An Introduction to the Market Sentiment Meter: Reimagining Probability Distributions to Calibrate Event Risk

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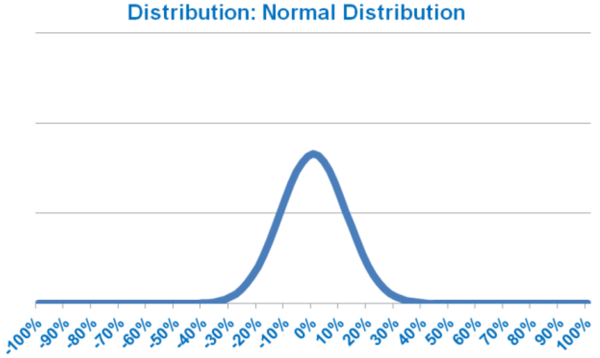
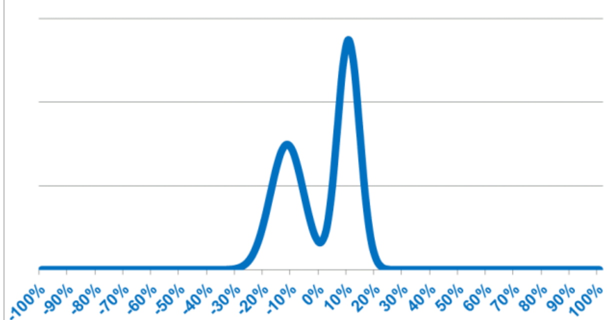
Event risk comes in a number of different forms, with perhaps some of the more difficult risk management challenges being posed when market participants split into two divergent camps associated with strikingly different views of the world. That is, there are two conflicting scenarios for how the future may develop and both have meaningful probabilities. In such cases, the risk probability distribution best describing event risk may have two modes or be highly skewed and not symmetric – definitely nothing like a typical bell-shaped curve. Our task is to develop a systematic and quantitative approach from observed market activity which allows us to imagine hypothetical risk probability distribution that are far from normal. One might want to adopt strikingly different approaches to financial risk management if faced with a two-humped distribution instead of a bell-shaped curve, even it the expected volatility was the same.

Figure 1: Risk-Return Expected Probability Distribution: Normal Distribution



Mean of Distribution = 0%, Standard Deviation = 12%
Source: Chart Created by CME Group Economics.

Figure 2: Risk-Return Expected Probability Distribution from a Two Scenario Mixture



Mean of Distribution = 0%, Standard Deviation = 12%
Source: Chart Created by CME Group Economics.

This research report takes us through our journey to develop the Market Sentiment Meter which allows for a quantitative examination of how market risk expectations may evolve as economic environments shift from complacency, to more balanced risks, to anxiousness, to conflicted event risk scenarios. First, we set the stage by describing our philosophy of financial risk analysis. Volatility is not risk. Starting points matter. Event risk has special characteristics. Then, we turn to our quantitative method of imagining an unobservable risk probability distribution using a carefully selected set of metrics and an innovative distribution-independent process that is fully capable of handling a simple normal distribution or a highly complex mixture distribution which may have more than one mode or be highly asymmetric.

Finally, we present several case studies to illustrate how our risk probability distributions evolved during some well-known historical volatility episodes. We examine the drought of 2012 and how it impacted the corn market. We take a look at how equities responded in late 2017 and early 2018 to the large US corporate tax cut, we also study the US-China trade tensions in the spring of 2018, and close with some observations on the evolution of risk distributions during the pandemic of the spring of 2020. The cases give a flavor for how the Market Sentiment Meter can provide useful insights into the behavior of markets during both calm and stressful periods. While we do not suggest that the Market Sentiment Meter has predictive qualities, much more research is needed, we do hope that the methodology and analysis of sentiment states and financial risk probability distributions can make a valuable contribution to approaches to risk management in stressful times.

