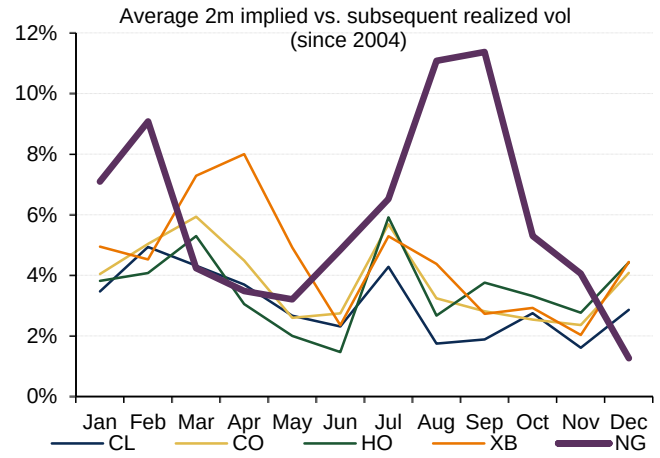
Source: Bloomberg, BofA Merrill Lynch Global Research

Energy commodities implied-realized vol is highest in winter

For oil, the seasonal peak in implied vs. subsequent realized happens in the winter when implied vol rises more than realized vol- the premium on protection increases as the risk of extreme price moves caused by weather is higher in the winter (Chart 56). For natural gas, the implied vs. realized spread peaks in Feb-Mar, which is also the seasonal peak implied vol. Both implied and realized vol rise during winter from November to March, yet implied vol peaks only in March towards the end of winter as the risk of very large upward prices moves goes up. Inventories are close to their seasonal low towards the end of winter, and a cold shock in Feb-Mar thus poses greater risk of a stock out than in the beginning of winter. And so the price risk is strongly skewed to the upside towards the end of the winter, and demand for upside protection from consumers is especially high towards the end of winter.

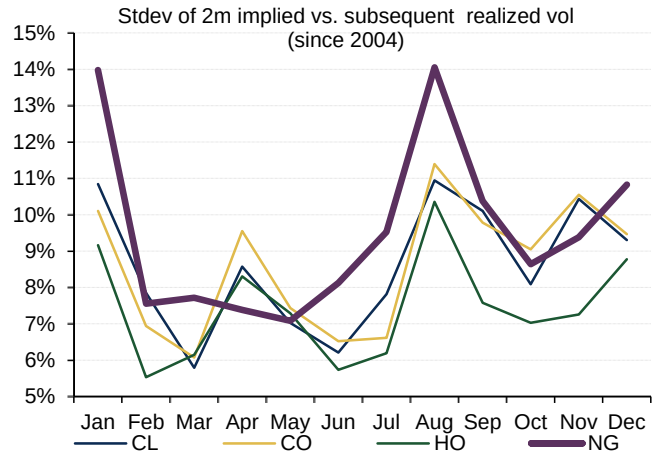
Interestingly nat gas implied vs. realized peaks again in Aug-Sep when the summer demand for gas for air-conditioning peaks. Gas demand for power generation actually peaks in the summer, not in the winter, as in the winter gas is too expensive (due to heating demand) and power generators switch to coal. So the summer peak in implied-realized likely reflects increased seasonal hedging demand from power generators. The variance of implied-realized peaks at similar times to the average spread, in winter and in Aug-Sep (Chart 57). So it is not necessarily beneficiary to increase exposure to short vol strategies during these seasonal peaks in the implied-realized spread.

Chart 56: For oil, the seasonal peak in implied-realized spreads happens in the winter when vol picks up due to seasonal fluctuations



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 57: The variance of implied-realized spreads peaks at similar times, in winter and in Aug-Sep



Source: Bloomberg, BofA Merrill Lynch Global Research

Implied vs. expected subsequent realized isn't directly tradable, but a good proxy

In practice, any strategy that seeks to harvest the short vol risk premia, like a short variance swap, a short delta-hedge straddle, or a call overwriting strategy, will capture somewhat different returns from the implied vs. subsequent realized vol spread. Aside from the choice of short vol strategy and its parameter choices, there is a more subtle reason for this. The "implied vol" that we observe is model based and typically an upward biased estimator of the true market expected future realized volatility[3]. Even so we find that the implied vs. subsequent realized vol is a good proxy for performance of a systematically short vol strategy selling delta-hedged straddles on single commodities (see section 4 on systematically short straddle strategies).

[3] Implied vol is typically calculated from a simple Black & Scholes (BS) (see appendix for details) model which assumes that log returns are normally distributed. In reality we know that commodities have fatter tails than the normal distribution which means the B&S tends to overstate the implied vol relative to what the market expects future realized vol will be. This bias is exacerbated for implied vol at the wings (i.e. the skew) yet the bias is also positive for at-the-money options.

4. Commodity volatility strategies

Many ways of monetizing the volatility risk premium in commodity markets

There are many ways to invest in commodity volatility and monetizing the volatility risk premium in commodity markets. We have written extensively about this in the past, focusing on the two main strategies: (1) Call overwriting and (2) delta-hedged strangle (or straddle) selling.

- **Call overwriting:** We first introduced a systematic call-write strategy on WTI crude oil in 2006. More recently, we have launched a series of systematic out-of-the-money (OTM) call selling strategies in April 2013 which are calculated using listed option prices (see Transparent call overwriting), and in September that same year augmented and improved these with a dynamic version using signals based on implied-realized vol spread and call skew (see Signal-based call overwriting, 4 Sep 2013).

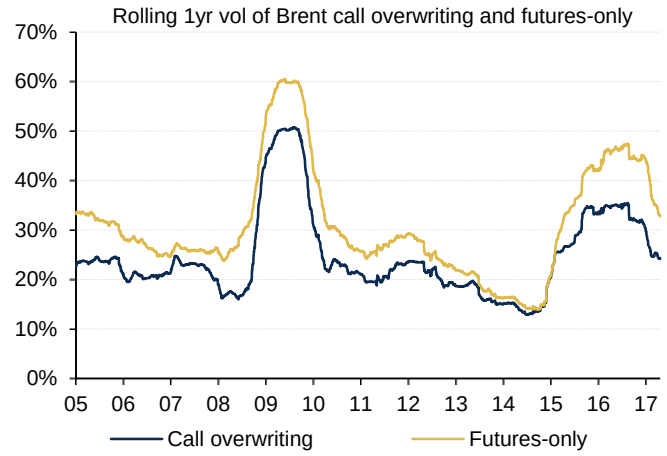
- **Delta-hedged strangle selling:** In August 2013 we launched a series of systematic delta-hedged strangle (OTM call and put) selling strategies (see Systematic strangle selling, 30 Aug 2013) on four key commodities WTI, Brent, Gold, and Nat Gas. And in December that year we expanded our delta-hedged strangle selling strategy by including four agricultural commodities (sugar, corn, soy, and wheat) in addition to the four major commodities (WTI, Brent, Nat Gas, and Gold) we considered earlier (see Delta-hedged strangle selling, 30 Dec 2013). In November 2015 we further extended our vol framework using dynamic signals provided by our predictive framework which employs implied-realized vol spread and vol skew as inputs (see Extending our vol framework). We also had a couple of publications on how to capture tactically volatility risk premium in commodity markets (see Selling vol in a low vol regime, 2 Jun 2014 and Commodity revolver).

Systematic call overwriting

Call overwriting strategies tend to outperform long futures rolling positions

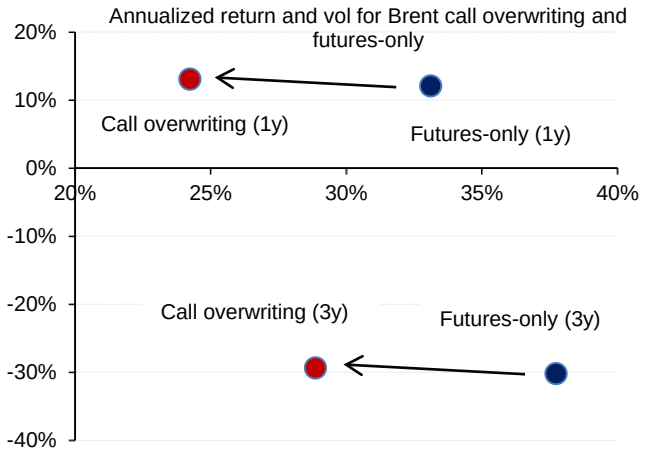
The systematic sale of out of the money (OTM) call options is one way to capture the volatility risk premium in commodity options markets, which exists because implied vol typically trades at a premium to subsequent realized vol. Thus call overwriting typically outpaces a futures-only index, unless the underlying commodity price spikes. The risk of having significant drawdowns when the futures price spikes well above the option strike price can be mitigated by combining call overwriting indices for many different commodities. For a call overwriting index, the systematic sale of an OTM call option outperforms a futures-only index because of the call premium. The systematic collection of the premium, along with the capped upside, typically leads to lower vol as compared to the futures-only index (Chart 58). Call overwriting can therefore be considered as an enhancement to an existing beta position (futures-only), with a higher info ratio – both by improving the returns and lowering the vol (Chart 59).

Chart 58: Call overwriting can help reduce volatility compared to a long futures-rolling index position…



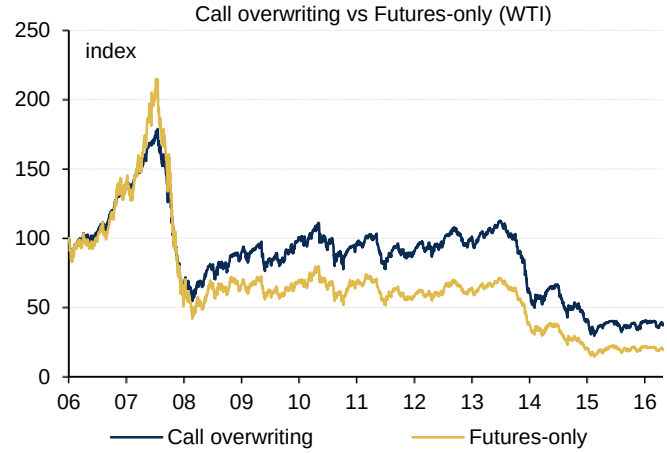
Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Mar 2003 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Chart 59: …and have higher info ratios due to enhanced returns and lower vols



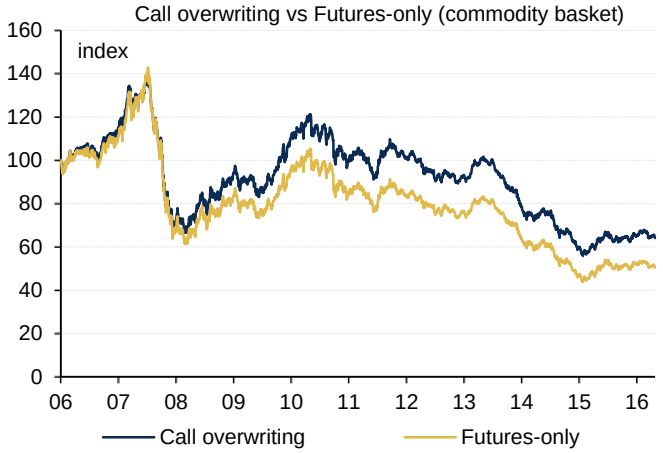
Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Mar 2003 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Chart 60: Call overwriting would have outperformed a long futures-rolling position in oil



Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Mar 2003 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Chart 61: Similarly, a broad commodity basket would have benefitted from call overwriting



Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Mar 2003 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Systematic strangle selling

Short strangle/straddle selling better captures the vol risk premium

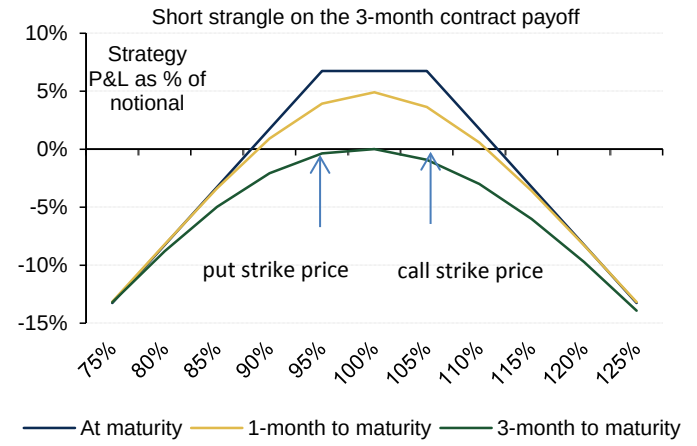
The systematic sale of simultaneous out of the money (OTM) call options and OTM put options, known as a short strangle, is another way of capturing the volatility risk premium in commodity options markets. A short strangle position earns a premium by selling an OTM call and put and incurs a loss if the price of the underlying moves too far beyond the call or the put strike such that the option is exercised (option seller pays buyer) at a greater cost than the premium earned by selling the options (Chart 62). The short straddle performs as long as the price of the underlying does not move too much relative to the premium received- in other words subsequent realized volatility is low compared to the implied vol at which the option was initially sold.

Short strangles are short vega (i.e. negative vega)

A rise in vol has a positive impact on option premiums, and hence a negative impact on the market value of the short strangle- i.e. the short strangle has a negative "vega". A strangle where the put and call have the same strike is called a straddle (Chart 63).

