GLOBAL VOLATILITY SUMMIT

December 2016 Newsletter

Dear Investor,

The Global Volatility Summit ("GVS") brings together volatility and tail hedge managers, institutional investors, thought-provoking speakers, and other industry experts to discuss the volatility markets and the roles volatility strategies can play in institutional investment portfolios. The GVS aims to keep investors updated on the volatility markets throughout the year, and educated on innovations within the space.

BNP Paribas has provided the latest piece in the GVS newsletter series on behalf of Pine River Capital Management.

Cheers,
Global Volatility Summit

Event

The eighth annual Global Volatility Summit ("GVS") is scheduled for Wednesday, March 15th, 2017 at Chelsea Piers in New York City. Alongside our featured volatility managers, we are excited to announce the addition of a Quantitative and CTA manager panel, featuring prominent portfolio managers in the space to share their views on the volatility markets and resulting impact on these strategies.

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2016 Event Recap

The 7th annual GVS featured ten volatility and tail hedge managers hosted a crowd of 350 attendees including senior investment representatives from the largest global pensions, sovereign wealth funds, endowments, foundations, and insurance companies. The 2016 keynote speakers were former US Congressman Barney Frank and decorated Navy Seal Marcus Luttrell, who received a Purple Heart and Navy Cross for his courage against Taliban fighters in Afghanistan in 2005.

Trading Relative Value Between Credit and Equity Volatility

- Credit spreads – credit default swaps (CDS) or cash – and equity option implied volatility are two different ways to look at the risk-performance of US corporations. One focuses on the likelihood of default (i.e. credit) while the other focuses on the movement of stock price (i.e. equity option implied volatility). In theory, both should be linked, because rising default probability (higher CDS spreads) should imply that stock prices should decrease in value (although there are some exceptions e.g. LBO), which would typically imply higher volatility (i.e. higher cost of put option/equity protection). Hence in theory, stock prices, CDS spreads, and stock implied volatility should be linked by a triangular relationship, and Merton's model (or more commonly referred as the capital structure arbitrage models) provided that modeling framework. These models evaluate the credit risk of corporate debt, and value the equity price as a call option on the asset value of the company (i.e. debt and equity), where the option value is dependent on the asset's implied volatility.

- Our experience with financial markets suggests that there is a link between credit spreads and equity implied volatility (although this link is not perfect, due to various market technicals), as a higher spread implies an increasing cost to buy protection which is consistent with a higher implied volatility. In this study we look at the relative value between CDS spreads and equity implied volatility (as opposed to equity prices, which is more common). Relative value trades between single-name CDS and equity prices have been pretty common, and market participants use many variants of capital structure arbitrage models to analyze such trades. However, both the volatility/variance swaps and CDS have a lower liquidity at the single name level but similar analysis can be extended to portfolio products in credit and equity, which are highly liquid.

- In this study, we examine the relative value between CDX IG index spreads and SPX index equity implied volatility (represented by the variance swap product). Alternatively, the VIX index and/or its short-dated futures can also be used for trading equity implied volatility. For those who are unfamiliar with the credit index (CDX IG index), the CDX IG index is a collection of 125 North American issuers, whose CDS has the highest liquidity. The current series on this product is 26 (i.e. IG26), and is often considered the barometer of the US IG credit market, similar to how the SPX and VIX are viewed as the barometers for the US equity and equity volatility markets respectively. Over the last two years, the average weekly traded volume for on-the-run CDX IG index has ranged from 60-80 billion notional. In terms of the equity-equivalent risk, this is similar to a 6-8 billion notional on the SPX index, or a 120-160 million vega notional. The CDX IG index is cleared and trades on the screen, which makes it a low entry barrier product for new institutional participants. There are other synthetic credit indices in US and Europe which trade very actively as well.

- In this note, we look at the attractiveness of relative value trading of CDX IG index against variance swaps, forward variance, and related equity portfolio products. We examine the historical stability of the relationship, construct sample trades, review the risks of the trade, and find that it can be an attractive area for relative value trading. We present a simplistic simulation trading strategy that identifies 17 trades in the last 6 years, which provide an average P&L of 600K each, on 100mm CDX IG index notional and the corresponding model adjusted variance swap notional. Even if one does not wish to trade the construct, the signals from one market can help one make more informed decisions about another market.