Market Sentiment Meter (MSM)

All of the original data, calculated metrics and quantitative sentiment state analysis, and a discreet-data probability distribution are all available for subscription through the CME Group DataMine platform. The MSM data sets are daily, going back to 2012, and cover eight products: E-Mini S&P, US Treasuries, Euro FX, Gold, WTI Oil, Natural Gas, Corn and Soybeans. The data sets are provided through a joint arrangement with 1QBit, a Vancouver-based machine learning and quantum computing firm specializing in solving complex data analysis and optimization challenges. https://datamine.cmegroup.com/#/datasets/cme.1Qbit

I. Research Philosophy

Our research approach contains four key tenets, as follows:

- Risk is a complex, forward-looking concept. Standard deviations are not adequate measures of risk and should not be used in the primary metric in risk management systems.
- Starting points matter. Specifically, basing one's risk analysis on implied volatility, as is quite common, introduces hidden biases that may lead to poor risk management decisions.
- Practical risk system must be capable of capturing two-scenario event risk with very special characteristics, including the possibility of bi-modal or highly asymmetric distributions.
- Expected risk-return probability distributions are inherently unobservable, yet we believe that a variety of price and volume metrics can be examined to make some useful inferences about the risk distribution and how it dynamically evolves through time.

A. Volatility is Not Risk

To begin with, volatility is a poor measure of risk.[i] Many analysts like to use volatility as their favorite risk metric because the historical standard deviation is easy to calculate and fits nicely into basic risk systems and mean-variance portfolio optimization models[ii].

One problem is that an investor, or a financial institution for that matter, may have asymmetrical risk preferences, preferring to avoid substantive losses rather than to make equivalently large gains. That is, if avoiding large losses is the primary risk, then a symmetrical standard-deviation based metric that only looks at the average noise level and not the extremes is certainly not appropriate.

Another challenge relates to using the implied volatilities typically calculated from straightforward options pricing models.[iii] Straightforward Black-Scholes-Merton options pricing models embed the heroic assumption that prices move up or down with continuous trading – that is, price breaks or price gaps are assumed never to occur. If market participants fear the possibility of price breaks or gaps, options prices will reflect this risk with a higher calculated implied volatility. That is, one number, implied volatility, contains both expectations of future volatility and expectations of a one-off major shift to a new center of gravity for price expectations. It will not be easily apparent that the implied volatility is reflecting price gap risk instead of an upward shift in the volatility regime. And, price gap risk is not the same risk as volatility regime shift risk. Depending on one's financial exposures, one of these risks could be much more important than the other. For those managing options portfolios, for example, the risk of an abrupt price break can do considerable damage to delta hedging strategies, while a volatility regime shift represents a different risk, commonly known as "vega" risk. What one needs to create is a comprehensive view of the whole risk probability distribution providing a robust perception of risks, allowing for decidedly different risk scenarios, and not being biased toward the bell-shaped curves that quickly come to mind when depending on implied volatility metrics or historical calculations of standard deviations.

B. Starting Points Matter

To build a risk probability distribution that is not necessarily bell-shaped or even of a single mode and can capture the extremes in a robust manner, we prefer to start from a very different point of view. We start with the Bayesian prior (i.e., our initial views before we even examine the data) of a very unusual distribution – in our case, a bi-modal distribution that might reflect a type of binary or two- scenario risk often associated with event risk. Then, we examine market data to see if the risks are more bell-shaped. While the implied volatility is one of the market metrics we examine, it does not necessarily have the primary influence it does when it is the starting point for the risk analysis.

Put another way, if we start from a prior of an extreme and unusual distribution, we know that it can exist, and we have not assumed it away. Starting from a standard deviation approach, such as implied volatility, may inadvertently make it very hard to estimate when extreme and highly dangerous risk distributions are present and focuses attention on what may happen in the middle of the distribution.

The mathematics behind this observation is quite old and goes back to the Russian mathematician, Pafnuty Lvovich Chebyshev (1821 – 1894). What most people take away from Chebyshev's *Inequality Theorem* is that if you know only the standard deviation you have a very good idea of the typical ranges in which values will fall most of the time. What we take away from the *Inequality Theorem* is that if you only know the standard deviation, you know absolutely nothing about the extremes of the distribution where the most dangerous risks reside. Our lesson from Chebyshev is spent considerable time understanding and appreciating the risks that may be embedded in more complex risk probability distributions.

