VOLATILITY EXPECTATIONS IN AN ERA OF DISSONANCE

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Options pricing depends critically on expectations of future volatility. Risk measurement and time series research methods often assume that volatility is constant over a given time period. If volatility repeatedly shifts to elevated levels and then moderates, the robustness of many models may be called into question. Financial practitioners often characterize such conditions as being "risk-on" or "risk-off" states, and during 2007–2011 there were many examples. This paper discusses how probabilities may shift between two distinct scenarios for the future. The first scenario describes a state in which economies settle into steady growth patterns and financial markets adjust accordingly, while the second scenario encapsulates the potentially dire consequences of considerable economic and financial disruption. This approach focuses attention on the robustness of many common practices that embed assumptions of steady levels of volatility.

Options pricing depends critically on expectations of future volatility. Many risk measurement systems as commonly practiced, such as Value at Risk methods, also depend on assumptions about future volatility. Quantitative research methods, such as least squares regression approaches, assume that volatility is constant over the time period being examined. If volatility shifts back and forth to elevated levels and then moderates, the robustness of many option pricing models, risk measurement systems, and time series quantitative research approaches may be called into question due to the existence of substantial heteroskedasticity, as observed volatility levels are not stable.

During the period 2007–2011, financial practitioners often characterized various markets as being in a “risk-on” or “risk-off” state, with volatility rising, and then falling, only to rise and fall again. From the U.S. subprime mortgage crisis in 2007 to the financial panic triggered by the bankruptcy of Lehman Brothers in September

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2008 and to the European sovereign debt crisis in 2010 and 2011, there was a series of events that destabilized markets and led to shifting patterns of volatility.

The ability to manage financial risk and price options in periods with severe volatility shifts depends critically on our understanding of the nature of the environment creating the unstable conditions. This paper interprets the nature of risk-on, risk-off markets in terms of how probabilities may shift between two distinct scenarios for the future. The first scenario describes a state in which economies settle into steady growth patterns and financial markets adjust accordingly, while the second scenario encapsulates the potentially dire consequences of considerable economic and financial disruption. The first scenario typically would have a relatively high probability, while the second scenario would usually have a very low probability, involving a highly disruptive outcome with extremely high volatility.

What matters for estimating future volatility as well as for understanding the nature of risk-on, risk-off markets, however, is how the probabilities shift between the two scenarios. The arrival of new information may cause market participants to adjust their expectations of the probabilities between the competing scenarios matters. Changes in the relative probabilities of the two scenarios can be shown to be a particularly important source of shifts in the volatility regime and, by extension, to the correlation structure of markets.

Our contention is that financial risk management and options pricing in markets characterized by risk-on, risk-off behavior requires a much greater appreciation and understanding of the implications of heteroscedasticity (i.e., changing volatility) as well as the related changes in the correlation structure of markets. This approach sheds light on the possible causes of shifting volatility expectations and focuses attention on the robustness of many common practices that embed assumptions of homoscedasticity or a steady level of volatility. The implications for how options are priced is directly linked to how expectations of future volatility are formed, since future volatility is one of the key unknowns that must be estimated in virtually all options pricing methodologies. In addition, the failure to understand the sources and the nature of a risk-on, risk-off financial environment can lead to dramatic overconfidence and, equally important, underestimation of potential volatility in a given portfolio of financial exposures. (See Figure 1 as an example.)

The paper is organized as follows. To set the stage, the first section discusses and illustrates the nature of the risk-on, risk-off environment of the 2007–2011 period and focuses attention on the issues of heteroscedasticity and changing correlation structures. The second section provides a very brief review of the literature related to heteroscedasticity and changing correlation structures, emphasizing the importance of understanding the reasons and nature of a market expectations model that has the potential to deliver the type of risk-on, risk-off behavior observed in the 2007–2011 period. The third section provides the basic structure of an intuitively appealing way to model the way expectations are formed taking a page from several scholars from the more distant past. The final section combines the lessons from the theory of expectations formation and the actual
experience in the markets to provide a short listing of the critical options pricing and financial risk management implications of a risk-on, risk-off environment.