Index Level Cross-Asset Opportunities Emerge

- Cross-asset relative value opportunities have grown in prominence in recent years.
- While Capital Structure Arbitrage strategies have been employed for years on a "Micro" level (Stock Option vs. company bond or CDS), the growth in liquidity of index derivative instruments in the equity and credit markets now allows for efficient index-level positioning between the two markets.
- In this note, we provide a methodology for trading arguably the most liquid index CDS instrument, the CDX IG index, against one of the most liquid equity volatility products, SPX variance swaps.

Considering Equity Implied Volatility Against CDX

- In evaluating a Relative Value opportunities between two asset classes, it is important to confirm that the following properties hold true:
  - There is reason to believe (fundamental and historical) that the securities at hand should be linked.
  - The relationship between the securities at hand (the "Beta") is and has been reasonably stable.
- Our experience with financial markets suggests that there is a link between credit spreads and equity implied volatility. Both metrics represent "risk premia" that are charged to take on financial market risk (CDX for credit risk; equity implied volatility for equity protection).
- A cursory glance at Charts 1 and 2 suggests that the first consideration holds true. In the remainder of this piece, we seek to confirm these points, and establish a profitable framework for trading equity implied volatility against CDX IG.

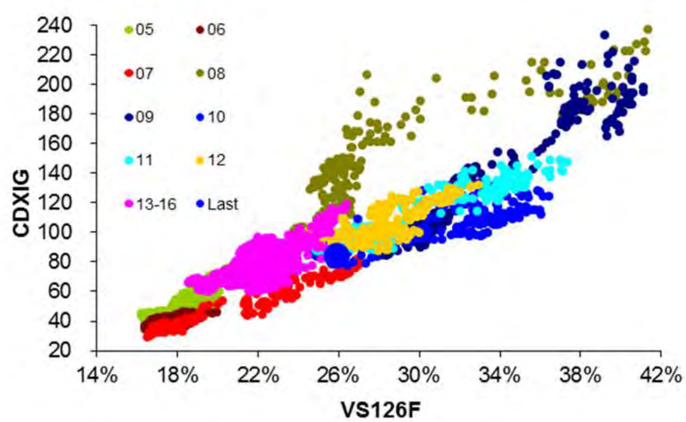
Equity Volatility via Forward Variance Swaps

- For exposure to equity implied volatility, we use forward-starting variance swaps. Since it can be replicated as a simple spread of 2 variance swaps, it is considered to be the most liquid structure to access the medium-term implied volatility of the S&P500.
- Unlike delta-hedged options or spot-starting variance swaps, forward-starting variance swaps allow one to take a direct position in implied volatility without exposure to the implied to realized risk premia.
- Our framework uses 6M-starting 12M variance (6M12M) to strike a balance between liquidity and stability considerations. This forward start / maturity combination results in a reasonably stable Beta (see Chart 3), while remaining within the liquidity of each listed maturities
- Chart 4 shows that the CDX IG/variance swap relationship has been relatively stable at longer-dated maturities (higher R^2 for longer-dated maturities).

Chart 1: CDX vs. SPX Variance Historical Levels

Source: BNP Paribas

Chart 2: SPX 6m-Starting 12m Variance Swap Strike vs. CDXIG



Source: BNP Paribas

Chart 3: 5Y CDX Beta to SPX Variance, By Maturity

Source: BNP Paribas. Beta represents the slope coefficient of a regression between 5Y CDX IG and the volatility level of the respective Variance swap maturity (in months)

The Stability of the CDX-Variance Relationship

Linking CDX and Volatility levels

- To analyze the relationship between CDX IG and SPX variance, we have plotted the rolling regression beta and the rolling R^2 between the two parameters in Chart 5.
- Specifically, it plots the 12M rolling parameters that solve the following equation

IG = **Beta** * Volatility + **Constant**

- where *Volatility* is the strike of the 6M12M SPX variance swaps in volatility points (e.g. 25), while *IG* is the spread of the 5y IG CDX index in bp (e.g. 75).
- As seen in Chart 5, the rolling beta has been in a relatively stable range when R^2 has been significantly high. In the last year however, the relationship has not been as stable, as the CDX IG index has been driven more by oil prices, while oil price volatility has less impact on SPX variance swap.