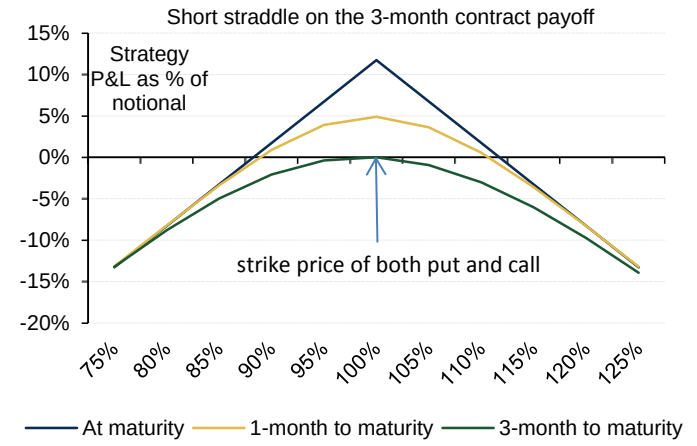
When shorting vol with straddles the strikes are typically chosen as close to at-the-money (ATM) as possible at inception. The short straddle has a more negative vega than the strangle because vega in absolute terms is highest for ATM options, and the straddle is as such the most pure exposure to short volatility of the two strategies. Still, both strategies have a significant exposure to movements in the underlying commodity price as well, though this can be mitigated by delta hedging.

Chart 62: A short strangle incurs a loss if the price of the underlying moves too far beyond the call or the put strike



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 63: A strangle where the put and call with the same strike is called a straddle



Source: Bloomberg, BofA Merrill Lynch Global Research

Short strangles are short gamma (i.e. negative gamma)

Strangles are not generally market (or "delta") neutral. One exception is if the strike of the put and the call in a strangle are equally far from the money, then the two options have an approximate equal and opposite delta (call delta ≈ - put delta), and the net position is approximately delta neutral (delta=0). The option strikes are typically chosen such that this is the case at inception, at which point the strangle is approximately delta neutral. Both the short put and call have negative "gamma" (gamma is the change in the delta w.r.t. the underlying) and so as the commodity price changes after inception the net position is no longer delta neutral. Thus if the underlying price moves down after inception the delta becomes positive, and if the price moves up the delta becomes negative.

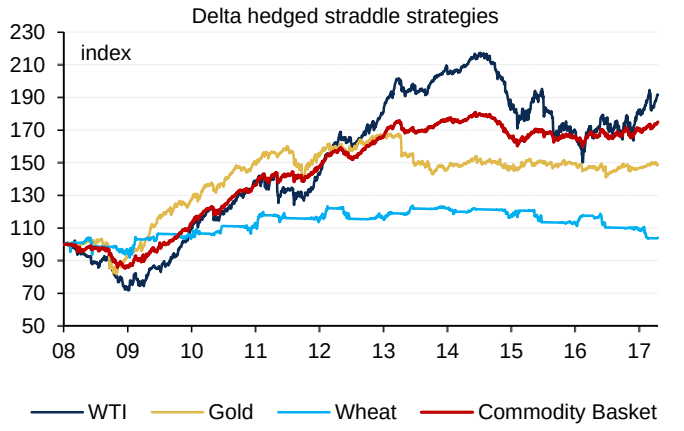
Delta hedging makes short strangles closer to a pure short vol play

The negative gamma means whether the price of the underlying goes up or down, the impact of the price moves on the short straddle is always negative and becomes increasingly negative the more the price moves (as the delta will move in the opposite direction to the price). Hedging the delta when the price of the underlying moves can bring the net position back to delta neutral, which limits the change in value from further price moves. But the gamma is still negative which means the negative impact of price moves on the short strangle can never be eliminated, only the magnitude of the negative can be mitigated the more frequent the delta hedging.

Delta hedged strangle selling suffered during the oil price crash of 2014…

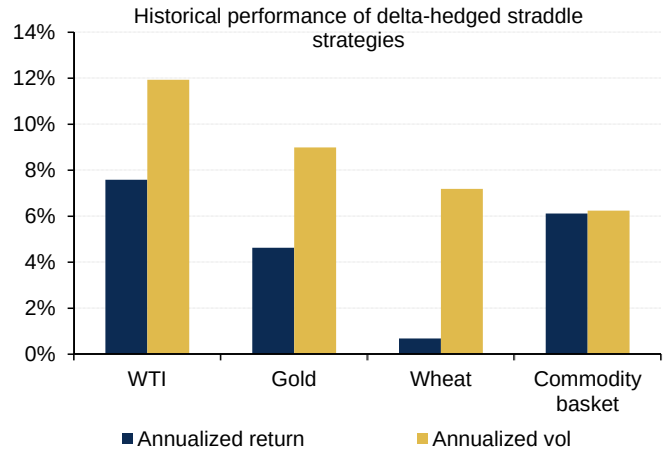
A diversified basket of short daily-hedged straddles on 8 different commodities would have on average performed well since 2008 (Chart 64 and Chart 65). It did, however, suffer two significant drawdowns, in 2008 and in 2014-15, both caused by oil. In both cases oil prices crashed which coincided with soaring volatility, and hence the negative impact from the short gamma and short vega created a double negative whammy on performance. A combination of falling prices and rising vol is not uncommon, though the magnitude of the moves in these two instances was, and that's what caused the drawdowns. It is important to keep in mind that vol does not have to fall for the short straddle to perform on average, it just has to not spike upwards so much that it erodes the generally positive risk premium on implied vs. subsequently realized vol.

Chart 64: Except for wheat, short vol strategies would have shown robust historical performance…



Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Jan 2008 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Chart 65: …and would have worked better had we diversified the strategy across a broad basket of commodities

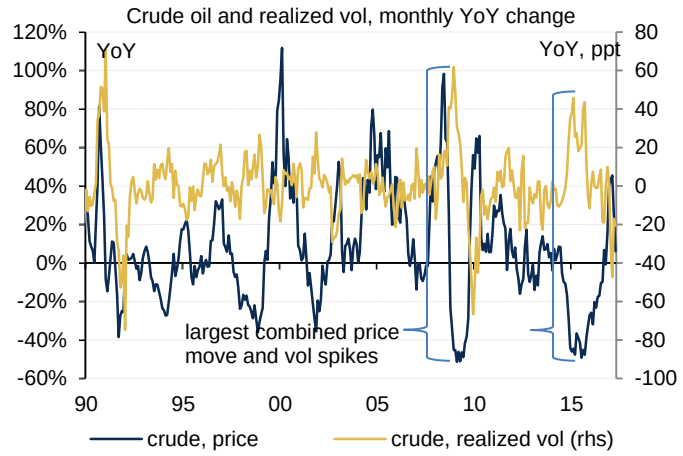


Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Jan 2008 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

…which was an exceptional market event, and performance has since recovered

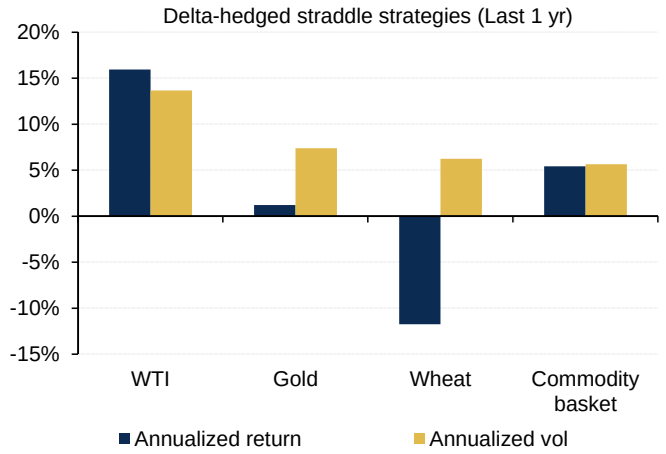
The two drawdowns in 2008 and 2014-15 were caused by two equally exceptional events which some of the largest combined oil price changes and vol spikes in history (Chart 66). The first came on the collapse of Lehman Brothers in late 2008 and the first global recession since the 1930s. The second came on Saudi's mid-2014 decision to stop balancing the oil market to test the breaking point of US shale producers and ultimately shut them and higher cost producers out of the market. The shale technology was new and its price elasticity of supply untested in a downward market, which meant no one knew how far priced had to go to cause a significant slowdown in production. Ultimately in percentage terms it turned out to be the biggest oil price crash in history as oil prices went from $115 to $27 in two years. In these extreme market moves when vol spikes and keeps rising, a dynamic filter which reduces exposure short vol strategies might help mitigate the drawdowns.

Chart 66: The two drawdowns in 2008 and 2014-15 were some of the largest combined oil price changes and vol spikes in history



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 67: ...and delivered high info ratios in the past 1yr on the back of strong performance of short vol in crude

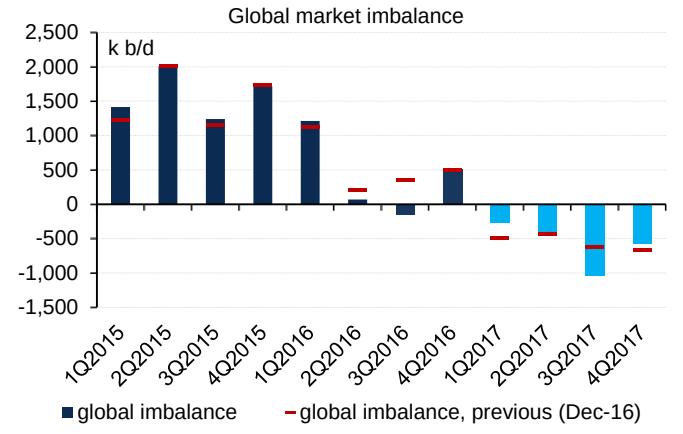


Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Apr 2016 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Tactically short vol straddles perform in a market recover phase

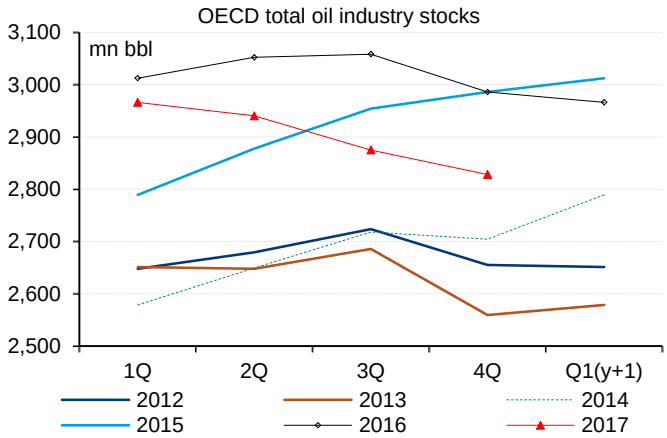
Since the drawdown the strategies have recovered, and the info ratio for oil as well as the basket of 8 commodities is close to 1 in the past year (Chart 67 above). Crude prices have stabilized after the initial crash and vol has come off its highs. With crude prices depressed at close to cost of production further big downward moves are less likely than before. Also, as the market has recently moved into deficit (Chart 68) prompting inventories to draw away from their record highs (Chart 69), vol is likely to fall gradually, which also benefits short vol strategies. In any case big spikes in vol are increasingly less likely as stocks draw away from the extremes. So a recovering crude oil market is generally a good time to go short commodity vol.

Chart 68: With the market moving into deficit, inventories should draw from their record highs...



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 69: ...vol is likely to fall gradually, which also benefits short vol strategies

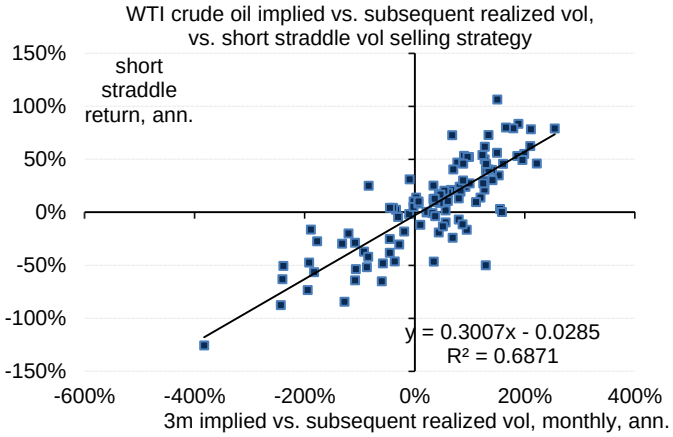


Source: Bloomberg, BofA Merrill Lynch Global Research

Implied vs. subsequent realized is a good proxy for delta-hedged short straddles

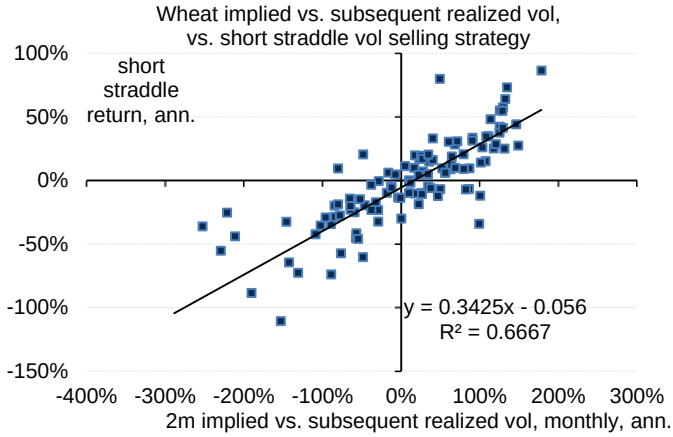
Does the short straddle do a good job of capturing the volatility risk premia in commodities? In our view, yes. The payoff from a short vol strategy such as a daily delta hedged short straddle strategy correlates tightly to the implied vs. subsequent realized vol spread (Chart 70). The R-squared from regressing such representative short straddle strategies on their respective commodity implied vs. subsequent realized spread and a constant is generally 60-70% (Chart 71). In our view such as a strategy is an effective way of capturing the implied vs. subsequent realized volatility risk premium in commodities.