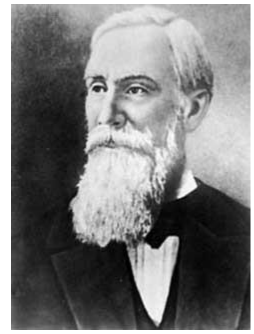


Figure 3: Pafnuty L. Chebyshev (1821-1894), from Wikipedia.

C. Conflicted Two-Scenario Event Risk Has Special Characteristics Not Captured by Standard Deviation Metrics

One of the key motivations for our research was the observation that in financial markets there are important episodes of event risk associated with elections and referendums, such as the UK Brexit Referendum of June 2016, US President election of November 2016, French and UK elections in 2017, Brazilian elections of October 2018, US Congressional elections of November 2018, US Presidential and Congressional elections of 2020, etc. This led us to a study of how markets cope with two strikingly different scenarios – a special type of event risk.

When there are two possible scenarios, then pre-event, the market is going to price the probability-weighted outcome, or the middle ground. So, post-event, when the outcome becomes known, the market immediately moves away from the middle ground to the "winning" scenario – a price break.

Figure 4: Hypothetical Pre-Brexit Vote: USD/GBP Expected Probability Distribution

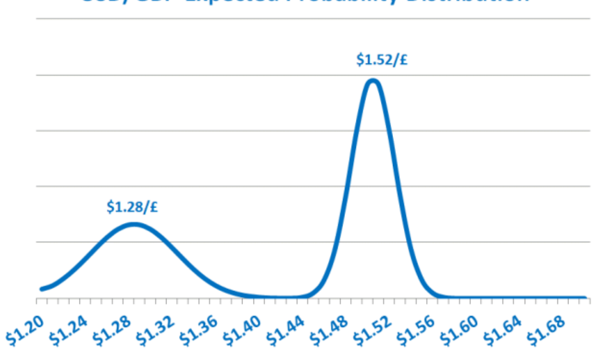


Chart Created by CME Group Economics.

Figure 5: USD per British Pound

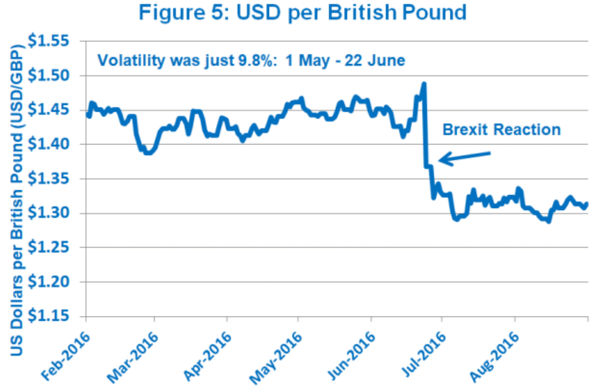


Chart Created by CME Group Economics.
Source: Bloomberg Professional (GBP)

Brexit was a classic example. The referendum was scheduled for the end of June 2016. The vote was a simple choice: either the UK should "Remain" in the European Union, or the UK should "Leave". The referendum was hotly contested. Most opinion polls indicated that the "Remain" vote would be a little larger than the "Leave" vote. Alas, the referendum results did not follow the polls. The "Leave" vote generated a sharp downward move in the British pound (vs USD), as the results became known. Presumably, a "Remain" vote would have generated a sharp and instantaneous rally in the pound – either way, the pre-referendum thinking was that the pound was no longer going to trade in the middle. Even if they are extremely rare, if one's risk system cannot create the possibility of a bi-modal probability distribution to represent highly conflicted sentiment in the markets representing the possibility of two distinctly different outcomes, then price break risk may be greatly underestimated.

Beyond elections, one can observe two-scenario event risk developing in a variety of circumstances. During the spring 2020 pandemic crisis, market participants had to weigh the considerable economic damage from the temporary shutdowns against optimism about the re-opening economies. In the spring of 2019, the challenge of conflicting scenarios was observed in the "deal" or "no-deal" possibilities related to the US-China trade tensions. The controversy over the OPEC decision in November 2014 to cut or maintain production in the face of falling oil prices was another two-scenario case of event risk. In the corn market in the US, the drought of 2012 created worries in the spring of 2013 as to whether the drought would return again and depress the corn harvest or whether rains would arrive and corn crop would be large.

