Dispersion Trading and Volatility Gamma Risk

Analysis of Tail Risk in Dispersion Trades

Summary

- Dispersion trading is a common way to capture correlation risk premium. In a dispersion trade, an investor sells index variance and buys variance in the index components in a hedge ratio that makes the dispersion trade volatility neutral at inception. However, this hedge ratio can change with the level of correlation and the dispersion trade can acquire a net volatility exposure. In a high volatility environment, the effect of an acquired volatility exposure may dominate the dispersion trade PnL.

- Because of the positive correlation between index volatility and correlation, a dispersion trade will acquire a short volatility exposure as volatility rises and a long volatility exposure as volatility drops. Therefore, a dispersion trade has a negative 'volatility gamma' exposure (this is analogous to a negative 'spot gamma' exposure of a short un-hedged straddle). The premium for volatility gamma risk is usually reflected as the premium of dispersion levels to correlation swap levels.

- Based on historical data, we estimate the volatility gamma for S&P 500, EuroStoxx 50, and Topix 30 dispersion trades. This analysis can help select the proper hedge ratio, and quantify the potential loss of a dispersion trade on account of volatility gamma. We also backtested the impact of the volatility gamma on dispersion trades during the surge in volatility and correlation over the past two months.

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Dispersion Trade – Volatility Neutral for Small Moves

On average, the implied volatility of major equity indices such as the S&P 500, the EuroStoxx 50, and Topix trades at a premium to realized volatility. Index implied volatility premium is to a large extent the result of implied correlation premium. One way to capture this risk premium is by outright selling index implied volatility. Another way is by entering into a dispersion trade in which a short index implied volatility is hedged by a long position in implied volatility of the underlying constituents. By choosing the proper hedge ratio (the amount of index volatility that needs to be sold for every unit of long single-stock volatility), one can make a dispersion trade volatility neutral. **In particular, if one chooses the ratio of total single-stock vega to index vega to be the square root of correlation** (see Appendix I), the dispersion trade will be approximately volatility neutral – i.e., the trade PnL will not vary with a small change in single-stock volatility, and will only change on account of a change in correlation.

Dispersion Trade – Short Volatility Gamma Risk

For most equity indices **there is a strong positive relation between index volatility and index correlation**[1] (i.e., when volatility is high, correlation is high and when volatility is low correlation is low as well). This relationship holds for several reasons – first, index variance is by definition proportional to correlation (see Appendix II). In addition, the relationship is a result of market dynamics and investors' behavior (in periods of high volatility equity prices are usually driven by common macro factors and there is little or no stock picking activity). A positive relationship between correlation and index volatility will cause dispersion trades to acquire volatility exposure in the following way: as correlation increases, the hedge ratio that makes a dispersion trade volatility neutral will decrease (the ratio of index volatility to single-stock volatility). For a trade that was initiated at a higher hedge ratio (higher short index volatility exposure), a dispersion trade will acquire a net short volatility component as volatility rises. This will lead to a loss as volatility increases. Similarly, if correlation decreases, the hedge ratio that makes the trade volatility neutral will increase (a volatility neutral trade should have larger short index exposure). As the trade was initiated at a lower hedge ratio (lower short index volatility exposure), a dispersion trade will acquire a net long volatility component as volatility falls. This will lead to a loss on account of a drop in volatility. **In both cases, large moves in volatility can result in a loss due to an acquired volatility exposure** (in addition to correlation PnL)**. Therefore, one can say that a dispersion trade has short 'volatility gamma' exposure.**

Selling correlation via a dispersion trade is therefore analogous to selling volatility via an un-hedged straddle. Initially, the delta of a straddle is zero (in a dispersion trade, the vega is zero), and there is only a short volatility exposure (in a dispersion trade, a short correlation exposure). If the underlying moves up, the straddle will acquire a negative delta – resulting in a loss on account of short delta, and if the underlying moves down, the straddle will have a positive delta – resulting in a loss on account of positive delta. In both cases, the acquired delta (in a dispersion trade, the acquired vega) will lead to a loss.

[1] Correlation of underlying index components.