Chart 70: A volatility seller will realize a profit on the trade if the subsequently realized volatility is below the implied volatility



Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Jan 2004 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

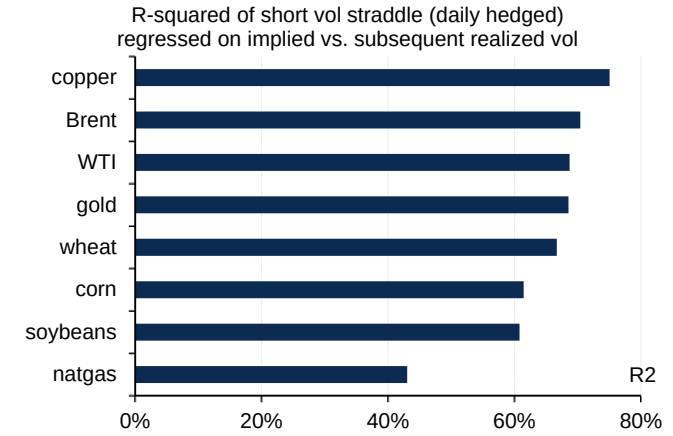
Chart 71: The profit is extracted by continuously re-hedging the short-option position and keeping it delta-neutral



Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Jan 2004 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Moreover the constant from such a regression is statistically indistinguishable from zero for all tested strategies with the exception of nat gas and the grains (corn, wheat, soybean). And once the grains are adjusted for reduced exposure in the summer (the low risk premia period) the intercept on the grains is also zero (Chart 72). In other words on average when implied vs. subsequent realized vol is positive so is the risk premia from systematically selling vol via delta hedge short straddles, which motivates looking at implied vs. subsequent realized as a proxy for short vol performance.

Chart 72: The R-squared from regressing short straddles on their respective commodity imp-realized is generally 60-70%



Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Jan 2004 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Table 3: The constant from the regression is not statistically different from zero for all tested strategies except nat gas and grains before adj.

	intercept		slope		R^2
	beta	p-value	beta	p-value	
WTI	-0.03	21%	0.30***	0%	69%
Brent	-0.02	33%	0.31***	0%	70%
nat gas	-0.11***	1%	0.31***	0%	43%
copper	0.00	98%	0.27***	0%	75%
corn	-0.07***	0%	0.32***	0%	61%
wheat	-0.06**	2%	0.34***	0%	67%
soybean	-0.11***	0%	0.44***	0%	61%
corn, summer adj.	0.01	61%	0.12***	0%	20%
wheat, summer adj.	0.00	96%	0.10***	0%	23%
soybean, summer adj.	-0.01	71%	0.15***	0%	27%

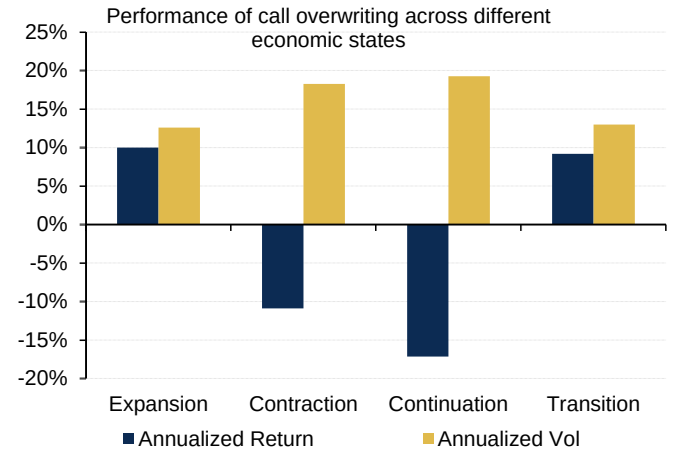
Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Jan 2004 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

The macro cycle and the commodity volatility risk premium

Short vol strategies like call overwriting and short delta-hedged straddles tend to perform best when the economy is in expansion or transition phase (Chart 73). Short delta-hedged straddles have the best performance of the two across all phases of the cycle (Chart 74), and returns are on average marginally positive even in economic contractions. The strong performance during expansions is likely due to the general fall in vol during such times when all markets are rallying. Performance is also strong in transition phases as vol tends to be stable and short vol strategies systematically earn the short vol risk premium. The rise in vol

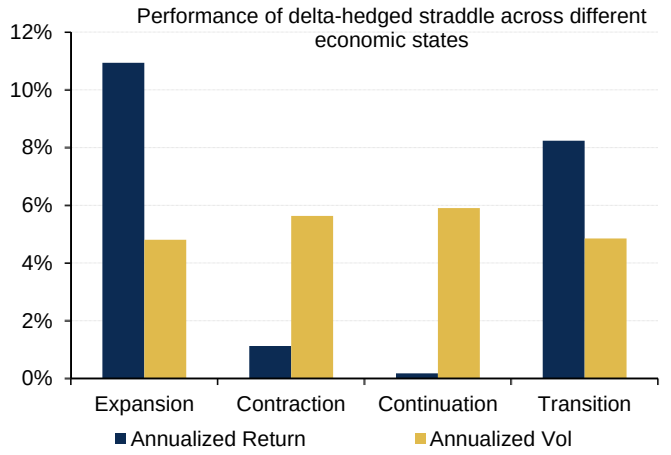
during contraction phases hurts the strategy, though not so much that it completely erodes the risk premia earned by systematically being short vol.

Chart 73: Call overwriting and short delta-hedged straddles tend to perform best when the economy is in expansion or transition phase



Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Apr 2007 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Chart 74: Short delta-hedged straddles have the best performance of the two across all phases of the cycle



Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Jan 2008 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Table 4: 1M standard deviations of WTI and BCOM across different economic states

	Expansion	Contraction	Continuation	Transition
WTI	8.6	9.8	11.6	7.3
BCOM	2.4	2.6	3.0	2.1

Data from Apr 2007 to Apr 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Short commodity vol has weak correlation with other risk premia

Delta-hedged strangle selling displays low correlation to other risk premia factors in the commodity space (Table 5), which makes them a strong complement to a commodity risk premia basket. For example, the delta-hedged strangle selling has strong performance during the transition phase of the economic cycle, in contrasts for example momentum strategies which tend to suffer during the transition as no clear trend can be found (see Momentum continues to deliver). These two risk premia strategies complement each other well with a correlation of -14%. The delta-hedged strangle selling also shows only modest correlation to the short vol strategies in other asset classes (Table 6), which makes them a good compliment to cross-asset risk premia baskets.

Table 5: Delta-hedged strangle selling displays low correlation to other risk premia factors in the commodity space...

	Congestion	Carry	Volatility	Contrarian	Momentum
Congestion	100%	31%	5%	8%	11%
Carry		100%	-11%	14%	21%
Volatility			100%	-6%	-14%
Contrarian				100%	-28%
Momentum					100%

Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Apr 2012 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Table 6: ... and modest correlation to the short vol strategies in other asset classes

	Commodity	Equity	Rates	FX
Commodity	100%	23%	16%	22%
Equity		100%	23%	29%
Rates			100%	25%
FX				100%

Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Apr 2012 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Dynamic enhancement of vol strategies

The implied vs. realized spread has predictive power over short vol performance

We introduced a predictive vol return framework to help investors determine when to sell delta-hedged WTI straddles (see Taking stock of commodity vol). In particular, we forecast straddle returns by regressing cumulative 3M straddle returns on the current level of the implied-realized spread and the put skew. Our analysis finds that both the implied-realized spread and the put skew have historically had some predictive power, at least over longer horizons, such as 3Ms. 3M-ahead returns to a delta-hedged WTI short straddle are regressed on the level of the spread and the 25D risk reversal for WTI. Data are weekly and span from Oct 2007 to Mar 2017.

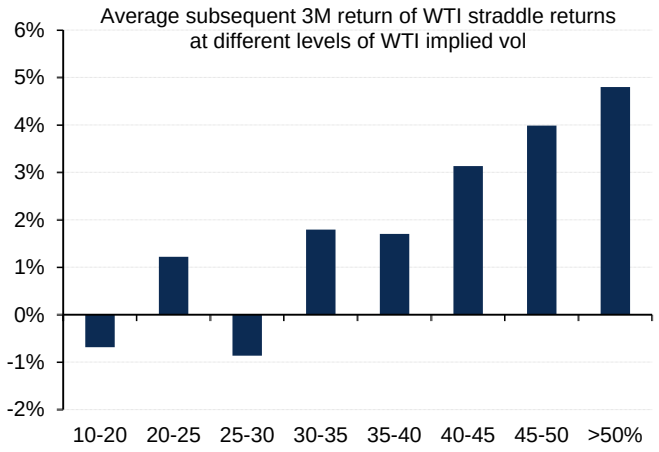
The data show that delta-hedged WTI straddle on average perform after an increase in implied vs. realized vol, due to the mean-reversing tendency of implied vol- shorting vol on average pays off when implied vol is above its historical average level. WTI straddle returns over the next 3 months have been generally positive when IV was above 30%, and returns are increasingly positive the higher the starting level of vol (Chart 75).

Table 7: Skew and implied and realized vol spreads help predict 3M-ahead WTI straddle returns

	beta	t-stat	p-value
Implied vol - realized vol	0.17	1.85	0.07
25D risk reversal	-0.98	-6.36	0.00
R-squared	0.26		

Source: Bloomberg, BofA Merrill Lynch Global Research
Note: 3M-ahead returns are regressed on the level of the spread and the 25D risk reversal for WTI. Data are weekly and span the period from Oct 2007 to Apr 2017. Implied volatility is measured using 3M ATM WTI options, and realized volatility is calculated as the average value of forecasted volatility over the following 3Ms using a GARCH(1,1) model. To correct for serial correlation in the residuals (due to overlapping data), Newey-West HAC standard errors are used to calculate t-stats and p-values.

Chart 75: Selling volatility on spikes has paid off due to the mean-reverting tendency of volatility



Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Nov 2007 to Jan 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Our predictive vol return framework can enhance delta-hedged straddle selling

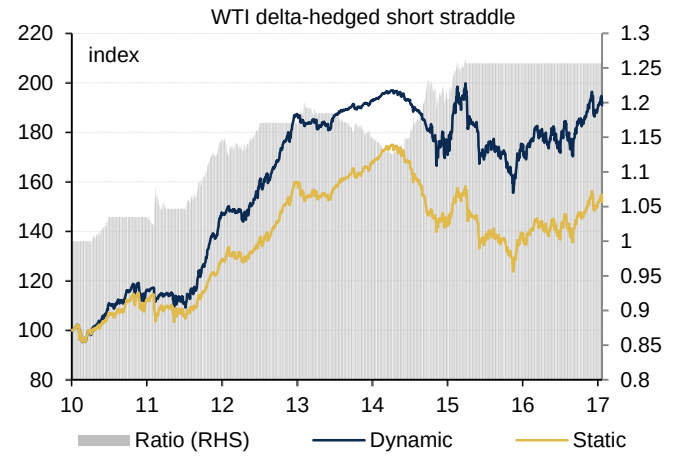
Our predictive vol framework can be effectively used to dynamically enhance the return of short vol strategies. We move from a systematic strategy that passively sells delta-hedged straddles to a dynamic vol strategy that adjusts exposure to short straddles based on forecasted straddle returns. In particular, when our signal predicts returns above the 60th percentile of the historical return distribution, we increase our notional exposure to a systematic, delta-hedged short straddle to 150%. However, if our signal predicts returns below the 40th percentile of the historical return distribution, we decrease exposure to 50%. In between these cutoff values, we maintain exposure at 100%. The dynamic strategy generally improves information ratios relative to a static delta-hedged short straddle strategy for the eight commodities. The improvement is particularly noticeable for WTI and Nat gas (Chart 76 and Chart 77).