Like elections, some of these examples had specific dates on which the outcome would become known (e.g., OPEC meetings), while others operated in a more nebulous time frame during which a resolution was expected (e.g., pandemic, trade tensions, drought). In every case, though, the key market characteristic was the presence of a pre-event bi-modal risk probability distribution reflecting highly conflicted, distinctly different scenarios, both with meaningful probabilities. The common characteristic is that once the outcome was known, markets quickly reflected the new reality and resolved to a single-mode, bell-shaped risk probability distribution centered on the outcome. Prior to the outcome becoming known, market price movements were often subdued, with a lower than typical standard deviation being observed. Then, the outcome would generate an abrupt price move one way or the other, after which the market would settle into a new volatility range depending on the expected longer-term ramifications of the outcome.

We also should note that event risk comes in other types than the special case of conflicting scenarios which we are studying. For example, considerable research has been done into extreme risk cases, where there is a very, very small probability of an event with massive consequences. The earthquake and tsunami that hit Japan in 2011 would be an example of extreme value risk. Extreme value analysis is most applicable for these exceptionally low probability cases, and risk management approaches often focus on an insurance model using deep out-of-the-money options.

There are also other types of risks that may seem like event risk yet would not qualify under our definition. That is, one might know the time and date of an important data release, such as the monthly employment situation report in the US. Just knowing a date, however, is not a sufficient criterion to earn the label of event risk. Most data releases are best described by bell-shaped probability distributions, as there is usually a strong consensus around an expected mean with an acknowledged appreciation of the volatility present in the specific data. Three or four standard deviation events may certainly occur, and, indeed, they seem to occur much more often than suggested by normal distributions. Again, an extreme value analysis in which the tails of the distribution are augmented is probably appropriate. Our system incorporates some important features of extreme value analysis and has the ability to identify and quantify unusually skewed or fat-tailed distributions.

II. Expected Probability Distributions are Unobservable – A Practical Solution

From a practical perspective, starting with the prior (e.g., our view of the world before examining any data) of an abnormal, bi-modal risk probability distribution requires some creativity that might put off some risk managers. The challenge is that expected risk-return probability distributions cannot be directly observed. What we can do is to estimate some of their characteristics from looking at market behavior – prices, volumes, futures versus options, intra-day activity, etc.

In our research, we have found a few metrics that are especially enlightening relative to the shape of the probability distribution. Our three primary metrics are: (1) the evolving pattern of put option trading volume relative to call option volume, (2) intra-day market activity, especially high/low spreads, and (3) implied volatility from options prices relative to historical volatility.

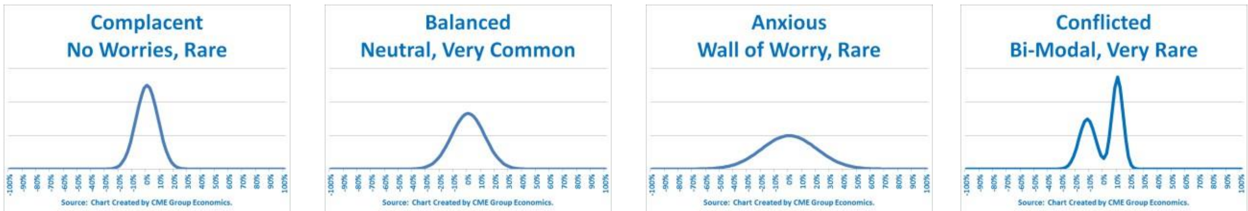
Studying put/call volume patterns helps us understand if one side of the market is more at the center of the current debate than the other side. For example, immediately after former Federal Reserve (Fed) Chair Ben Bernanke threw his famous “Taper Tantrum” in May 2013, he set off a debate about when the Fed would withdraw quantitative easing (QE) and raise interest rates. Put volume on Treasury note and bond prices soared relative to call volume as an indicator that a two-scenario situation had developed. While there is a buyer and a seller for every trade, one side thought prices would fall (yields rise) and volatility might rise very soon (buyer of puts), while the other side thought the process of exiting QE would take a long time (seller of puts).