Historical stability of the relationship

- In addition to analyzing the beta, we look at a time series of the regression residuals since 2010 (Chart 6). The regression residual is the difference between the actual IG level and the IG level inferred by the volatility level.
- We highlight historical residuals using both 1) a rolling regression beta (12M); and 2) a regression over the entire post-crisis period (i.e. since 2010; we refer to this as the "Constant Beta Residual"). Both sets of residuals suggest mean-reverting behavior, as seen in Chart 6.

Statistics on Residuals Since 2010

	Avg	Median	Stdev	Max	Min
Rolling Beta Res	0.9	-0.3	7.9	30.7	-17.8
Constant Beta Res	0.7	0.5	9.0	25.7	-22.3

- A regression on data since 2010 gives

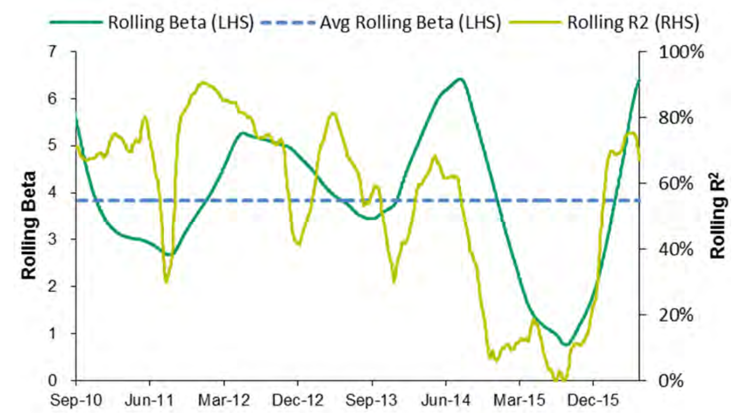
IG = 3.98 * Volatility - 0.1

- The reasonably stable beta and mean-reverting residuals, even in tumultuous markets (e.g. in August 2011), suggest that the relationship between CDX IG and variance swap may provide attractive relative value trading opportunities.
- If we look at the beta and residuals in the late '08 / early '09 and late '15 / early '16 periods, we will see that the relationship breaks down, as the CDX IG widened significantly, relative to its beta-predicted levels. In both periods, the behavior was mainly driven by idiosyncratic sector concerns (i.e. financials and energy respectively).
- Hence, in addition to the empirical analysis, we also need to understand what other macro and technical factors are impacting the credit and equity vol markets.
- In our opinion, combining the empirical approach with the fundamental knowledge of macro and technical drivers in both markets can lead to profitable trade opportunities.

Chart 4: CDX regression R^2 since 2010

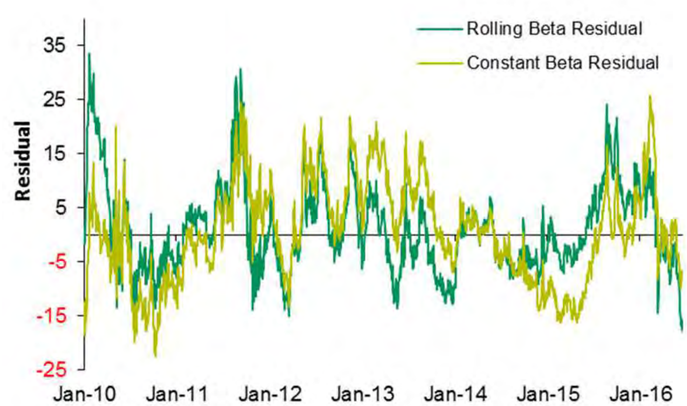
Source: BNP Paribas. The R^2 is from the regression between CDX IG and the corresponding variance swaps.