Table 8: Dynamic vol selling delivers a more attractive risk-reward profile than static vol selling in WTI, Brent, Nat Gas, Soy, Corn, Gold, and EW-basket

		Avg Return	Avg Vol	Info Ratio
WTI	Static	6.4%	9.8%	0.65
	Dynamic	9.7%	10.2%	0.95
Brent	Static	9.7%	9.6%	1.01
	Dynamic	10.0%	9.7%	1.03
Nat Gas	Static	1.7%	9.5%	0.18
	Dynamic	3.1%	10.0%	0.31
Wheat	Static	-2.9%	9.1%	-0.32
	Dynamic	-3.5%	9.9%	-0.36
Soy	Static	0.5%	7.0%	0.06
	Dynamic	1.2%	7.8%	0.15
Corn	Static	1.2%	8.6%	0.14
	Dynamic	1.4%	8.5%	0.16
Sugar	Static	-1.5%	4.6%	-0.31
	Dynamic	-2.1%	5.4%	-0.4
Gold	Static	3.0%	6.4%	0.46
	Dynamic	2.2%	3.7%	0.6
EW portfolio	Static	2.3%	4.0%	0.56
	Dynamic	2.8%	4.1%	0.68

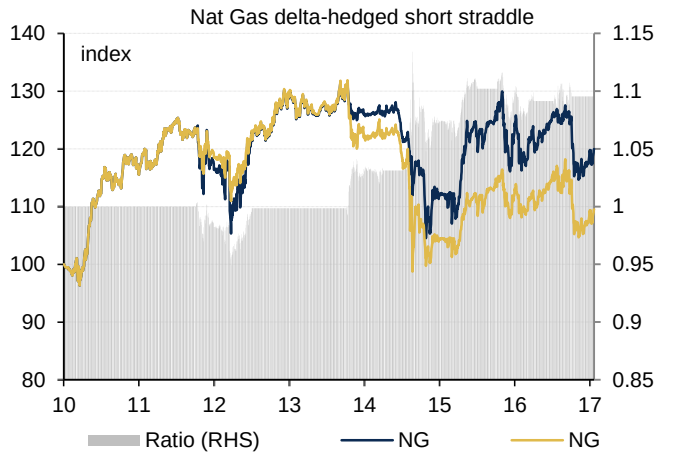
Data from Apr 2010 to Apr 2017. Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 76: WTI dynamic vol selling



Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Apr 2010 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Chart 77: Nat Gas dynamic vol selling

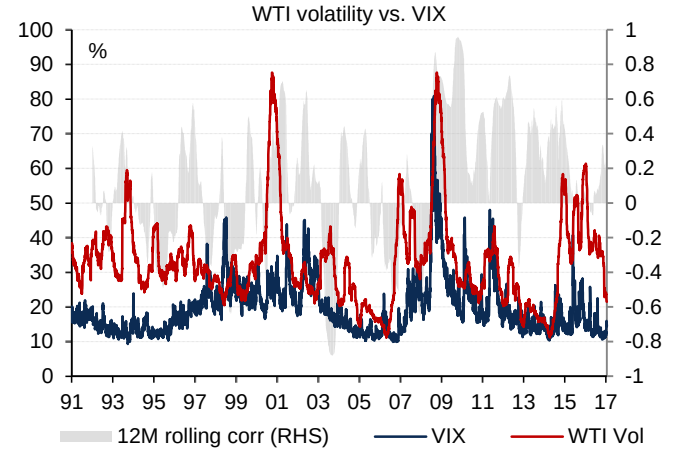


Source: Bloomberg, BofA Merrill Lynch Global Research
Shows back-tested results for the period Apr 2010 to Apr 2017. Back-testing is hypothetical in nature and reflects application of the strategy prior to its introduction. It is not actual performance and it is not intended to be indicative of future performance.

Commodity vol is a function of S&D fundamentals and macro

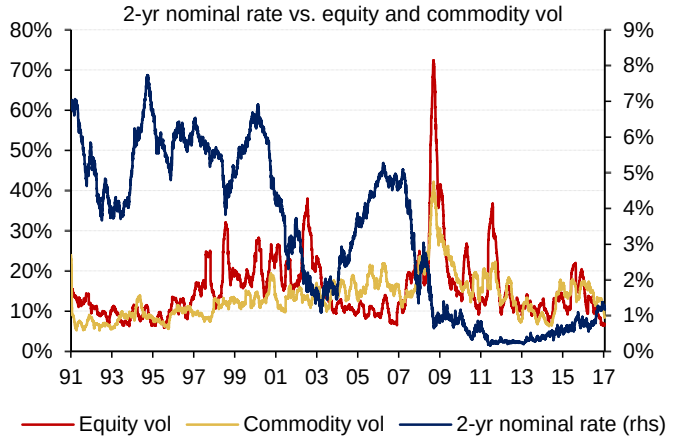
Dynamically predicting the future of commodity vol can be used to construct dynamic signals to enhance the performance of systematic vol strategies. We analyzed what factors are driving commodity (BCOM), oil, and equity volatility as a proxy for broader macro vol which also affects commodity vol (see Taking stock of commodity vol). Oil volatility and equity volatility (VIX) tend to be highly linked over long periods of time (Chart 78). Moreover, higher interest rates generally tend to drive volatility for commodities as well as other asset classes (Chart 79).

Chart 78: Oil volatility and equity volatility (VIX) tend to be highly linked over long periods of time



Source: Bloomberg, BofA Merrill Lynch Global Research

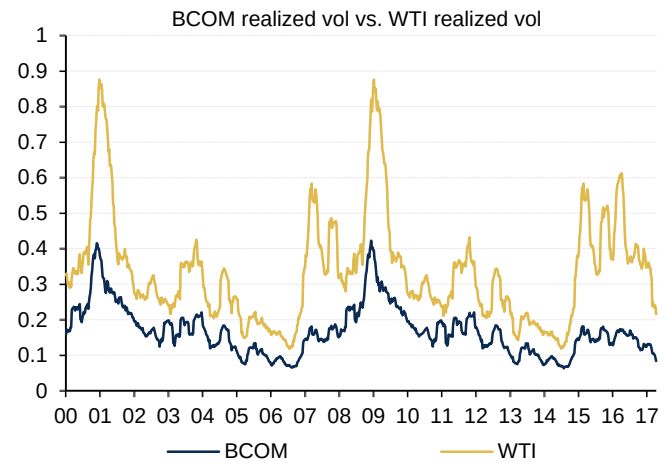
Chart 79: Higher interest rates generally tend to drive volatility for commodities as well as other asset classes



Source: Bloomberg, BofA Merrill Lynch Global Research

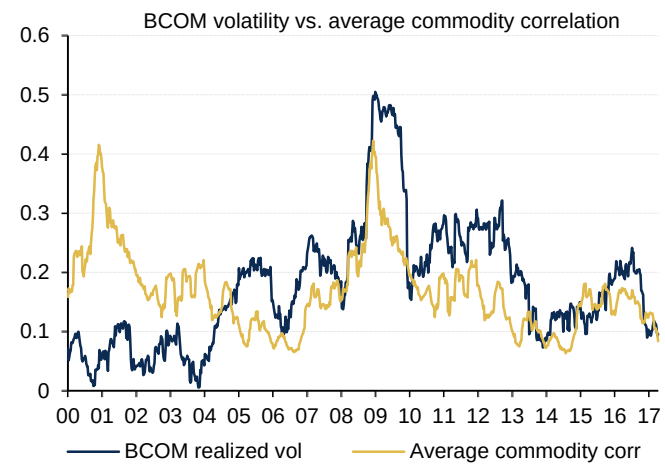
Commodity index (BCOM) volatility is also closely connected to vol across other asset classes like equities. Yet it is ultimately more linked to micro fundamentals through the vol of major underlying components like oil (Chart 80). Meanwhile, correlation and index vol tend to go hand in hand, as cross-commodity correlations generally pick up rapidly in times of market turbulence and drop swiftly as commodity micro fundamentals reassert themselves (Chart 81). As such, we use oil volatility and cross-commodity correlations to predict commodity index vol in our simple framework (Table 10).

Chart 80: Commodity index volatility is closely connected to micro fundamentals through the vol of major underlying components like oil…



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 81: …and tends to go hand in hand with cross-commodity correlations



Source: Bloomberg, BofA Merrill Lynch Global Research

Table 9: BCOM volatility is driven by oil volatility and correlations across the commodity sector

	beta	t-stat	p-value
WTI realized vol	0.23	9.80	0.00
Average commodity correlation	0.31	9.41	0.00
R-squared	0.79		

Source: Bloomberg, BofA Merrill Lynch Global Research

Note: Data are weekly and span the period from Jan 2004 to Apr 2017. 3M realized vol for BCOM and WTI. Average commodity correlation is measured at the weekly frequency as an equally-weighted average of all pairwise correlations (1yr MA) between each of six BCOM sectors. Newey-West HAC standard errors are used to calculate t-stats and p-values.

Furthermore, we constructed a parsimonious model to establish a fair value for WTI crude oil vol that incorporates the VIX, interest rates, and inventories as the key explanatory variables of volatility (Table 11). Since crude volatility tends to spike both at times of very low and high inventory levels generating a u-shaped curve, we included a quadratic term to capture it.

Table 10: WTI volatility is driven by interest rates, equity volatility, and crude inventories

	Beta	t-stat	p-value
2YR UST	1.12	1.76	0.08
VIX	0.01	7.45	0
DOE crude stocks (linear)	0.9	4.79	0
DOE crude stocks (squared)	4.41	2.49	0.01
R-squared	0.65		

Source: Bloomberg, BofA Merrill Lynch Global Research

Note: Dependent variable is logarithm of trailing 3M realized volatility of the Brent BCOM subindex (BCOMCL). De-trended and de-seasonalized stocks enter the regression in both linear and quadratic terms in order to capture a U-shaped relationship between inventories and realized volatility. Newey-West HAC standard errors are used to calculate t-stats and p-values. Data are weekly and span the period from Jan 2004 to Apr 2017.

Lastly, macro risks, broadly captured by indices like the VIX or our own Global Financial Stress Indicator (GFSI), can be interpreted as a composite of economic drivers and market indicators. In our simple framework, volatility in US equity markets (VIX) can be described as a function of the PMIs, the unemployment rate, personal consumption expenditures (PCEs), interest rates, and policy news risk (see Policy risk is underpriced).

Table 11: VIX tends to be driven by macro risks

	Beta	t-stat	p-value
2Y US nominal rate	0.15	4.84	0.00
Unemployment rate	0.66	5.36	0.00
Consumer spending	-0.05	-1.62	0.11
PMI	-1.19	-5.57	0.00
uncertainty index	0.40	5.27	0.00
R-squared	0.66		

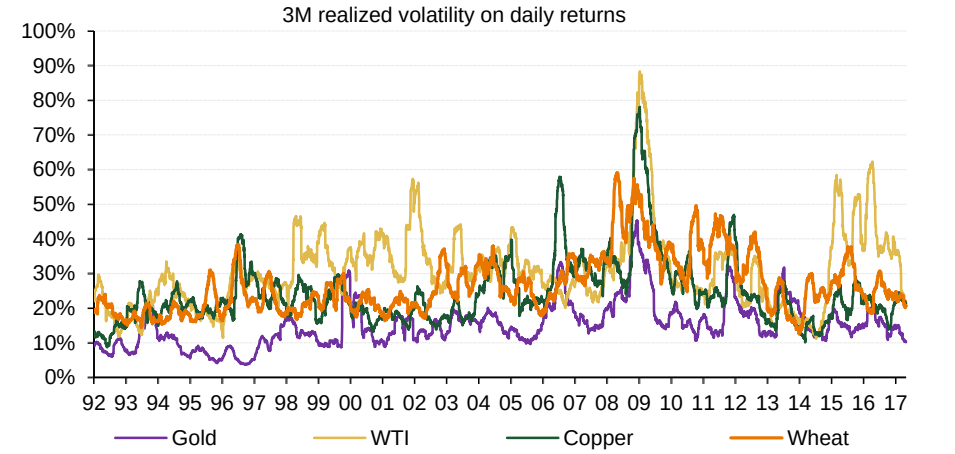
Source: Bloomberg, BofA Merrill Lynch Global Research

Note: Regression is estimated in log-levels on monthly data spanning Jan. 2000 to Dec. 2016. Dependent variable is logarithm of trailing 3M realized volatility of the SPX Index. Given the log-log specification, the coefficients can be interpreted as long-run elasticities. Consumer spending is the percentage deviation of real US Personal Consumption Expenditures from its 1yr moving average. Policy uncertainty index refers to US news-based economic policy uncertainty index from www.policyuncertainty.com. Newey-West HAC standard errors are used to calculate t-stats and p-values.

5. Trading commodity volatility

Broadly, commodity investors will use options to express leveraged views on directional commodity price movements. In addition, some investors will also want to trade volatility outright to express a tactical view on the volatility levels implied in the commodity options markets. As we have discussed in the previous sections, commodity volatility is closely connected to developments in the physical commodity markets and depends on fundamental factors such as storage, weather, seasonality, supply disruptions and geopolitical events. Investors usually seek to trade volatility-sensitive products in order to monetise outright views on volatility (Chart 82).

Chart 82: Option strategies may be powerful sources of 'alpha' as they combine views on commodity prices with views on volatility



Source: Bloomberg, BofA Merrill Lynch Global Research

Taking pure volatility views using options and hedging unwanted risks away has not been as commonly practiced in commodities as it has been in other markets such as equities and interest rates. Commodity market participants have, however, been trading derivative products for a long time that give direct exposure to commodity volatility. In fact, the commodity options market is among the oldest options markets in the world. Over the last decade volatility products such as commodity varswaps that take away the burden of isolating volatility exposure have been developed in commodities as well.

Using options to express tactical views in commodities

Option strategies are highly efficient vehicles to express tactical views on commodity prices. They also may present some advantages over positions in commodity futures in terms of risk-adjusted returns. Buying options typically does not require initial margins and the holder's liabilities are capped at the premium of the option, making risk management much easier than with commodity futures. At the same time, option strategies may be powerful sources of 'alpha' as they combine views on commodity prices with views on volatility (Table 13).