Intra-day market dynamics help us appreciate risk in a different way. The observed high price to low price intra-day trading spread is informative in helping us assess the degree to which fat-tails might be present. Mathematically, work by Mark B. Garmin and others back in the 1970s and 1980s has shown that if one assumes a normal distribution then there is a straightforward way to estimate the standard deviation of daily returns from the intra-day high-to-low spread. Put another way, if the relationship between intra-day dynamics and the day-to-day standard deviation diverge in a significant manner, then this is strong evidence that the risk probability distribution is not normally distributed.

To ascertain the risk of price breaks we track the evolving pattern of implied volatility relative to historical volatility. While it is usual for implied volatility to exceed recent historical standard deviations, a shift in the pattern toward a much higher implied volatility may indicate that expectations for the potential of a sharp price break are building in the market. And, if a price break occurs, scenarios resolve one way or the other, so post-outcome we often see a quick decline in the implied volatility representing a shift back to a single-mode bell-shaped distribution.

To gather all our risk information and create a probability distribution, we use a probability mixture technique that is distribution independent – that is, it is not constrained to take on a given specified shape. Most of the time, bell-shaped curves are appropriate descriptions of the probability distributions – balanced risk distributions. Our method does, however, occasionally generate some especially tall distributions (i.e., relatively lower volatility), which we classify as “complacent” and worthy of special study to see if the market may be underestimating risks. We also see on occasion some very flat distributions, not unlike the Wall Street maxim about the equity markets “climbing a wall of worry” which we call “anxious” risk distributions. And, finally, on rare occasions our metrics support the idea of a two-scenario, event risk, bi-modal distribution. That is, we classify expected risk distributions into four types: "Complacent" which are very tall and thin, "Balanced" or neutral risks with a typical bell-shape, "Anxious" reflecting a relatively flat bell-shape with very fat tails and possibly skewed one way or the other, and finally our bi-modal (aka, "Conflicted") or event risk distribution which are trying to anticipate what happens if one of two very divergent scenarios is the outcome.

Figure 6: Market Sentiment Meter categories of perceptions of risk



III. Case Studies

To illustrate our probability risk distributions, we will start by examining two examples from US equities, one involving a complacent distribution and one involving potential event risk. And, we will also examine an event risk distribution from the commodity markets, specifically in corn.

A. US Equity Index Examples

In late 2017, our probability risk distribution for US S&P500® (CME E-Mini Futures) shifted from "balanced" to "complacent". US stocks were being propelled higher in no small measure by the large and permanent US corporate tax cut which was increasingly likely to become law and, indeed, was passed by Congress and signed into law by the President in December 2017.

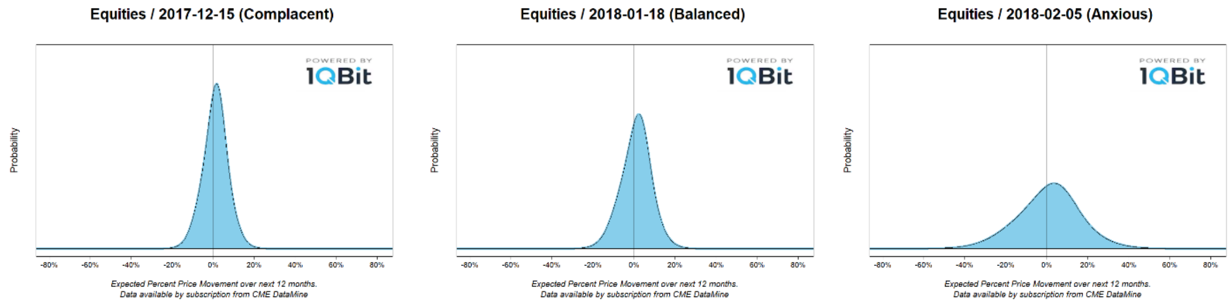
Due to the corporate tax cut, market participants were expecting more stock buybacks and higher dividends, among other things. As it turned out, the complacency was somewhat misplaced. Early in 2018, the market narrative shifted abruptly from optimism about the tax cuts to worries that the US Federal Reserve (Fed) would be raising rates in lock-step fashion during 2018. The rate hike fears resulted in a sharp market selloff, temporarily higher volatility, after which the market that started to gain ground again with diminishing volatility.

