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Fat tails

Changes in oil and gas prices do not follow a normal distribution. Price movements are larger than might be expected, and extreme volatility occurs more often than many Value-at-Risk models assume. In contrast to natural gas, oil price volatility is higher in periods of price decline than in periods of rising prices, while overall gas price volatility is higher than that for oil. The danger is that periods of stability lure traders into a false sense of security. **Sam Van Vactor**

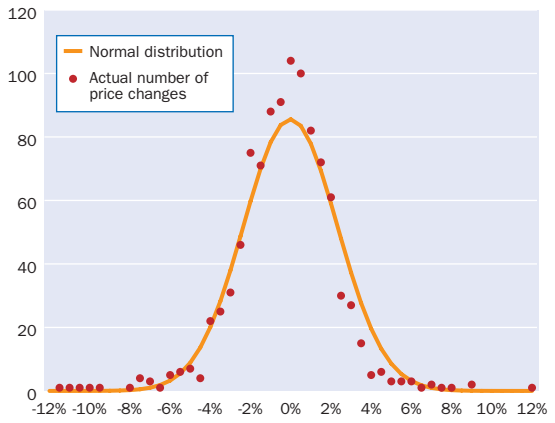
When asked, "What is the sweetest death?" Julius Caesar snapped: "The unexpected." Caesar did not hang out on trading floors or he might have been less flippant. For most investors the unexpected is not so sweet. All too often, the unexpected signals a premature cashing-in of earthly possessions, without an Ides of March warning.

Statisticians refer to extreme departures from the norm as "fat tail" events. Visually it means that there are unaccounted for observations to the left and right of the bell curve that defines a "normal distribution." Reliance on the normal distribution for statistical analysis has become so pervasive in modern life that radical departures are often unthinkable.

What are the odds that stock or commodity prices will depart by two standard deviations more or less than the average of historical price changes? Nearly everyone presumes the answer to be less than 1 in 20. In fact, they are much greater, because price movements frequently depart from those predicted by a normal distribution.

Observed price variation has two features. First, it captures a degree of randomness associated with variation in information, transaction costs, and other imperfections that lurk in real markets. Second, there is the shock arising from a sudden shift in expectations, as markets absorb brand new information.

Figure 1: Distribution of daily NYMEX crude oil prompt price changes



Source: Economic Insight, Inc.

It is the second type of impact that causes prices to change radically without warning, and there is no reason to believe that the resulting change will match historical experience. In practice, these events stretch out the tails of the normal distribution.

Many observed historical price changes are larger than those predicted assuming a normal distribution. However, it does not follow that conventional risk management tools are invalid, even if they do have their limitations. The tools simply reflect a conventional view of the market looking forward. The unexpected is, by definition, the unexpected. Indeed, when price changes depart a "normal" pattern there is usually a change in underlying market fundamentals.

Oil price movements

Oil prices bottomed out during the Asian financial crisis of 1997-98 and began a gradual ascent that peaked in July 2008. As the financial crisis widened, fear of an economic collapse pummeled the oil market and by year's end, the front-month NYMEX contract had dropped to close at $44.60 a barrel, less than one-third of the peak. There were 1,004 trading days from 2004 through 2008, and since the starting price was near the ending price; the average change was effectively zero. The standard deviation of price changes during the four-year sample was 2.34%, reflecting daily changes of multiple dollars per barrel.

Figure 1 illustrates the daily price changes in a distribution segmented into groups spanning 0.5 percentage points. Most price changes were quite modest. 83% of daily prices moved 2.5% or less from the day before. A normal distribution would predict 76%. There were also more extreme price changes than might be expected. In this case, a normal curve would predict that there would be only one observation with a price increase of 7% or more and only one with a price decrease of 7% or more. In fact, there were 11 observations outside the range. In one case, December 31, 2008, oil prices actually increased 12%, five times the standard deviation. The probability of a change that large, given conventional calculations, is near zero.

The wide distribution of price changes reflects a simple fact – expectations varied widely over the time-period. Figure 2 is a scatter diagram that illustrates both the extent of the price change and the time-period in which it occurred. Note that all of the big changes occurred during the steep price decline in

response to the 2008 financial crisis. What might be surprising is the fact that during the period of rapid price decline there were nearly as many large price increases as there were sharp price drops. In other words, from August through December 2008, there was a substantial increase in price volatility.

Previous prices are often the key variables in the determination of a trader's Value-at-Risk and are used to calculate historical price volatility. Following in Figure 3 is a chart of 20-day historical price volatility beginning at the start of NYMEX crude oil trading in 1983. Three extraordinary events greatly increased price volatility during this period.