Table 12: Basic option strategies

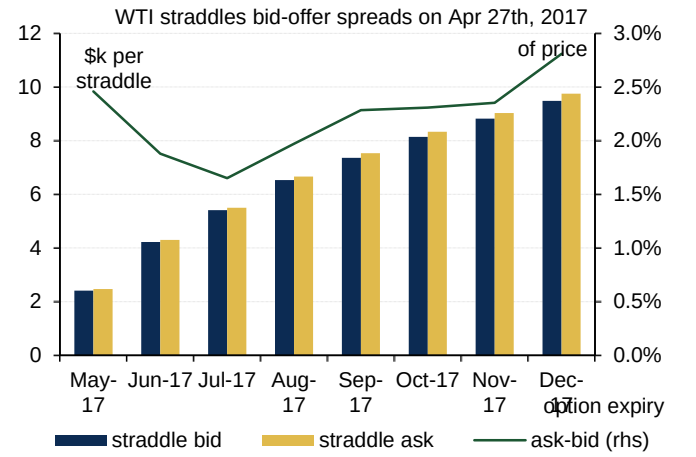
Strategy	Price outlook	Volatility outlook	Theta (time value)*
Long call	Bullish	Bullish	Negative
Short put	Bullish	Bearish	Positive
Call spread	Bullish	Neutral	Depends on the price of the underlying
Long put	Bearish	Bullish	Negative
Short call	Bearish	Bearish	Positive
Put spread	Bearish	Neutral	Depends on the price of the underlying
Long straddle	Neutral	Bullish	Negative
Short straddle	Neutral	Bearish	Positive

Source: BofA Merrill Lynch Global Research

Note: As each days passes and time to maturity decreases, the strategy value may go up (positive theta) or down (negative theta).

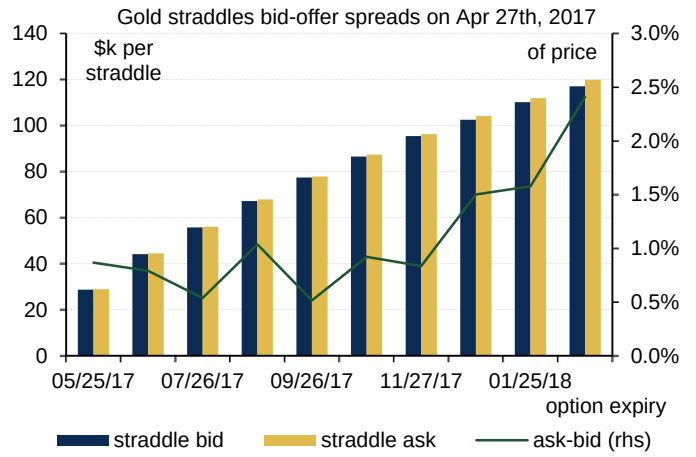
Consumers and producers are important providers of liquidity in the market for commodity options. For those market participants, the OTC market presents advantages in terms of physical specifications, margin requirements and flexibility to meet cash flow characteristics. In commodities, particularly in energy, the OTC market dwarfs the exchange-based market and as a result it is difficult to assess precisely its size and liquidity characteristics. In general, the WTI crude oil market is the most liquid options market in the energy sector, and gold, major base metals and gains options are also fairly liquid. Bid-offer spreads on WTI and gold contracts are relatively tight (Chart 83 and Chart 84).

Chart 83: Bid-offer spreads on WTI contracts are relatively tight



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 84: Bid-offer spreads on gold contracts are relatively tight

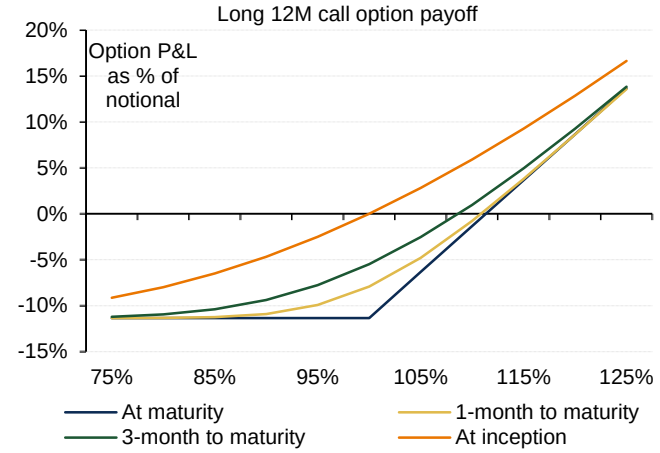


Source: Bloomberg, BofA Merrill Lynch Global Research

Expressing a bullish view

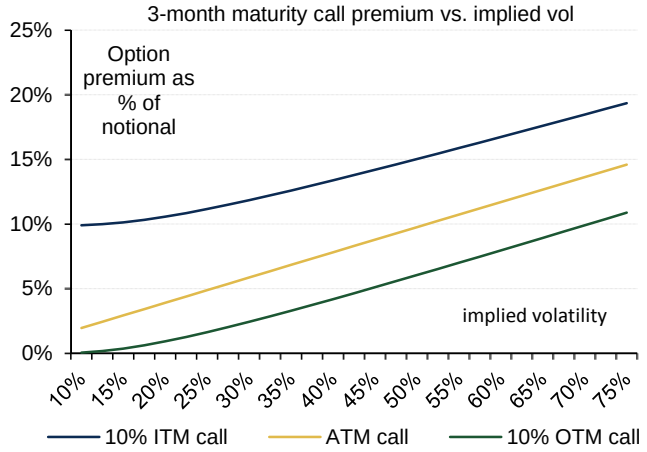
Buying calls is probably the most straightforward way of expressing a bullish price view with commodity options. When exercised, calls will pay the buyer the difference between the underlying price and the strike price as long as this difference is larger than zero. Hence, they benefit from an increase in the underlying price while having the downside limited to the option premium (Chart 85). Options prices have direct exposure to implied volatility movements and buying calls to express a bullish price view is best when coupled with a bullish view on implied volatility (Chart 86). As time to maturity decreases, the option time-value should decrease and this effect is higher for ATM options than for other strikes.

Chart 85: A long call option position benefits from an increase in the underlying price while the downside is limited by the option premium



Source: BofA Merrill Lynch Global Research

Chart 86: Buying calls to express a bullish price view is best when coupled with a bullish view on implied volatility

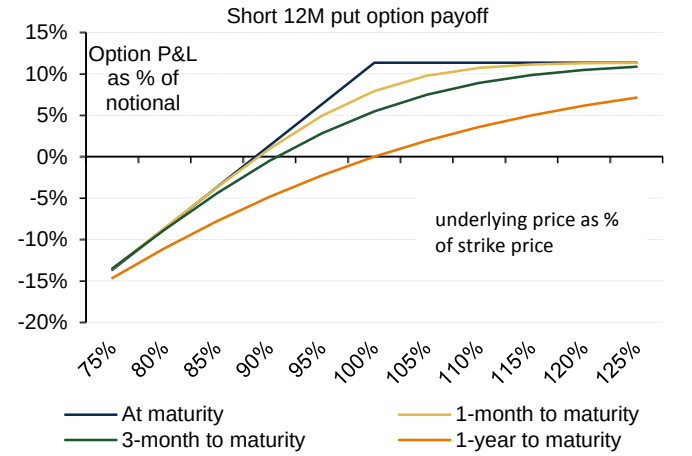


Source: BofA Merrill Lynch Global Research

Selling puts is also a way of expressing a bullish price view. Whenever they are exercised, they will pay the buyer the difference between the strike price and the underlying price as long as this difference is larger than zero. Selling puts will benefit from an increase in the underlying price while generating revenue for the seller in the form of the premium paid by the buyer (Chart 87). Since their prices are directly linked to the level of implied volatility, selling puts to express a bullish price view is best when coupled with a bearish view on implied volatility. As time to maturity decreases, the option's time-value should decrease, which goes in favour of the option seller.

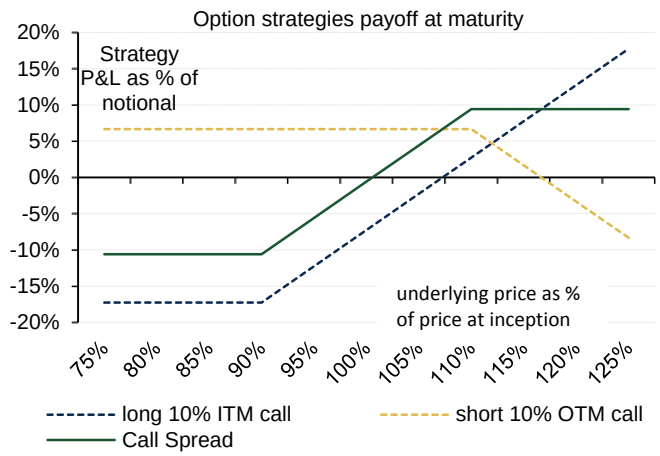
An alternative way to express a bullish price view is through call spreads, i.e., by selling calls to finance the purchase of calls with lower strikes (Chart 88). While giving the investor direct exposure to price movements, the payoff of a call spread is capped on the downside as well as on the upside. Since call spreads are buying and selling volatility at the same time, the sensitivity to volatility movements is often negligible.

Chart 87: Chart 44: A short put position will benefit from an increase in the underlying price and generate a premium for the seller of the option



Source: BofA Merrill Lynch Global Research

Chart 88: The payoff of a call spread is capped on the downside as well as on the upside



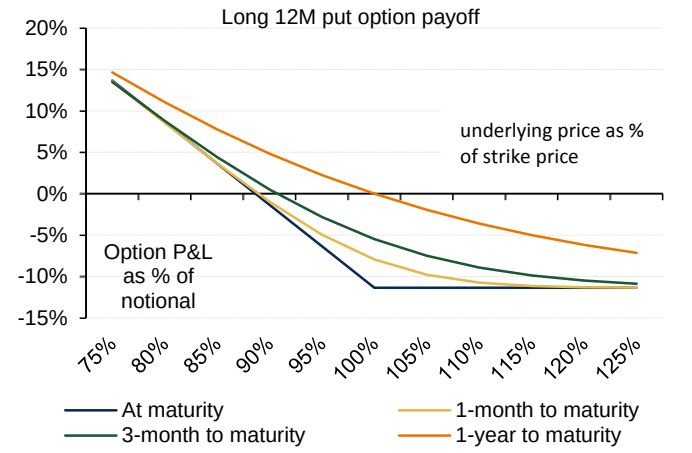
Source: BofA Merrill Lynch Global Research

Expressing a bearish view

Put options benefit from a decrease in the underlying price and they are a straightforward way to express a bearish price view. Buying puts presents an advantage for the option holder over shorting futures, as the holder cannot lose more than the option premium (Chart 89). Selling calls is also another way of expressing a bearish price

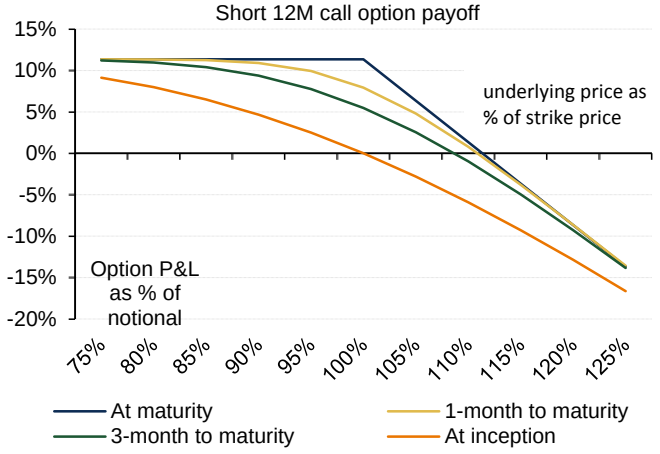
view. Selling calls will benefit from a decrease in the underlying price while generating revenue for the seller in the form of an option premium (Chart 90).