I. RISK-ON, RISK-OFF: THE PRACTITIONER PERSPECTIVE

When the financial panic of 2008 hit markets, volatility spiked. Many financial practitioners, however, came to the view during 2009 that conditions would become more settled as markets adjusted to the new reality. But the “new normal,” as some practitioners were expecting, did not materialize, at least in the 2009–2011 period. The implications of a financially-induced economic recession are severe and were examined thoroughly by Reinhart and Rogoff (2009).

There were waves of secondary shocks. The sovereign debt crisis in Europe spread from Greece to Portugal; market contagion spread to Spanish bonds, and in the summer of 2011 to Italian bonds and European bank stocks. Along the way the Swiss franc appreciated markedly against the euro and global equities dropped. From the United States came the debt ceiling debacle in the summer of 2011, which threatened a default of U.S. Treasury securities. China turned off its policy of allowing the renminbi to appreciate incrementally prior to 2008, turned it back on later, only to turn it off again in the second half of 2011. Facing a disruption in its wheat crop, in the summer of 2010, Russia barred exports of wheat, later allowing wheat exports again as its new crop was harvested in 2011. Japan suffered a violent earthquake with supply lines disrupted across the world. As one can tell from this only partial list, not all of these disruptions to financial markets were directly or indirectly associated with the Financial Panic of 2008. Some were natural disasters and some were man-made political debacles, but they played into and interacted with the challenging financial context in which they occurred. Regardless of the causes, markets in the crisis phase of 2007–2008 and the post-crisis phase of 2009–2011 did not return to any type of regime that would be categorized as stable with predictable levels of volatility.

What financial practitioners and economists alike observed was that the volatility of returns in a variety of markets was strikingly different for periods as long as months or quarters and, as well, even annual measures were shifting in a meaningful manner. Moreover, correlation structures were moving around, too. When a crisis erupted and fear spread through markets, the correlation between exposures within an asset class tended to rise, even as correlations across asset classes diverged, especially as regards assets considered “safe havens” relative to assets considered “risky.” For financial risk managers, this meant that expectations associated with the Value at Risk (VaR) could dramatically underestimate portfolio risks if the original expectations were built on an assumption of a correlation matrix derived primarily from more stable periods in the past.

Given that a large number of quantitative financial tools embed the specific assumption of homoscedasticity (i.e., stable level of volatility) and also assume a stable and measurable correlation structure, a great deal of uncertainty and concern was apparent among financial risk managers and practitioners as well as regulators.
and central bankers. Indeed, basic tools from least squares multiple regression analysis, a number of typical option pricing models, mean-variance portfolio construction tools, and many forms of VaR models as commonly practiced, among others, were potentially weakened in terms of the robustness and applicability of their insights.

II. KEY INSIGHTS FROM THE STATISTICAL AND FINANCE LITERATURE

Statistical issues associated with heteroscedasticity and with shifting correlation structures are well known and have been studied in considerable depth, by Brown (1977), Berry and Feldman (1985), Poon and Granger (2001, 2005), Gabrisch and Orlowski (2012). There are specific challenges for regression methods and for risk measurement or portfolio systems that rely on mean-variance optimization or stable covariance structures.

For example, in regression methods, the existence of heteroscedasticity casts doubt on the parameter estimates in terms of their likely significance. For example, parameter estimates from a standard regression model would not be best linear unbiased estimates (BLUE) if the variance was heteroscedastic. They would, however, still be unbiased. That is, assuming homoscedasticity when sufficiently severe heteroscedasticity is present can lead to undue confidence in the parameter estimates, among other things.

In mean-variance portfolio models of the type developed by Markowitz (1959) and his followers, or in many portfolio risk measurement methods, the assumption of a stable covariance is critical. When volatilities or correlations are shifting, the results can be highly misleading and/or sub-optimal by a serious degree.