Figure 7: E-Mini S&P500® Futures 1H/2018: Tax Cut Story gives way to Rate Hike Worries

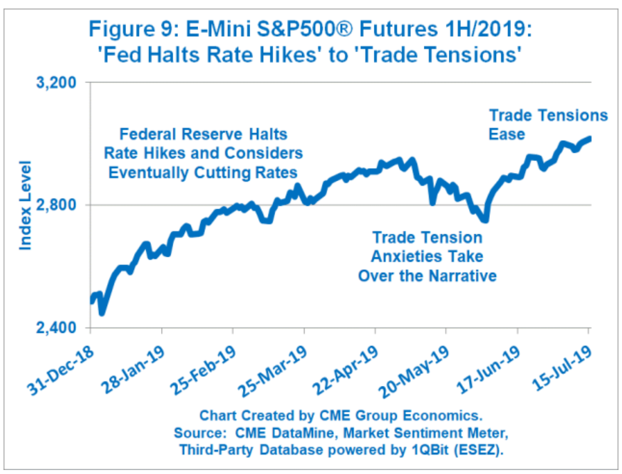
Chart Created by CME Group Economics.
Source: CME DataMine, Market Sentiment Meter, Third-Party Database powered by 1QBit (ESEZ).

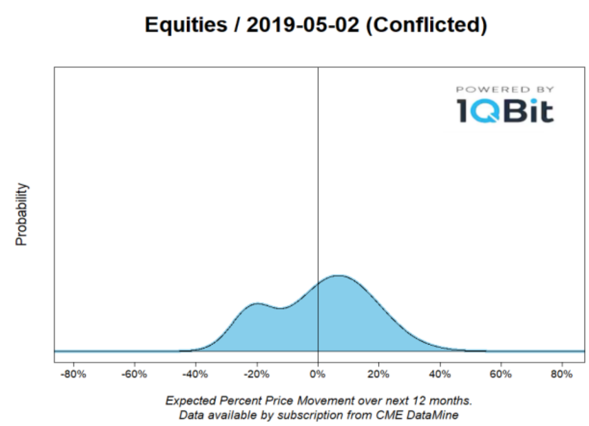
The progression of sentiment states went from "Complacent" on December 15, 2017, shifted to "Balanced" in mid-January 2018, and then became "Anxious" by February 5, 2018, as worries about coming Fed rate hikes began to dominate the tax narrative.

Figure 8: Evolution of Equity Sentiment States from December 2017 to February 2018



Early in the spring of 2019, the trade tension news was a drumbeat of positive information flowing from both Washington and Beijing that a deal could possibly be coming soon. Unfortunately, in late April and early May 2019, the negotiations became more acrimonious and talk of a quick deal faded. The trade narrative shifted to focus increasingly on whether there would be a deal soon or no deal at all. This was reflected in our 'Market Sentiment Meter', which shifted to the extremely rare 'conflicted' state. The 'conflicted' state involves a bi-modal risk distribution, which we interpret to mean the narrative is weighing two very different scenarios (i.e., deal or no-deal) with the potential for shifts in the relative probabilities towards or away from one or the other scenarios with each news cycle.