Chart 89: Put options benefit from a decrease in the underlying price and they are a straightforward way to express a bearish price view



Source: BofA Merrill Lynch Global Research

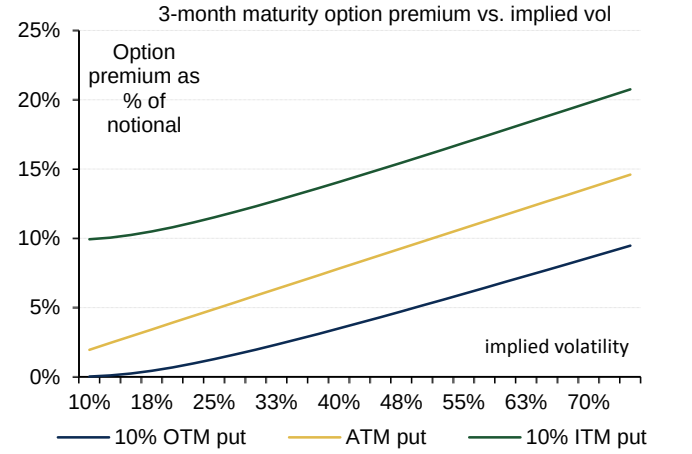
Chart 90: Selling calls will benefit from a decrease in the underlying price while generating revenue for the seller in the form of a premium



Source: BofA Merrill Lynch Global Research

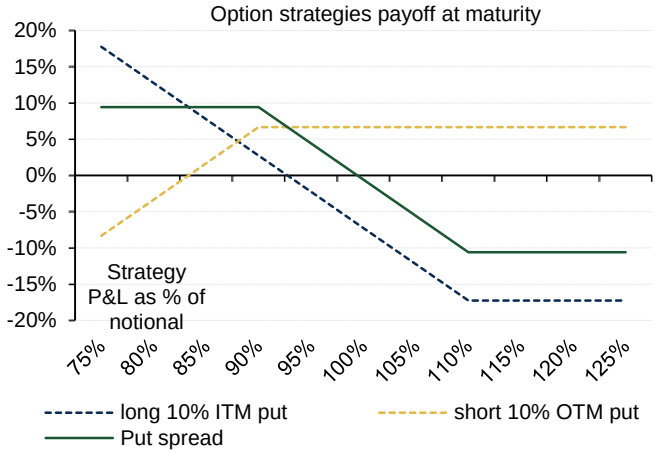
Because buying options always gives exposure to implied volatility, buying puts works best when a bearish price view is coupled with a bullish view on implied volatility (Chart 91). Put spreads can also be an alternative way to express a bearish price view. Selling puts to finance puts with higher strikes will give the investor a bearish position where the payoff is capped on the downside as well as on the upside (Chart 92). Since put spreads are buying and selling volatility at the same time, the sensitivity to volatility movements is often negligible.

Chart 91: Puts works best when a bearish price view is coupled with a bullish view on implied volatility



Source: BofA Merrill Lynch Global Research

Chart 92: A put spread will give the investor a bearish position where the payoff is capped on the downside as well as on the upside



Source: BofA Merrill Lynch Global Research

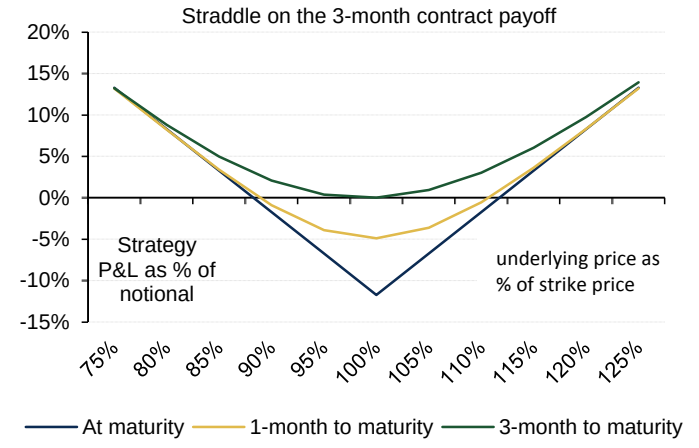
Volatility plays

Commodity options can also be used to get exposure to movements in commodity volatility with reduced directional exposure to the underlying commodity contracts. By simultaneously buying a call and a put option on the same contract, investors will benefit when the price of the underlying contract moves significantly in either direction, but the strategy will yield a loss if only a small movement in the price occurs (Chart 93). When the call and the put have the same strike, typically the ATM strike, this strategy is called a straddle.

In contrast to the straddle, the call and the put will have different strikes in a strangle. More importantly, the call will have a higher strike than the put so both options are

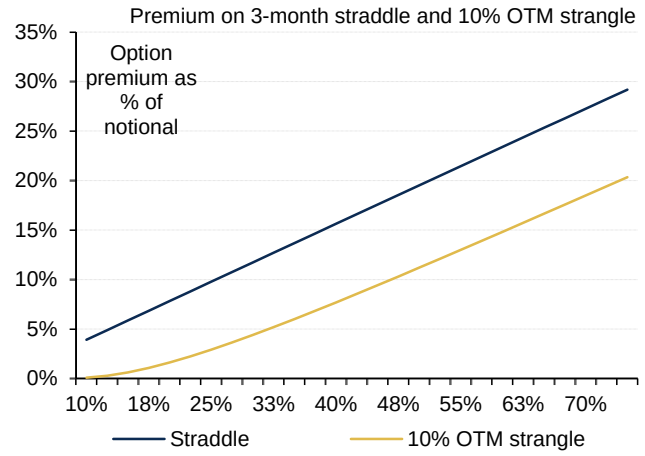
cheaper than the ATM options used to construct a straddle. In effect, straddles and strangles are among the most common ways of getting exposure to volatility exposure to movements in the underlying reduced (Chart 94).

Chart 93: Straddles will generate profits when the price of the underlying contract moves significantly in either direction



Source: BofA Merrill Lynch Global Research

Chart 94: Straddles and strangles have direct exposure to movements in implied volatility



Source: BofA Merrill Lynch Global Research

Delta-hedged straddles were the most efficient way to get exposure to close to "pure" volatility exposure. Delta-hedging a portfolio of options, however, can be complicated to manage. Instead many investors prefer varswap products which are available from financial institutions, and give direct exposure to volatility, taking away from the investor the need to continuously manage option positions.

Commodity variance swaps

Commodity variance swaps allow investors to trade the level of volatility without having to worry about dynamically managing their risks. These OTC contracts exchange a notional amount based on the realized variance of the underlying commodity future.

The buyer of the variance swap (long volatility) receives

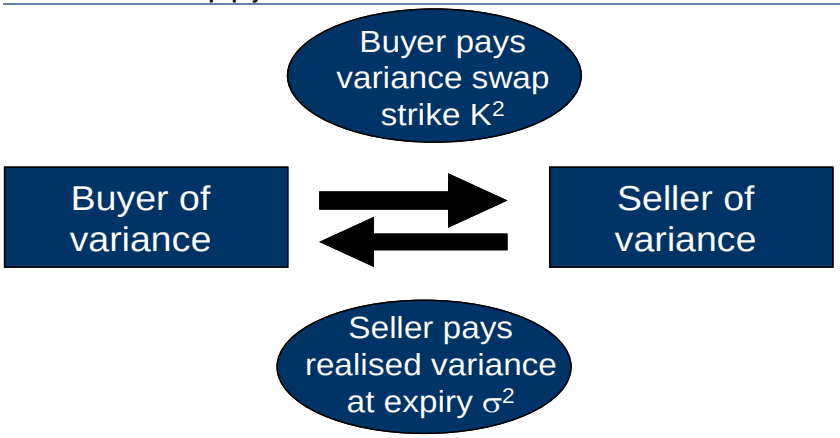
$$\text{Notional} \times (\sigma^2 - K^2)$$

and the seller of the variance swap (short volatility) receives

$$\text{Notional} \times (K^2 - \sigma^2),$$

where K is the strike volatility and σ is the realized volatility over a specific period.

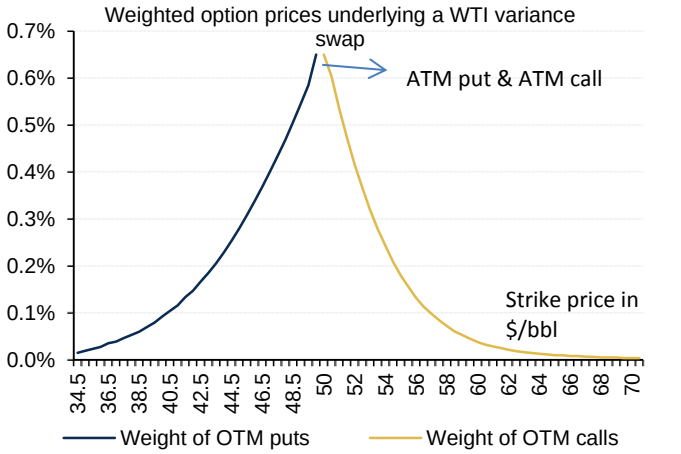
Chart 95:-Variance swaps payoffs



Source: BofA Merrill Lynch Global Research

The payoff of a variance swap is replicated by purchasing a strip of options with maturity equal to the swap and weighted according to a function of their strike price, time-to-maturity and interest rates (Chart 95). The strike volatility K is then typically calculated according to the price of those options to make the swap have zero value at inception. The payoff of a variance swap is based on realized variance and is therefore convex in terms of realized volatility (Chart 96).

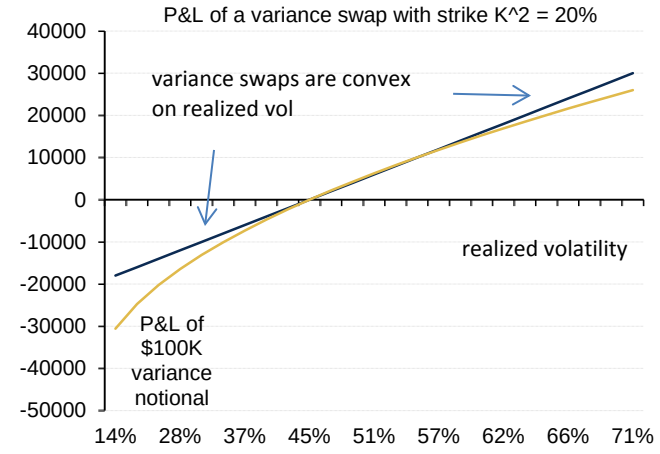
Chart 96: The payoff of a variance swap is replicated by a strip of options weighted by a function of their strike price



Source: BofA Merrill Lynch Global Research

Note: Option prices are weighted by a function of their strike, time-to-maturity and interest rates

Chart 97: The payoff of variance swap is based on realized variance and is convex in terms of realized volatility



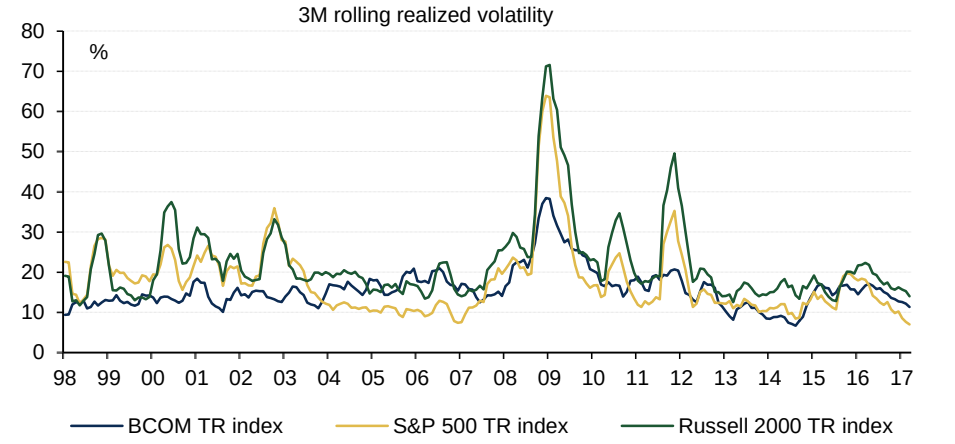
Source: BofA Merrill Lynch Global Research

The commodity variance swap market has growing in the last decade and in our view is likely to continue to gain popularity among investors. The convenience of trading volatility through variance swaps brings interest from volatility hedge funds as well as from traditional commodity investors. In addition, producers and consumers in commodity markets have direct exposure to commodity volatility through their assets and liabilities. Depending on their hedging policies, these companies may be heavily exposed to sharp movements in commodity prices and commodity risk should have a direct impact on the company's equity value. In our view, corporate clients may use volatility-sensitive products such as variance swaps to hedge away some of their commodity risk exposure. At the same time, for commodity-related stocks, the link between the price of risk in the commodities market and the price of risk in the equity market may provide interesting trading opportunities for investors.

6. Basics of volatility math and the Greeks

Broadly speaking, the term volatility stands for a more or less precise measure of the degree of randomness found in the price movements of financial assets. The standard deviation of annualised log-returns is perhaps the most common measures of volatility in finance and is often called *realized* volatility (Chart 97). Estimates of realized volatility can be obtained using slightly different methods. In particular, log-returns may be calculated using intra-day, daily, weekly or monthly prices and they can be annualised in different ways — calendar days vs. business days for instance. Each method will have advantages and disadvantages according to the purpose of the estimation.

Chart 98: The standard deviation of annualized log-returns is perhaps the most common measures of volatility in finance and is often called realized volatility



Source: Bloomberg, BofA Merrill Lynch Global Research

Realized volatility is important for assessing how commodity prices have behaved historically, but it does not incorporate any information about how prices are likely to behave in the future. While, realized volatility is a backward looking measure of volatility, as it is based on past price movements, *implied* volatility is a forward looking measure of volatility as implied by the options market.

The pricing and hedging of options is based on certain assumptions about the distribution of log-returns of the underlying asset and the value of the standard deviation of log-returns is among them. In commodities, the most commonly used option pricing model is the model proposed by Black (1976) for options on commodity contracts.[4] The Black (1976) formula can be used to price European options with strike price X when the underlying security is a forward or futures contract with price *F*:

$$call = e^{-rT}\left[F\Phi(d_1) - X\Phi(d_2)\right]$$
$$put = e^{-rT}\left[X\Phi(-d_2) - F\Phi(-d_1)\right],$$

where

$$d_1 = \frac{\ln(F/X) + (\sigma^2/2)T}{\sigma/\sqrt{T}}$$
$$d_2 = \frac{\ln(F/X) - (\sigma^2/2)T}{\sigma/\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

r = risk-free rate

T = time to expiration in years

[4] Black, F. (1976): "The Pricing of Commodity Contracts", *Journal of Financial Economics*, 3, 167-179.