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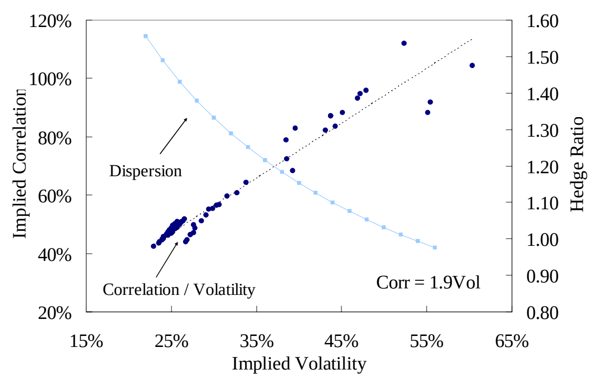
The short 'volatility gamma' of a dispersion trade is illustrated in the example below. The scatter-plot (dark blue dots) shows the positive relationship between implied correlation and index implied volatility for Topix from 8/1/2008 to 11/1/2008. The light blue line shows the hedge ratio that makes the dispersion trade volatility neutral (the ratio of index vega sold to single-stock vega bought). At high volatility levels, the hedge ratio is close to 1 (the short index vega is hedged by the same amount of long single-stock vega), and at low volatility/correlation levels, the hedge ratio is close to 1.5 (one needs to short 50% more index vega than single-stock vega).

Figure 1: Correlation – Volatility Regression and Dispersion Trade Hedge Ratio for TOPIX



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

For small moves in volatility, the loss in a dispersion trade due to short volatility gamma should not be large. However, for large moves in volatility, this loss may be a significant or even the more dominant part of a dispersion trade PnL. For instance, during the rise in Topix volatility and correlation over past two months, volatility increased from 25% to 55% and the trade hedge ratio dropped from 1.45 to 1.05. As a result of this move, an average short volatility exposure of 20% was acquired (the initial volatility exposure was 0 at a hedge ratio of 1.45, and the final volatility exposure was 40% at a hedge ratio of 1.05). A 20% short volatility exposure over a ~30 volatility point increase would have lead to a ~6 vega loss. This is equivalent to a ~25 correlation point loss (see Appendix II). Note that correlation itself increased by ~50 points – hence the dispersion PnL was significantly impacted by the volatility gamma.

The 'volatility gamma' of a dispersion trade can be defined as the change in vega exposure of a dispersion trade for every one point change in index volatility (see Appendix III). Essentially, 'volatility gamma' is the rate of change of a dispersion trade 'hedge ratio' with volatility:

$$\begin{matrix} Volatility \\ Gamma \end{matrix} = \frac{\Delta HedgeRatio}{\Delta Volatility}$$

As the hedge ratio is a function of the inverse of correlation, volatility gamma will be higher at lower levels of correlation (and hence lower levels of volatility). While volatility gamma is higher in a low volatility (low correlation) regime, the overall PnL impact of the volatility gamma will be larger in a high volatility environment. The reason for this is the relationship between volatility and the volatility of volatility. The PnL impact of the volatility gamma is proportional to the size of

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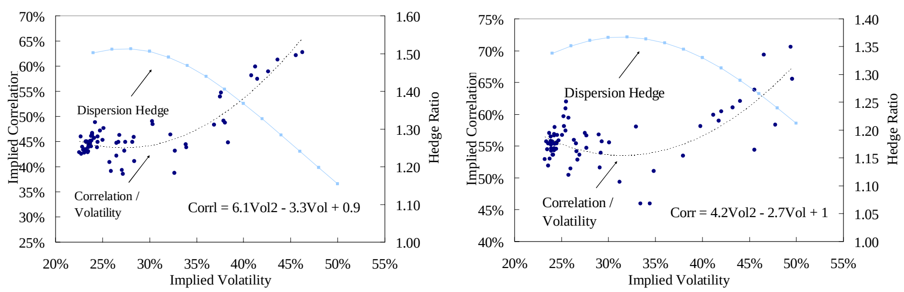
volatility moves, and volatility moves are large in a high volatility environment (high volatility coincides with high volatility of volatility). In a high volatility regime (correlation approaches 100%), volatility gamma will drop but converge to a constant value[2], while the size of volatility moves can increase without limit causing a large volatility gamma loss.