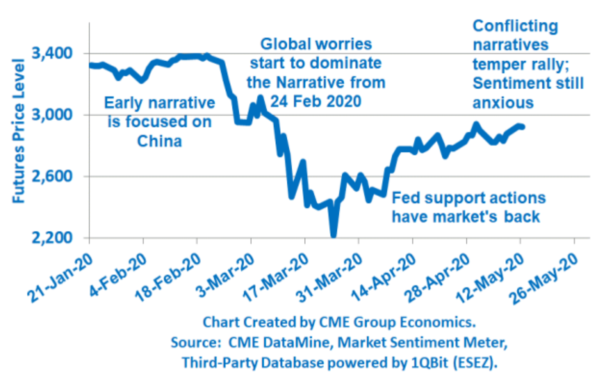




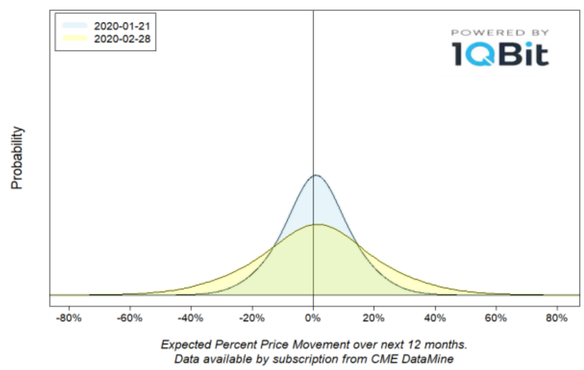
For our next illustration, we examine interesting shifts in the narrative coming from the evolution of the pandemic. The COVID-19 virus broke onto the scene in mid-January 2020 initially as a China-only narrative. US equities reflected a 'balanced' sentiment state during the early stages when the narrative was mostly about China. During the weekend of February 22-23, 2020, the news and the narrative shifted to a global focus, and shortly thereafter our Market Sentiment Meter showed that US equities had entered an "anxious" sentiment state, reflecting a sharp increase in worries about the future. Then, as the narrative developed into an even more worrisome storyline, focused on the serious ramifications of shutting down travel, tourism, restaurants and bars, and generally depressing global demand for goods and services, US equity markets entered bear market territory in early March 2020.

The narrative went through several more evolutions. Equities hit the bottom of the bear market sell-off on March 23, 2020, as the narrative shifted to reflect the degree of asset price support that the Federal Reserve (Fed) was willing to provide, with announcements of current and forthcoming purchases of US Treasuries, Mortgage-Backed Securities, Corporate bonds, and Municipal bonds. Effectively, the Fed was promising multi-trillion-dollar support for the entire spectrum of the US fixed income marketplace. Equities rallied from their low points on the back of the “Fed has the markets back” narrative.

Figure 11: E-Mini S&P500® Futures evolve with the Shifting Narrative



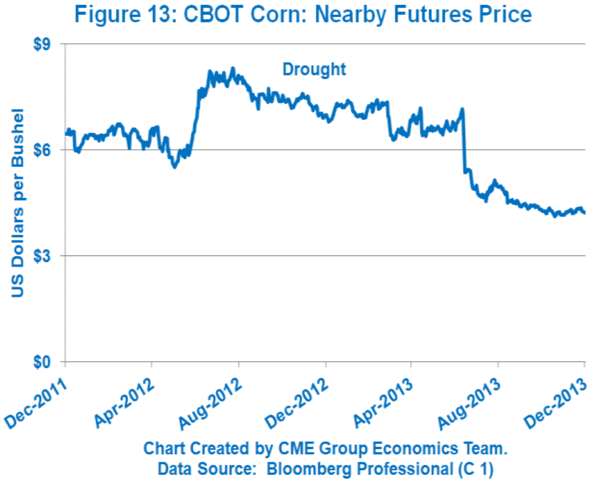
Equities / 2020-01-21 (Balanced) & 2020-02-28 (Anxious)

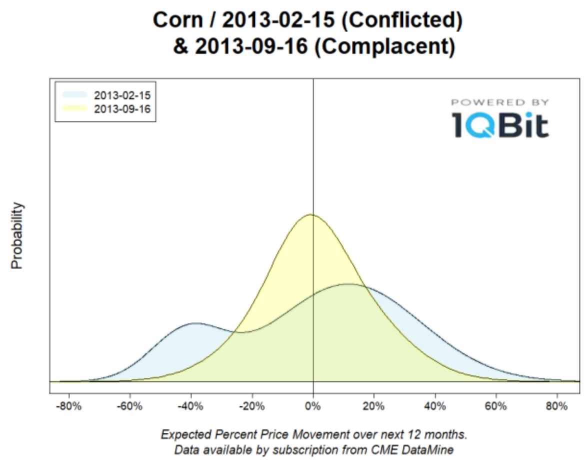


These three US equity index cases – tax cut of 2017, trade tensions in 2019, and the pandemic in 2020 – illustrate the Market Sentiment Meter’s ability to identity the evolution of a hypothetical expected risk-return probability distributions. They provide a quantitative assessment of how the risk states were dynamically evolving, and may allow for interesting and informative insights, especially around the rare “conflicted” or event risk cases.