The first event was the collapse of oil prices in 1986. Prices dropped two-thirds in three months (as they did in 2008). To some extent, traders anticipated the event because the demand for OPEC oil had halved over the previous five years and Saudi Arabia was no longer able to stabilize prices. However, at the time, the industry did not fully appreciate the impact of the shift in structure from OPEC's administered marker price to a commodity market. Once a commodity market was in place, daily prices fluctuated over a far greater range than before. In 1986, price volatility rose sharply from around 10% to over 100%.

The next great disturbance was Saddam Hussein's invasion of Kuwait. The shock of the invasion immediately increased price volatility. Interestingly, the volatility accelerated even higher, to 174%, just after the start of Operation Desert Storm. Following the clear victory by the Allies, price volatility plummeted (along with oil prices). Price volatility rose modestly during the Asian financial crisis, but between 2000 and mid-2008 generally declined. Then, as the full significance of the financial crisis unfolded, volatility for oil prices and just about every other financial asset increased sharply, peaking in early January 2009.

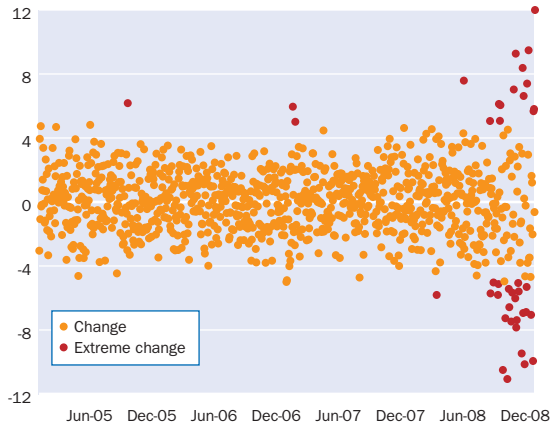
Of course, very few traders anticipate the sort of events described above. A long period of market calm can mislead traders as to the extent of the risk they actually face. On the other hand, once an unexpected event reveals itself, the increased price volatility automatically increases VAR and other measures of risk. Thus, the widespread use of risk management tools explains, in part, the massive shift to liquid assets that occurred in fall 2008, when price volatility increased significantly in virtually every stock and commodity market.

Natural gas price movements

Even a brief review of natural gas price volatility reveals a pattern distinct from oil price movements. Most obviously, weather drives gas price changes – cold snaps in the winter and, to a lesser extent, hurricanes in the summer. Price volatility does not necessarily correlate well with dramatic events. Hurricanes Katrina and Rita devastated much of the gas production infrastructure and caused dramatic price increases, but did not significantly increase price volatility. Prices, of course, increased, but at least for a while stabilized at a new higher level. Likewise neither oil nor gas price volatility increased significantly after the 9/11 terrorist attacks. As extraordinary as the event was, it did not have a substantial impact on energy market fundamentals.

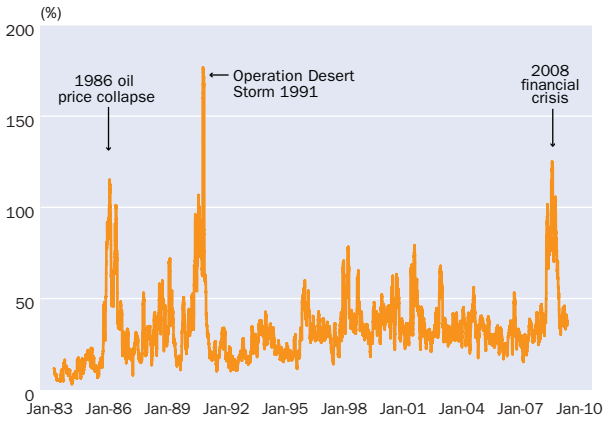
The most dramatic price change in the gas market occurred in the winter of 1995-1996, which was very cold with some gas wells freezing. In the first week of January the eastern seaboard experienced a severe blizzard with up to four feet of snow in various locales. Low prices generally help explain why day-to-day percentage price movements were so radical. Henry Hub gas prices averaged only $1.69/MMBtu in 1995. It did not take much of a dollar-value change to translate into large percentage gains and losses.

Figure 2: Scatter of NYMEX daily prompt crude oil price changes



Source: Economic Insight, Inc.