Current Volatility Gamma for S&P 500, EuroStoxx 50, and Topix Dispersion Trades

The current volatility gamma of dispersion trades can be estimated from the recent regression between correlation and volatility. In this section, we estimate volatility gamma[3] for the EuroStoxx 50 and S&P 500 dispersion trades with a maturity of one year. Figure 2 below depicts the positive relationship between implied correlation and index implied volatility over the past three months. The light blue line shows a hedge ratio that makes the dispersion trade volatility neutral (ratio of index vega sold to single-stock vega bought).

Figure 2: S&P 500 (Left) and EuroStoxx 50 (Right)



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

Volatility gamma is estimated from the slope of the hedge ratio as a function of volatility[4]. To demonstrate the significance of the volatility gamma on dispersion trading, we backtested one-year dispersion trades in the S&P 500, the Euro Stoxx 50, and Topix over the past two months. A large increase in volatility led to a significant mark-to-market loss both on account of increased correlation, and short volatility gamma exposure[5]. The table below shows the actual PnL of a dispersion trade, the actual loss due to volatility gamma, and the actual loss due to the increase in correlation. We also show a simple estimate of the loss due to volatility gamma, derived by multiplying the acquired volatility exposure (change in hedge ratio from Figures 1 and 2) with the increase in volatility.

[2] See Appendix III; in a simple linear model of correlation/volatility regression, volatility gamma will tend to equal to half the value of the correlation/volatility slope.

[3] Our volatility gamma estimates are based on implied volatility and implied correlation and are therefore relevant for dispersion trades' mark-to-market.

[4] For S&P 500 and SX5E, we use a quadratic regression model, and for Topix we use a linear regression.

[5] In order to separate these two contributions to dispersion PnL, we have separately calculated the PnL of a long correlation swap of notional exposure equivalent to the dispersion trade correlation exposure.

Figure 3: Dispersion Trade Mark-to-Market PnL: $100,000 Index Vega Exposure, Past Two Months

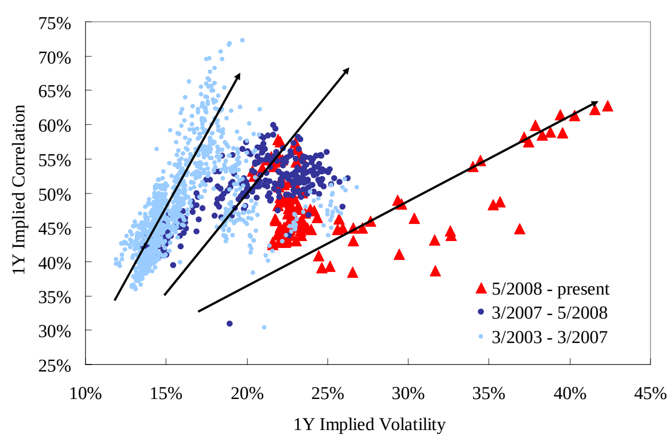
Index	Dispersion P/L ($100K Index Vega)	Correlation P/L (Actual)	Vol. Gamma P/L (Actual)	Vol. Gamma P/L (Estimated)
S&P 500	($2,036,000)	($910,000)	($1,126,000)	($762,000)
Euro Stoxx 50	($1,164,000)	($646,000)	($518,000)	($391,000)
Topix	($2,014,000)	($1,399,000)	($615,000)	($642,000)

Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

One can see that the volatility gamma loss was an important driver of the trades' performance over the past two months. For the S&P 500 and EuroStoxx 50 dispersion trades, the PnL impact of the volatility gamma was of equal size to that of correlation. A PnL impact of similar magnitude is expected for trades initiated at the current volatility and correlation level, should the volatility and correlation drop following the same path.

The volatility gamma of a dispersion trade depends on the level of correlation and volatility (similarly to a straddle gamma depending on volatility and spot). However, volatility gamma also depends on the average level of single-stock volatility (single-stock volatility defines the relationship between index volatility and correlation – see Appendix II). The amount of stock-specific risk has considerably changed in various market regimes. Figure 4 below illustrates different S&P 500 volatility/correlation regimes characterized by different levels of stock-specific risk. We separately show the relationship of index volatility and correlation for the time periods 2003-2007, 2007, as well as the most recent six-month period of extreme market volatility.