B. Corn

We now move to a commodity market – corn. This case covers a very interesting evolution of our probability risk distributions in the corn market in late 2012 and into the first half of 2013. The summer of 2012 had seen large swaths of the US corn belt experience severe drought. Late in 2012, after the harvest, market participants’ thoughts turned to the 2013 crop, about which there was much disagreement. How much acreage would be planted after the drought year? Would 2013 see another drought or its disappearance? While not of the political version of event risk, corn market participants were worried about the drought and a two-scenario market developed for a while in February 2013 as one side of the market took the view that the 2013 crop would be much better than 2012’s drought-constrained crop and other market participants worried about another poor crop. Our probability risk distribution was already in an “anxious” state late in 2012, shifted to “event risk” in February 2013, went back to "anxious" for most of the spring of 2013, before returning to the most common state, "balanced risks" in the summer of 2013.





IV. Conclusions and Possible Future Research

These case studies are presented purely as illustrations to demonstrate that our research methods allow for the rarest of market states – event risk with a bi-modal probability distribution. This "conflicted" sentiment state has occured in all of the product classes we have studied so far, which includes US Treasury notes futures, equity index futures, Euro FX (versus USD), gold, oil, natural gas, soybeans and corn.

We do not expect the most common state – "balanced risks" – occurring as much as two-thirds to three-quarters of the time, depending on the product, to provide any critical information that one would not acquire looking only at implied volatilities from options markets. We do think, however, that when the probability risk distribution shifts into a less typical state – "complacent", "anxious", or especially "conflicted" or event risk state – that risk managers should go on high alert.

We also warn that while our naming conventions describe the risk distributions, they may not describe what happens. "Complacent" states may well be followed by volatility when some new and unexpected risk factor takes priority. "Anxious" states may or may not overstate fears, Equity analysts often observe that "a market may climb a wall of worry". "Conflicted" or Event risk" states do not last long. With event risk, there is usually an outcome, and so the sentiment state is resolved back to a one scenario, single mode distribution when the event occurs, and the outcome becomes known or when market participants become more confident that a one scenario outlook with appropriate skepticism is more appropriate than a conflicted two- scenario approach.

Our future research path is taking us in several directions. One study we are conducting looks at whether there is a higher propensity for three or even four standard deviation events occurring once the sentiment state is moved to one of the extremes – "Complacent", "Anxious", or "Conflicted". Our preliminary findings are that the "Complacent" state is just as likely to signal the heightened possibility of three or four standard deviation events as is the "Anxious" state, although there are some differences across products. Another direction for our research is examining options strategies and how different types of structured positions would have fared during the different sentiment states. This line of research is being conducted jointly with 1QBit and we look forward to some interesting insights from our work together.

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End Notes

[i] Please see Chapter 9, "Volatility & Uncertainty" in *Economics Gone Astray* (World Scientific Publishing Co.), by Blu Putnam, Erik Norland, and KT Arasu, 2019.
[ii] Please see Chapter 11, "Portfolio Optimization", *Economics Gone Astray* (World Scientific Publishing Co.), by Blu Putnam, Erik Norland, and KT Arasu, 2019.
[iii] Black, Fischer; Scholes, Myron (1973). "The Pricing of Options and Corporate Liabilities". *Journal of Political Economy*. 81 (3): 637–654. doi:10.1086/260062.
Merton, Robert (1973). "Theory of Rational Option Pricing". *Bell Journal of Economics and Management Science*. 4 (1): 141–183. doi:10.2307/3003143.