Figure 3: NYMEX Crude oil prompt price historical volatility, 1983-2008

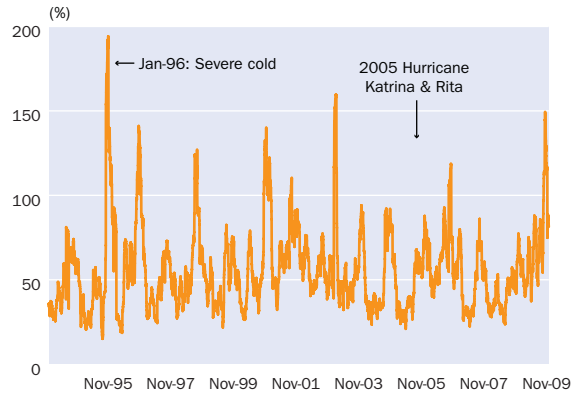


Source: Economic Insight, Inc.

The financial crisis had an impact on natural gas price volatility too, but the relative impact was far less noticeable than in the oil market. Overall natural gas price volatility has averaged 56% since 1993, while the oil market averaged 36% during the same period.

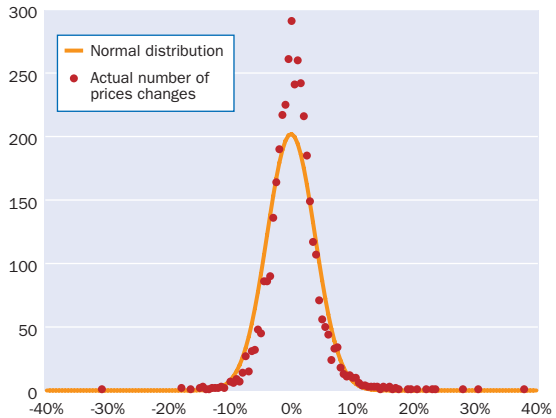
The difference in price volatility in oil and gas markets raises an interesting question. Does higher gas price volatility imply a distribution of price changes that is closer to or farther from a normal distribution as compared with the oil market? The answer can be found by categorizing gas price changes in the same manner as oil price changes displayed in Figure 1. That is, segmenting price changes into groups with a span of 0.5 percentage points. Once again, a large majority of daily price changes were within a small range, 63% of the price changes were plus or minus 2.5%, as compared to 83% of oil price changes. However, a higher standard deviation (3.9% instead of 2.3%) in the gas price set is the primary explanation for the difference.

Figure 4: NYMEX natural gas prompt price volatility, 1993-2009



Source: Economic Insight, Inc.

Figure 5: Distribution of NYMEX daily natural gas prompt price changes



Source: Economic Insight, Inc.

The proportions of extreme price changes were similar for both commodities, around 1.2% for natural gas and 1.1% for the oil market. For the natural gas market, the bell curve of a normal distribution predicts that there would be only four daily price increases greater than 12% and four price drops of more than 12%. In fact, there were 49 such events. There was one price change of 38%, which is just shy of ten times the standard deviation. Either it was a highly improbable event or, more likely, energy price changes are not normally distributed.

Complacency threat

Energy price changes are a combination of random fluctuations reflecting an imperfect market and substantive changes in expectations caused by shifting market fundamentals and unexpected events. It is frequently the case that a major shift in market fundamentals also increases price volatility.

This makes sense because new information is seldom absorbed immediately, and its true nature often dribbles out mired in contradictions; for example, during black September 2008 Lehman Brothers was in trouble on Monday, near possible rescue midweek, and collapsed completely over the weekend. Likewise, the invasion of Kuwait was brutal and quick, settlement seemed possible, then elusive, then possible, etc. Iraq's standing army seemed formidable, but in the endgame, it turned out to be a pushover. Where were the weapons of mass destruction? Saddam appears to have moved them to Wall Street.

It is tempting to infer more from historic oil and gas price changes than would be prudent, but here are a few observations. So far, oil price volatility appears to be higher during periods of price decline than periods of rising prices. In contrast, gas price volatility increases sharply during periods of price rise and unusual weather.

Threats of extreme cold weather, low inventories, and poor information caused natural gas prices in California to soar to a record of $58/MMBtu in December 2000, setting up weeks of incredible volatility and much higher prices for six months.

For risk managers the biggest threat is not a disruption and attendant excitement, it is boredom. Years of stable and reliable pricing lulls everyone into unwarranted complacency. Hedging is costly and, in a calm market, benefits seem remote. That, of course, is just about the time that all hell breaks loose. In short, risk management based solely on statistical analysis will always be an imperfect tool, and should not replace thorough analysis of market fundamentals and healthy skepticism.

Dr. Van Vactor is an energy economist who has analyzed oil, natural gas and electricity markets since 1973. He is president of Economic Insight, Inc. (EII), in Portland, Oregon. His website can be found at www.econ.com