In the case of heteroscedasticity, there are a variety of ways to measure whether it is present and to try to assess whether this impacts the robustness of the results of models that assume homoscedasticity. Measures of heteroscedasticity, however, are dependent typically on what causes the shifting of volatility regimes in the first place. For example, the Breusch-Pagan test as used in statistical studies assumes the underlying model is linear and looks at the residuals to test for heteroscedasticity (see Lin 2001). Other tests for heteroscedasticity can be even more narrow in terms of the assumptions about the structure of the underlying model. The White Test, for example, is a special case of the Breusch-Pagan test (see Alexander 2008).

In general, tests for heteroscedasticity require assumptions about what is causing the heteroscedasticity and the functional form that is implied by the nature of the causality assumptions. Our purpose here, however, is not to enter into a discussion of the pros and cons of different tests for heteroscedasticity. Instead, we want to focus on a common characteristic of the tests and what that implies for options pricing and financial risk management.

That is, there is a type of intellectual feedback loop when measuring for heteroscedasticity, because misspecified models can appear to have
heteroscedasticity when a better specified model might mitigate the problem. The key point we wish to emphasize here is that to understand how much of a problem heteroscedasticity and shifting correlation structures are for financial practitioners and especially risk managers, it is absolutely critical to understand the underlying economic or financial conditions that are causing the heteroscedasticity and changing correlation structures.

Many observers, notably Mandelbrot (1997) and Mandelbrot and Hudson (2004) which reprises and updates earlier work from the 1950s and 1960s, emphasizes the existence of potentially extreme skewness and/or kurtosis in the distribution of financial market returns. To interpret the skewness and kurtosis observed in the 2007-2011 period, we want to couple our observations about the shifting volatility patterns with an interpretation of why they occur in the first place.

III. A TWO-SCENARIO APPROACH TO VOLATILITY EXPECTATIONS

Our presumption is that there is a fundamental difference in the volatility and correlation behavior of markets depending on whether (a) expectations are governed by shared fundamentals or (b) expectations are governed by sources of dissonance that result in the possibility of widely divergent outcomes. The shared fundamentals category generally produces a probability distribution of expectations around a single most likely outcome (mode) and maintains a relatively consistent volatility (variance). By contrast, expectations constructed in what we call the "sources of dissonance" category are much more complex and may have multiple and quite different
competing scenarios. Even more disturbing for markets, estimated volatilities are not confined to a reasonable range but can shift, sometimes abruptly and dramatically. The practical implications for how market conflicts are resolved relate in no small way on which categorization is in the ascendant.

A. Expectations Governed by Shared Fundamentals

The typical underlying assumption about the expectations of market returns is that they are centered around a single mode and with defined variance (i.e., volatility, typically measured by the observed standard deviation). For most market models the assumption is even more specific — expectations of returns are drawn from a normal distribution or can be described by a normal distribution without doing damage to the basic conclusions, even if the distribution is non-normal. In our case, the normal distribution assumption is not the important part. What is critical is that there is a single mode, even if the distribution has a one-sided fat tail (skewness) or a relatively higher peak around the central section (leptokurtic) leading to fat tails in the extremes.

If market participants broadly share a similar vision of the fundamentals guiding economic behavior, then when market participants receive new information, such as new economic data or a policy announcement, the expected mean of future returns shifts, but the expected volatility remains more or less the same. (See Figure 2.) Broadening the case into a multi-exposure environment, market participants would also share a similar view of the correlation structure of expected returns,
which is assumed to remain stable even as market return expectations change with new information.

Take for example what happens when new information is available to market participants, say in the form of the U.S. employment data, which is released for the previous month on the first Friday of every month. When this data release surprises the market in terms of the outcome being different than the consensus expectation, market participants quickly revise their perspective on U.S. Treasury yields, equities, and other securities. For example, a negative surprise generally means lower U.S. Treasury bond yields and lower stock prices, while a positive surprise is often accompanied by higher U.S. Treasury bond yields and higher stock prices. This means that the expected mean of the probability distribution for both U.S. Treasuries and stock prices has shifted. But the degree of confidence with which market participants hold their newly-revised views does not change much — it stays in a reasonably well-defined range, or confidence interval, for both bond yields and stock prices. That is, what we have is a new probability distribution with a new mean but more or less the same variance (i.e., volatility or confidence).