σ = volatility

$\Phi(\cdot)$ = standard normal cumulative distribution function

The Greeks

The option price sensitivity to small movements in parameters such as volatility or time have been nicknamed "the Greeks" because they are commonly denoted by Greek letters such as Δ (delta) or Θ (theta).

Delta (Δ)

Delta is the option's sensitivity with respect to the price of the futures or forward contract *F*. The delta is positive for call options as their price appreciates with the underlying price *F* and negative for puts as their price depreciates with *F*:

$$\Delta_{call} = \frac{\partial c}{\partial F} = e^{-rT}\Phi(d_1) > 0$$

$$\Delta_{put} = \frac{\partial p}{\partial F} = e^{-rT}\left[\Phi(d_1) - 1\right] < 0.$$

Gamma (Γ)

Gamma is the delta's sensitivity to a small movement in the futures or forward contract *F*. The gamma is the same for calls and puts and is always positive, illustrating that options are *convex* instruments. When the option being measured is deep in or out of the money, gamma is small. When the option is near the money, gamma is largest.

$$\Gamma_{call,put} = \frac{\partial^2 c}{\partial F^2} = \frac{\partial^2 p}{\partial F^2} = \frac{e^{-rT}\phi(d_1)}{F\sigma\sqrt{T}} > 0,$$

where $\phi(\cdot)$ is the standard normal density function.

Vega

Vega (which is not a Greek letter but still a "Greek" in the option's jargon) is the option's sensitivity to a small movement in volatility, σ. The vega is the same for calls and puts and is always positive, illustrating that the option value increases with risk. Vega is highest for ATM options, and is lower when options are ITM and OTM.

$$Vega_{call,put} = \frac{\partial c}{\partial \sigma} = \frac{\partial p}{\partial \sigma} = Fe^{-rT}\phi(d_1)\sqrt{T} > 0,$$

where $\phi(\cdot)$ is the standard normal density function.

Theta (Θ)

Theta, or time decay, is the option's sensitivity to a small movement in time to maturity, *T*. As time to maturity decreases, the option value should decrease. Theta is highest for ATM options, and is lower as options are ITM and OTM. Theta also increases as the options approaches maturity and when volatility decreases.

$$\Theta_{call} = -\frac{\partial c}{\partial T} = -\frac{Fe^{-rT}\phi(d_1)\sigma}{2\sqrt{T}} + rFe^{-rT}\Phi(d_1) - rXe^{-rT}\Phi(d_2)$$

$$\Theta_{put} = -\frac{\partial p}{\partial T} = -\frac{Fe^{-rT}\phi(d_1)\sigma}{2\sqrt{T}} - rFe^{-rT}\Phi(-d_1) + rXe^{-rT}\Phi(-d_2)$$

where $\phi(\cdot)$ is the standard normal density function.

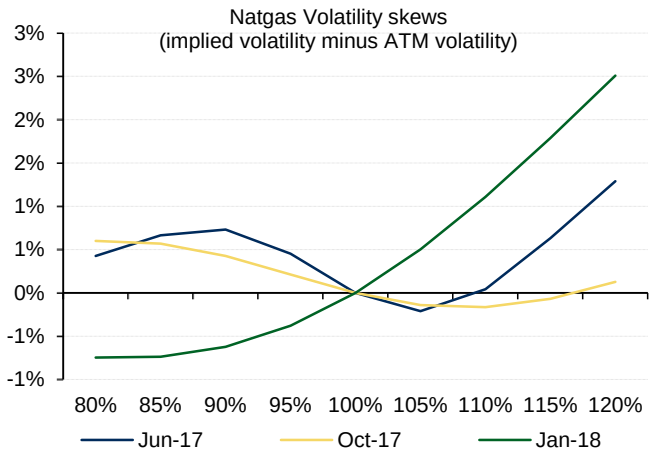
The implied volatility surface

The Black (1976) formula is derived under assumptions that are typically not met in practice such as frictionless market, the ability to hedge continuously without transaction costs, no jumps, independent and normally distributed price shocks and constant volatility. However, the model is still widely used in practice in order to compare prices of options with different strikes or maturities. For this purpose, it is not necessary to believe in the assumptions of the model as it simply acts as a tool that helps market participants better communicate.

Given the price of a European option, one can back out what value of σ would be consistent under the Black (1976) pricing formula with that observed price. The option *implied volatility* is then the value of σ that makes the theoretical and the observed price equal. Since implied volatility may be obtained for different strikes X and different times to maturity T, the graph showing how implied volatility varies across strikes and maturities is called the *implied volatility surface*. The graph of implied volatility across different strike prices for a given maturity is called the *volatility smile* or *volatility skew*. It is often convenient to normalize the strike prices in terms of their *moneyness*, i.e., to express the option strike price as a percentage of the underlying price, *K/F* (Chart 98).

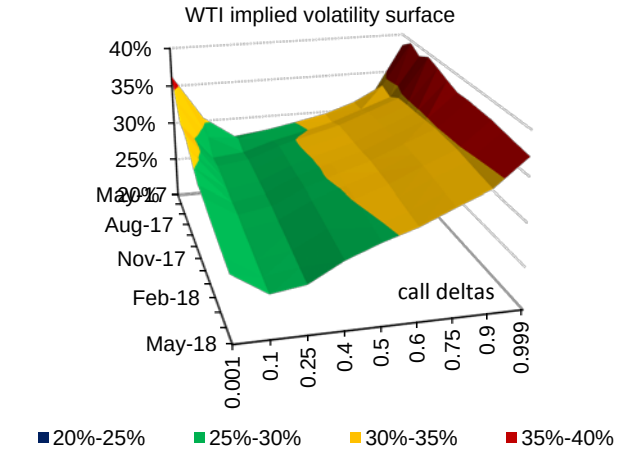
The volatility surface changes over time, especially as a result of changes in the underlying price. For a given level of the underlying price and volatility, there is a one-to-one relationship between moneyness and the deltas and "sticky-delta" pricing models assume that volatility will remain the same for a given "delta". The underlying assumption about this normalization is that when the underlying moves, the shape of the volatility curve remains the same when plotted in a delta-vol space but not necessarily in the strike-vol space. Hence, expressing volatility surfaces in the delta-vol smiles, i.e. plotting implied volatility across different call deltas, is among the most common practices (Chart 99).

Chart 99: The graph of implied volatility across different strike prices for a given maturity is called the volatility smile or volatility skew



Source: Bloomberg, BofA Merrill Lynch Global Research

Chart 100: The volatility surface reflects the volatility implied in options prices across different maturities and strikes (or deltas)

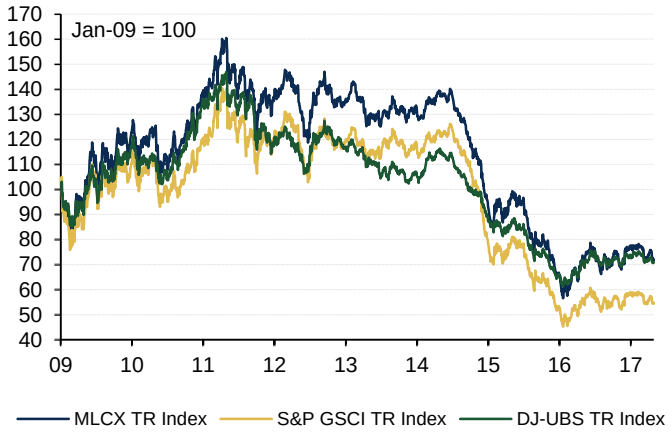


Source: Bloomberg, BofA Merrill Lynch Global Research

Appendix

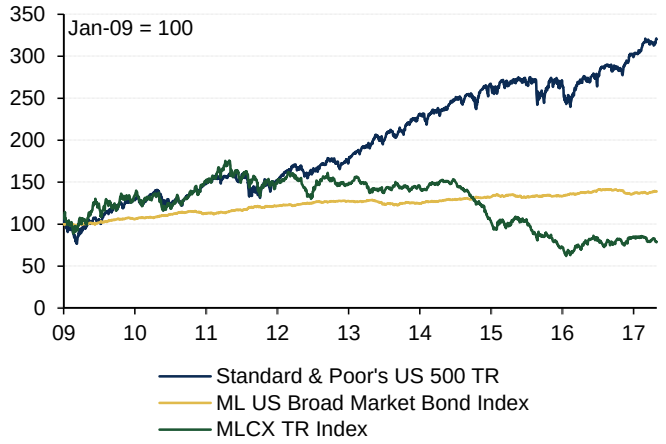
The BofA Merrill Lynch Commodity index eXtra

Chart 101: Performance of total return commodity indices



Source: BofA Merrill Lynch Global Research

Chart 102: Performance of commodities vs other asset classes



Source: BofA Merrill Lynch Global Research

Table 13: Performance of total return commodity indices

Benchmark	S&P GSCI	BCOM
MLCX alpha* relative to benchmark	2.83%	0.94%
MLCX beta* relative to benchmark	0.94	1.11
MLCX correlation with benchmark	98.63%	92.58%
Average tracking error**	3.41%	8.33%

Source: BofA Merrill Lynch Global Research
Based on performance from 31-Dec-2008 to 30-Apr-2017
* Alpha and beta coefficients are annualised intercept and slope coefficients of a linear regression of MLCX TR daily log-returns on the benchmark's daily log-returns.
** Average tracking error is the annualised residual standard deviation of a linear regression of MLCX TR daily log-returns on the benchmark's daily log-returns.

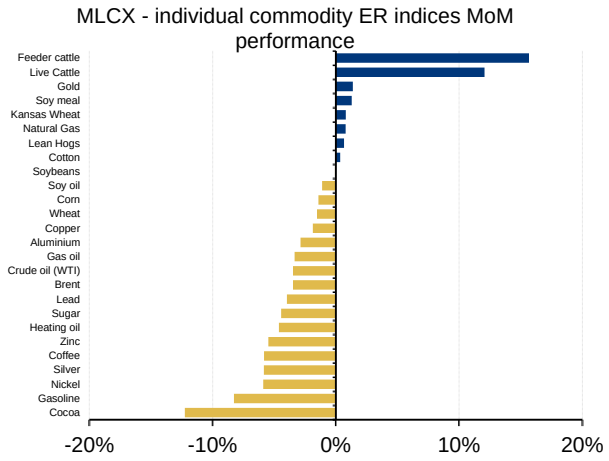
Table 14: Performance of commodities vs other asset classes

From 31-Dec-08 to 30-Apr-17	Annual return	Vol	Sharpe
Standard & Poor's US 500 TR	14.79%	17.23%	78.49%
NASDAQ 100 STOCK INDX	20.13%	18.44%	102.30%
MSCI Daily TR Gross EM USD	9.68%	17.90%	46.97%
ML US Broad Market Bond Index	4.05%	3.52%	79.00%
MLCX TR	-3.58%	20.80%	-23.31%
S&P GSCI TR	-6.68%	21.94%	-36.24%
BCOM TR	-3.79%	16.04%	-31.58%
3-month T-bill returns (risk-free)	1.27%		

Source: BofA Merrill Lynch Global Research
Annualised performance based on daily returns from 31-Dec-2008 to 30-Apr-2017

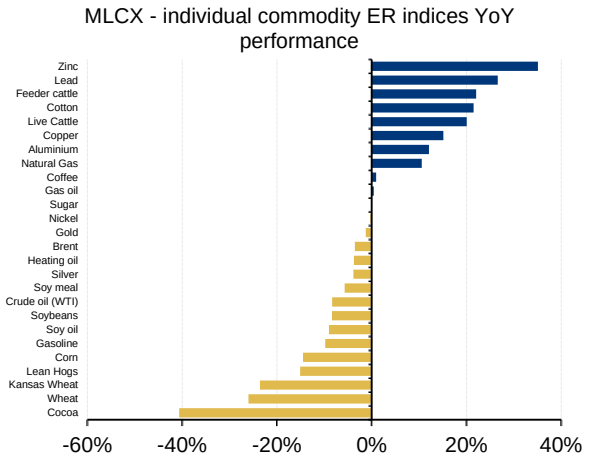
MLCX sub-indices

Chart 103: Performance month-on-month (MoM)



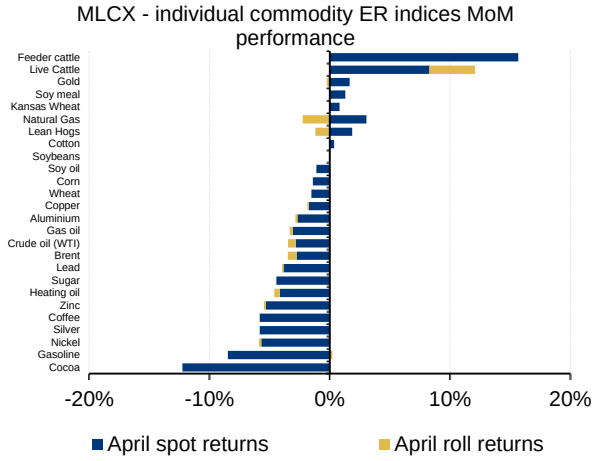
Source: BofA Merrill Lynch Global Research

Chart 104: Performance year-on-year (YoY)