Figure 4: Correlation – Index Volatility Regimes from 2003 to Present



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

One can see that the slope of the correlation/volatility regression was high in the declining volatility regime from 2003 to 2007. This was a consequence of a sharp drop in index volatility in 2003 on account of a drop in single-stock volatility while implied correlations remained high, and declined only gradually (a quick drop in single-stock volatility, and a slow drop in correlation). During 2007, the slope of the correlation/volatility regression was lower as index volatility increased from all-time lows to historical average levels. Currently, the slope is low as the large increase in index implied volatility was caused to a large extent by a rise in single-stock volatility (index implied correlations increased at a much slower pace).

Appendix I

A sample dispersion trade implemented with variance swaps calls for shorting one unit of index volatility vega and going long w_i vega of volatility of index constituent stock *i* (strikes of variance swaps are denoted with *X*). The payoff of the dispersion trade is:

$$\sum_i w_i \frac{\sigma_i^2 - X_i^2}{2\sigma_i} - \frac{\sigma_{Index}^2 - X_{Index}^2}{2\sigma_{Index}}$$

One can choose the single stock vega exposures w_i in such a way that the trade is initially vega neutral (i.e., for small changes in volatility, the PnL does not change). In instances where correlation does not change and the volatility of each stock increases by a small amount δ,, the profit/loss of the dispersion trade due to the change in volatility would be[6]:

$$profit / loss = \sum_i w_i \delta - \Delta\sigma_{Index} = \sum_i w_i \delta - \sqrt{\rho}\delta = \left(\sum_i w_i - \sqrt{\rho}\right)\delta$$

If one chooses the ratio of total single-stock vega to index vega to be the square root of correlation, the dispersion trade will be approximately volatility neutral. For instance, with correlation at 25% (square root of 25% is 50%), one has to short $600k of index vega for every $300k long single-stock vega exposure. However, if correlation increases, the vega-neutral ‘hedge ratio’ will change and the dispersion trade will acquire vega exposure.

Appendix II

Index volatility and correlation are related through the average single-stock volatility $\langle\sigma\rangle$

$$\rho \approx \frac{\sigma_{Index}^2}{\langle\sigma\rangle^2}$$

Assuming that single-stock volatility does not change, but that correlation does, the change in correlation should lead to a change in index implied volatility that affects the payoff of a dispersion trade:

$$\Delta\rho = \frac{2\sigma_{Index}}{\langle\sigma\rangle^2}\Delta\sigma_{Index} = \frac{2\sqrt{\rho}}{\langle\sigma\rangle}\Delta\sigma_{Index}$$

For instance, at correlation levels of ~40% and average stock volatility of 25%, a one point increase in correlation will lead to a ~ 0.2 point increase in index volatility (2 times the square root of 40% divided by 25%). One would have to short $500k vega of index volatility in a dispersion trade to match the long correlation swap exposure

[6] Note that index volatility is proportional to the square root of correlation, and that therefore the change in index volatility is the square root of correlation multiplied with δ.

of a $100k notional correlation swap. Notice that the ratio (0.2) depends on single-stock volatility and correlation.

Appendix III

Volatility gamma is defined as the change in a dispersion trade hedge ratio with a change in volatility (change in net index vega of the trade, divided by change in index volatility). By taking the first derivative of the hedge ratio with respect to volatility we get the volatility gamma of a dispersion trade:

$$\begin{matrix} Volatility \\ Gamma \end{matrix} = \frac{\Delta HedgeRatio}{\Delta Volatility} = \frac{\partial}{\partial \sigma}\left(\frac{1}{\sqrt{\rho}}\right) = -\frac{1}{2}\frac{1}{\rho^{3/2}}\frac{\partial \rho}{\partial \sigma}$$

We see that a dispersion trade has negative volatility gamma, as long as correlation and volatility are positively related. Based on the historical regression of correlation to volatility, we can approximate the linear relationship between correlation and volatility. In that case, volatility gamma is proportional to the regression slope, and inversely proportional to correlation:

$$Linear \quad Model: \ \rho \approx \alpha \cdot \sigma, \qquad \begin{matrix} Volatility \\ Gamma \end{matrix} \approx -\frac{1}{2}\alpha\frac{1}{\rho^{3/2}}$$

As correlation approached 100%, volatility gamma approaches a constant value – equal to the correlation/volatility regression slope (and multiplied by -0.5).

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