B. Expectations Governed by Sources of Dissonance

The distribution of expectations of future market returns can take on a very different shape when there are two potential outcomes that are very far apart from each other. The challenge is that the market is trying to combine expectations of market participants that cannot be reasonably described by a distribution with a single mode.

Let’s take an example from the world of mergers and acquisitions. Suppose company A has made a bid for company B at a price of $120 representing a 20% premium over the previous market price of $100; that is, the bid represents a substantial premium to gain full control of the target company. Now, suppose that the regulatory authorities decide to review the potential merger and that there is a reasonable probability that the merger might be rejected. Let’s say that after the merger is announced but before the regulatory authorities make their decision, there is a 50/50 probability of approval of the merger. How does the market resolve these conflicting expectations?

Effectively, there is one set of expectations for the stock price of company B if the merger is approved and that is $120, with a very small variance, since an adjustment to the bid in this case is not assumed to be very likely. (See Figure 3.) And if the merger is rejected by the authorities, then the stock price of company B would likely fall back to its pre-merger announcement price of $100, give or take, and there would be considerable uncertainty as to the future of company B (high variance) since a new suitor might appear or the company might be perceived as damaged goods and the stock price spiral downward. (See Figure 4.)

The expected value (mean) of the combined distributions depends on the probability of scenario A (merger approved) or scenario B (merger rejected). At 50/50 probabilities, the expected mean for the combined probability distribution is
Figure 3. Scenario A: Merger Approved (Mean = 120, STD = 2).

Figure 4. Scenario B: Merger Rejected (Mean = 100, STD = 6).
Volatility Expectations

Figure 5. Mixture of Scenarios A & B at 50% Each (Mean = 110, STD = 4.47).

110 and the standard deviation is 4.47 (i.e., square root of the probability weighted sum of the variances).

The probability distribution is a mixture of a 50% chance of Scenario A with a 50% chance of Scenario B, and the mixed distribution is clearly not a bell-shaped curve and also has two modes. Many quantitative models assume that reality is represented by a probability distribution that is normally distributed with a single-mode. In many financial environments over the last half of the previous century this was not necessarily a bad assumption to make, at least some of the time. If the reality is more like the bi-modal distribution in Figure 5, however, then just knowing the mean (expected return) and the standard deviation (estimated future volatility) is not remotely enough to manage risk properly.

Indeed, the likely market volatility actually depends importantly on how the probability of Scenario A (merger approved) versus Scenario B (merger rejected) changes over time. That is, the expected volatility the market is pricing (e.g., in options) moves with the perceived likelihood of each scenarios, rather than the scenarios themselves changing. As the likelihood of Scenario A (merger approved) gains favor, the mean (stock price) rises toward the acquisition bid price, and the estimated volatility declines. Thus, in our example the expected volatility goes from 6.0 to 2.0 as the probability of the merger being approved (Scenario A) goes from 0% to 100%.

Let’s explore this more. Now, some new information arrives. Maybe it is a rumor that the regulatory authorities are leaning against merger approval. If the odds against merger approval go down, the expected mean of the combined
probability distribution declines and the estimated standard deviation (volatility) rises (Table 1). Another form of new information would be the possibility of a white knight with a higher bid. A new suitor entering the fray would shift the expected mean higher and might decrease the standard deviation.

Note that both the expected mean and the estimated standard deviation (volatility) shift in these cases where a bi-modal distribution of two far-apart scenarios with different probabilities govern the combined distribution that sets market prices. Put another way, what is nearly certain is that the market price will not stay where it is once the regulatory authorities make their decision. The status quo is decidedly unstable.