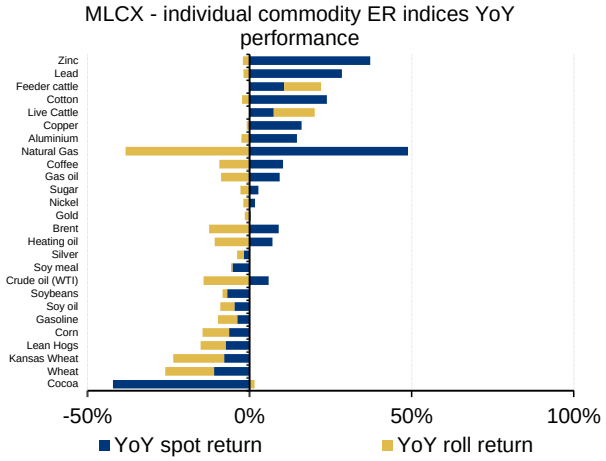
Source: BofA Merrill Lynch Global Research

Chart 105: Spot and roll returns month-on-month (MoM)



Source: BofA Merrill Lynch Global Research

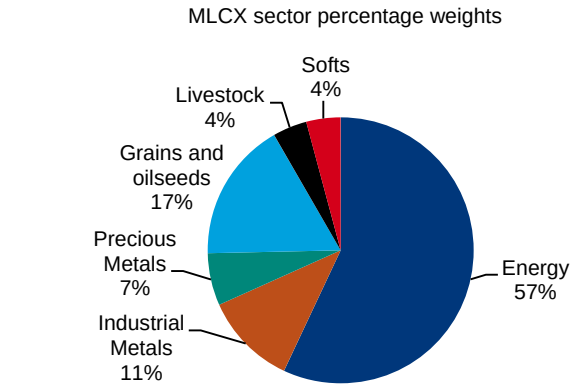
Chart 106: Spot and roll returns year-on-year (YoY)



Source: BofA Merrill Lynch Global Research

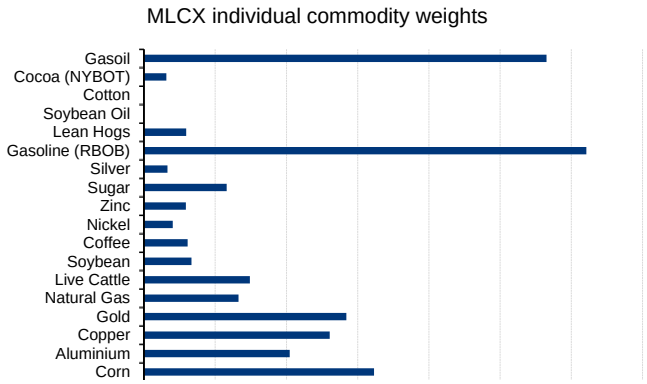
Weights and contracts

Chart 107: Sector weights in the MLCX



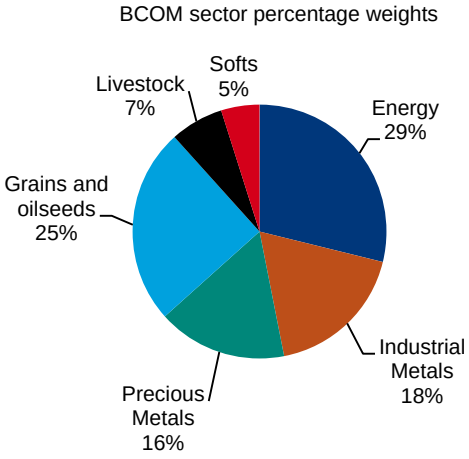
Source: BofA Merrill Lynch Global Research

Chart 108: MLCX individual commodity weights



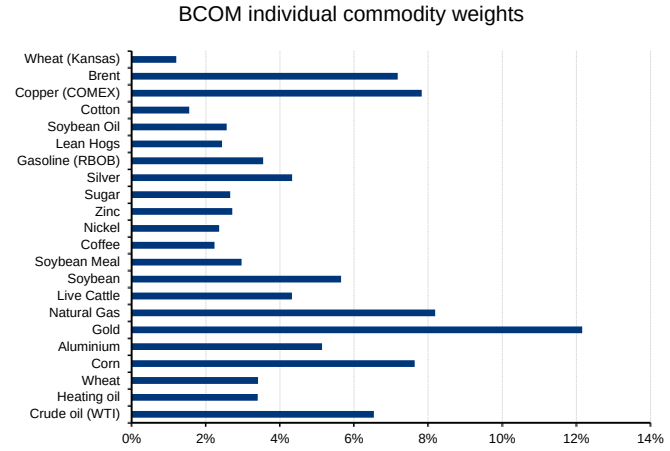
Source: BofA Merrill Lynch Global Research

Chart 109: Sector weights in the BCOM



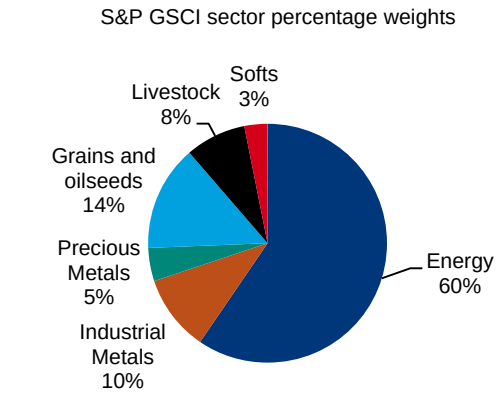
Source: BofA Merrill Lynch Global Research

Chart 110: BCOM individual commodity weights



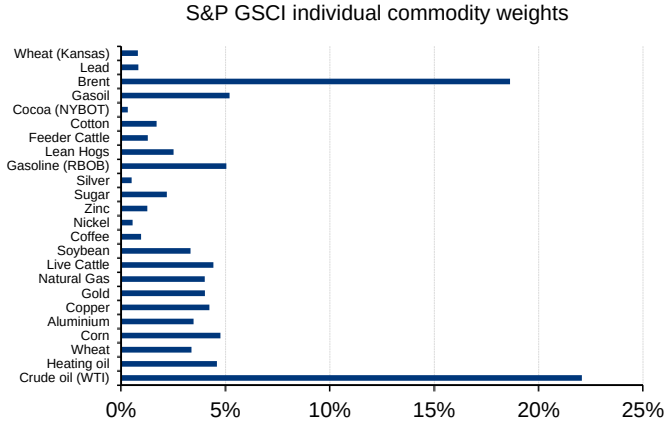
Source: BofA Merrill Lynch Global Research

Chart 111: Sector weights in the S&P GSCI



Source: BofA Merrill Lynch Global Research

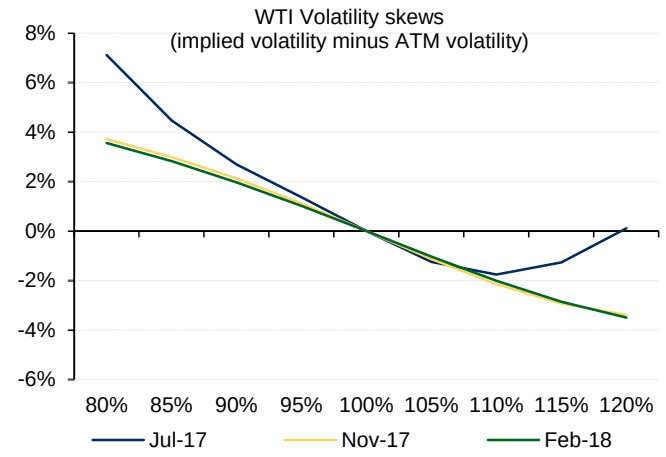
Chart 112: S&P GSCI individual commodity weights



Source: BofA Merrill Lynch Global Research

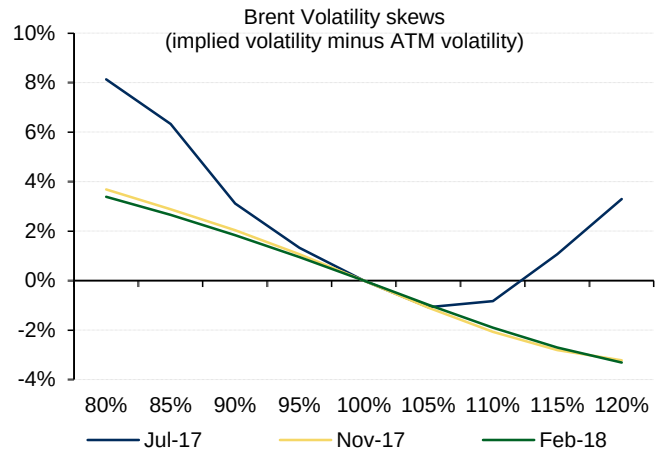
Energy Volatility Skews

Chart 113: WTI Crude Oil



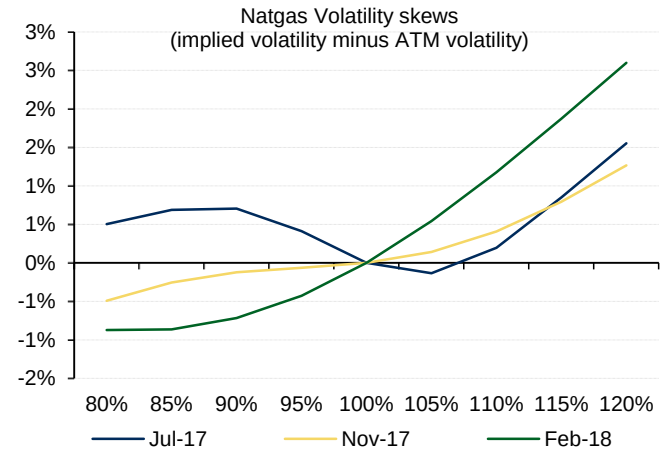
Source: BofA Merrill Lynch Global Research, Bloomberg

Chart 114: ICE – Brent Crude Oil



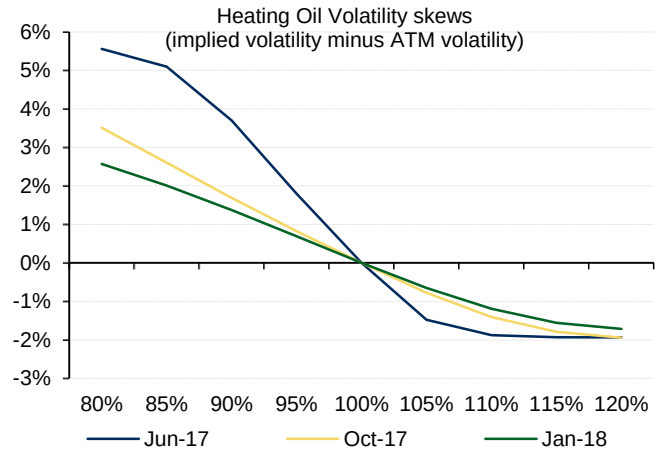
Source: BofA Merrill Lynch Global Research, Bloomberg

Chart 115: Natgas



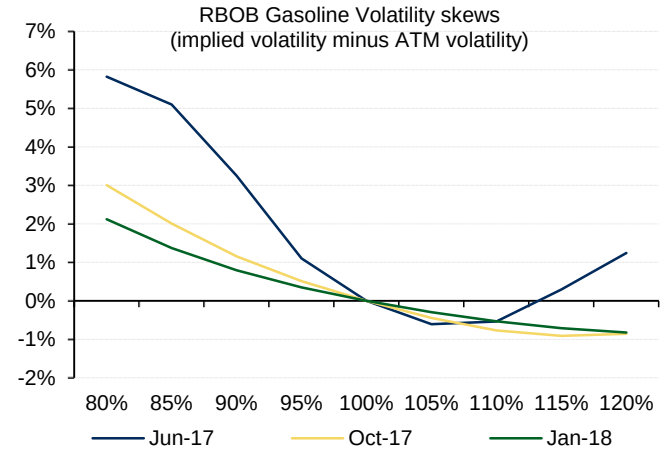
Source: BofA Merrill Lynch Global Research, Bloomberg

Chart 116: Heating Oil



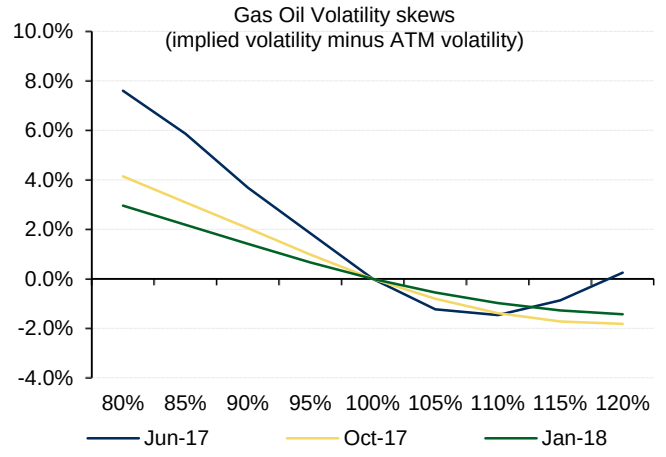
Source: BofA Merrill Lynch Global Research, Bloomberg

Chart 117: RBOB Gasoline



Source: BofA Merrill Lynch Global Research, Bloomberg

Chart 118: ICE – Gas Oil



Source: BofA Merrill Lynch Global Research, Bloomberg

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