The alternative explanation of volatility and correlation shifts comes under the heading of extreme value theory, for example in Focardi and Fabozzi (2004). In the extreme value approach, the presumption is that the underlying probability distribution governing financial markets is not a normal distribution, but is highly skewed to the left (fat-tail), which accommodates the possibility of very bad outcomes or extreme losses. Extreme value theory and the bi-model approach suggested here share some similarities. In fact, one will not see a bimodal shape when using a mixture of two normal (bell-shaped) distributions unless the difference between the two expected means is quite large. Thus, when the two opposing scenarios are different, but not different enough to produce a bi-modal distribution, one would see the heavily skewed distribution that is typically examined in extreme value theory. In this regard, the extreme value approach assuming a heavily skewed yet single mode distribution is merely a subset of the two scenario approach. In essence, what Mandelbrot (1997) has been warning for decades is that we often observe skewed distributions in financial markets and that our risk measurement processes should not assume normal distributions.

A number of researchers have explored the quantitative implications of the relatively common occurrence of extreme values and non-normal probability distributions in financial markets, such as Christie-David and Chaudrey (2001), Clark (1973), Neftci (1996), and Tauchen and Pitts (1983), among many others. The approach we want to pursue goes further back in time to the work of Pearson.
Volatility Expectations

(1894) and Charlier and Wicksell (1923), in which they examine the concept of mixtures of probability distributions. We might note that though these were mathematicians, they were often influenced by economists. S.D. Wicksell, for example, was the son of Knut Wicksell, the great Swedish economist, who himself was a mathematician before he switched to the study of economics in his middle-age years. More modern work on mixtures of probability distributions along the lines we wish to pursue here includes research by Clemen and Winkler (1997) and Cohen (1967).

C. Outline of Basic Model

We start with what is termed here, the “expectations governed by shared fundamentals” environment. That is,

\[ f(x) = N(\mu_1, \sigma), \quad (1) \]

where \( N(\mu_1, \sigma) \) represents the normal distribution with mean, \( \mu_1 \), and standard deviation, \( \sigma \), of the market returns variable, \( x \).

Now, new material information is received that did not confirm prior expectations, and so the expectations of the mean changes, from \( \mu_1 \) to \( \mu_2 \) but the standard deviation is not altered, meaning that the volatility structure of the market has not been altered by the receipt of the new information. That is, after the receipt of new information and after revising our market expectations, we now have:

\[ f(x) = N(\mu_2, \sigma), \quad (2) \]

This is what is typically being assumed about volatility in many risk measurement models, time series research studies, and some option pricing approaches; that is, homoscedasticity is being assumed and embedded into the analytical approach.

Our more complex approach introduces two possible scenarios for our market returns variable, \( x \), represented by two different probability functions. For simplicity, both probability distributions are assumed to be normally distributed, but now there are two different means and two different standard deviations, as well as probabilities associated with each scenario and a set of explanatory factors associated with determining the probabilities for the two scenarios.

\[ f(x) = \alpha f_1(x) + (1 - \alpha) f_2(x) \quad (3) \]

\[ f_1(x) = N(\mu_1, \sigma_1) \quad (4) \]

\[ f_2(x) = N(\mu_2, \sigma_2) \quad (5) \]

\[ f(\alpha) = f(z_0, z_1, z_2, z_3, \ldots, z_n) \quad (6) \]
where there are 0 to \( n \) factors labeled \( z_i \) that influence the probability, \( \alpha \), of the typical state in which \( x \) is found, relative to the probability, \( 1 - \alpha \), of the “dire consequences” or extreme state.

Note that in this two-scenario system, the variance (volatility) will shift when the probabilities associated with each scenario shift.

\[
\sigma^2 = \alpha \sigma_1^2 + (1 - \alpha)\sigma_2^2
\]  \hspace{1cm} (7)

That is, the volatility is determined by the probability, \( \alpha \), which in turn is determined by a set of explanatory factors. This means that the variance will change whenever the probability, \( \alpha \), changes due to shifts in the factors.

In the base case, which is characterized as “expectations governed by shared fundamentals,” volatility is unchanged. That is, we have the special case where:

\[
\sigma_1 = \sigma_2
\]  \hspace{1cm} (9)

As discussed earlier, in the “expectations governed by shared fundamentals” environment, the effect of new information is only to change the expected mean, \( \mu \), of future values of \( x \) and not to shift the volatility.

One can extend this analysis to multiple markets and to the correlation structures associated with each scenario. That is, there would be two scenarios with different assumed volatilities and a different correlation structure. Again, if new information is received that shifts the probabilities of the two scenarios, then this would also shift the correlation structure. The mathematics get much more complex when there are multiple variables and correlation structures to consider, but the intuition is the same.

In Bayesian statistics, for example, an inverse Wishart distribution is used to form the prior for the covariance matrix (i.e., volatilities and correlation structure) under the assumptions of a multivariate normal distribution, as described in O’Hagan and Forster (2004), where the previous assumption (prior) for the volatility and correlation structure is being revised based on new information about how the volatility and correlation structures are evolving. That is, the new Bayesian prior for the covariance structure is a mixture of the previous prior and the covariance implied by the new information.

While the assumption of normal distributions is retained in this approach, the Bayesian system allows for the estimated covariance for the next period ahead to be revised each period in which new information is received. Dynamic updating, where the covariance structure is treated as a time-varying random variable to be estimated, is certainly one approach to working with the challenges of shifting patterns of volatility and correlations. This is the same approach adopted in the Bayesian forecasting and portfolio construction processes developed by Quintana and Putnam (1994).
IV. OPTIONS VALUATION AND RISK MANAGEMENT

As we have discussed, risk-on, risk-off market environments challenge some key assumptions embedded in many options pricing models and risk measurement approaches; namely, the assumptions that volatilities remain in a relatively accepted range for each type of exposure and that the correlation matrix that represents how the movements of different exposures work together is stable. In an era of dissonance, assuming a stable regime for volatilities and correlations may turn out to be extremely dangerous to one’s financial health. In options-speak, an era of dissonance is all about “vega” risk, the Greek letter that represents the risk of shifting volatilities in options trading.

Our conclusions may be summarized as follows:

A. Options Pricing Models May be Challenged

Options pricing methods typically involve a set of known factors, such as the strike price, current price of the underlying security, time to maturity, and borrowing rate. But then in options valuation (see Bookstaber 1987), there is always the factor that must be estimated, namely, expected volatility. Volatility estimation is likely to be considerably more difficult and the volatility expectations held with much less confidence in an era of dissonance type of environment.

B. Static Asset Allocation May Become a Legacy Approach

Static asset allocation based on asset class categories may not work nearly so well in periods of severe dissonance than in the past. The old long-term rule of thumb of 55% equities, 35% fixed income, 10% cash allocation may need to be carefully and critically re-evaluated and possibly relegated to the dust bin in favor of more flexible and dynamic asset allocation methodologies.

C. Dependable Diversification May Be Hard to Achieve

Dependable diversification can be especially hard to achieve when correlations can switch directions. This argues for a much more forward-looking approach to risk management, as discussed in Smith, Smithson, and Wilford (1990). The clear and present danger in an era of dissonance is that risk assessment and risk management are both more important than ever and also more complex. What is required is a forward-looking view of risk and a much more dynamic analytical process for risk assessment and management. The search by some for the “Holy Grail” of risk measurement, namely one number that provides a measure of risk for a complex organization or portfolio, may need to be abandoned completely. Risk management is part art as well as science. Moreover, risk management involves forecasting and cannot be solely dependent on data calculations made from historical time series.

Adding to the challenge, policy decisions can be made suddenly and often have many hidden, indirect, and unintended consequences. In an era of potentially
abrupt policy shifts and confusion in market expectations, markets may tend to remain in a risk-on, risk-off mode for long periods of time. That is, instead of focusing more on relative value within an asset class, market participants are forced into a situation in which their biggest decision is not where to position their risk, but how much risk to take. And unlike the past half century, the risk level decision must be managed continuously rather than made once and put into action for an extended period of time.

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