Chart 5: Rolling 12M Beta and R^2 (IG vs. Variance)



Source: BNP Paribas. Beta is computed on volatility level of 6M12M variance swap against CDX IG level, and compares a volatility level vs. a CDX spread in bps (e.g. 80, not 0.0080)

Chart 6: CDX regressions residuals since 2010



Source: BNP Paribas. Rolling Beta Residual is based off of trailing 12M regression. Constant beta regression equation described above

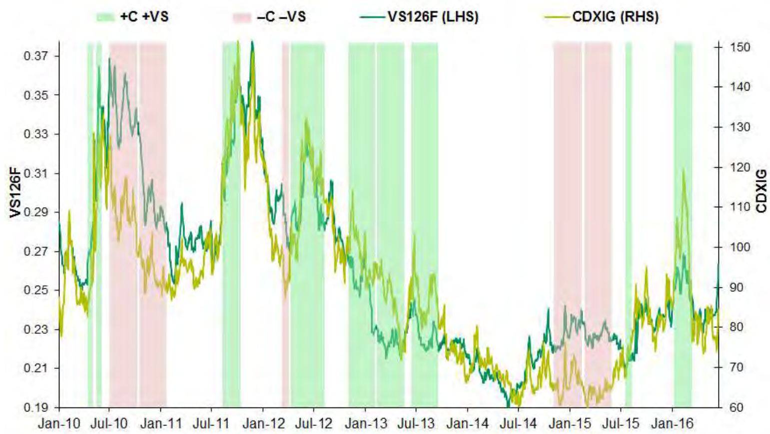
A Simplistic Trading Strategy to Consider

- We employ a trading strategy that buys IG CDX protection and shorts SPX variance swaps when IG appears rich, relative to variance (and vice versa), using the regression function discussed on the previous page (Constant Beta), and generated trading signals via the residual of the IG vs. volatility regression.
- We enter into a long-credit (selling IG protection) and long-forward starting variance swap trade when the Z-score of the regression residual hits 1.5 standard deviations above the regression.
- Similarly, we enter a short-credit (long IG protection) and short-forward starting variance swap trade when the residual breached -1.5 standard deviations.
- We also exit the trade once the residuals move to 0.
- For trade sizing, we took a $100mm notional position in the CDX IG index against a roughly $175K vega notional position in the variance swap. Please note that the variance swap notional would be different for each trade, and we used the entry level of variance swap to determine the notional. We calculated the sizes by using the Beta from before, assuming a duration of 4.75 for CDX IG index.
- As a rule of thumb, a one standard deviation move in the residual (8bp) results in a P&L change of roughly $380,000 in either direction.

Trading Strategy P&L Analysis and Considerations

- Chart 7 gives an overview of the strategy positions since mid-2009. Of 17 trades, 10 trades were long credit (sell CDX protection, long variance swap) and 7 were short credit (buy CDX protection, short variance swap).
- The average P&L of each trade was $658K and the average drawdown on any given trade was -$110K. Note that drawdown refers to the maximum negative P&L (on a mark-to-market basis) during the life of a particular trade.
- The final P&L calculation of each trade incorporates both “carry” (credit coupon payments) and “roll down” (change in parameter level due to moving to a shorter-dated maturity). These costs must be accounted for in the final P&L, and can deviate from the expected P&L suggested by the residuals (especially if the trade is held for extended periods of time).
- We have not included bid-offer in our P&L calculations. We estimate total bid-offer costs on each trade to be approximately $115K (round trip). We calculate this by assuming that the CDX leg costs 0.5bp roundtrip (4.75bp on notional, with duration), which costs $24K on $100 million notional. For variance swap, we assume a round trip bid/offer of 0.5 volatility points (which costs $90K).
- Please note that the trades entered and exited in this simulation strategy are very simplistic. For example, trade #6 in the simulation (see Table 1 below) maintained a short-credit position during a CDX roll period, which any informed CDX market participant would not like to maintain. To some extent, it explains the negative P&L in that trade.

Chart 7: Simulated Strategy Positioning



Source: BNP Paribas

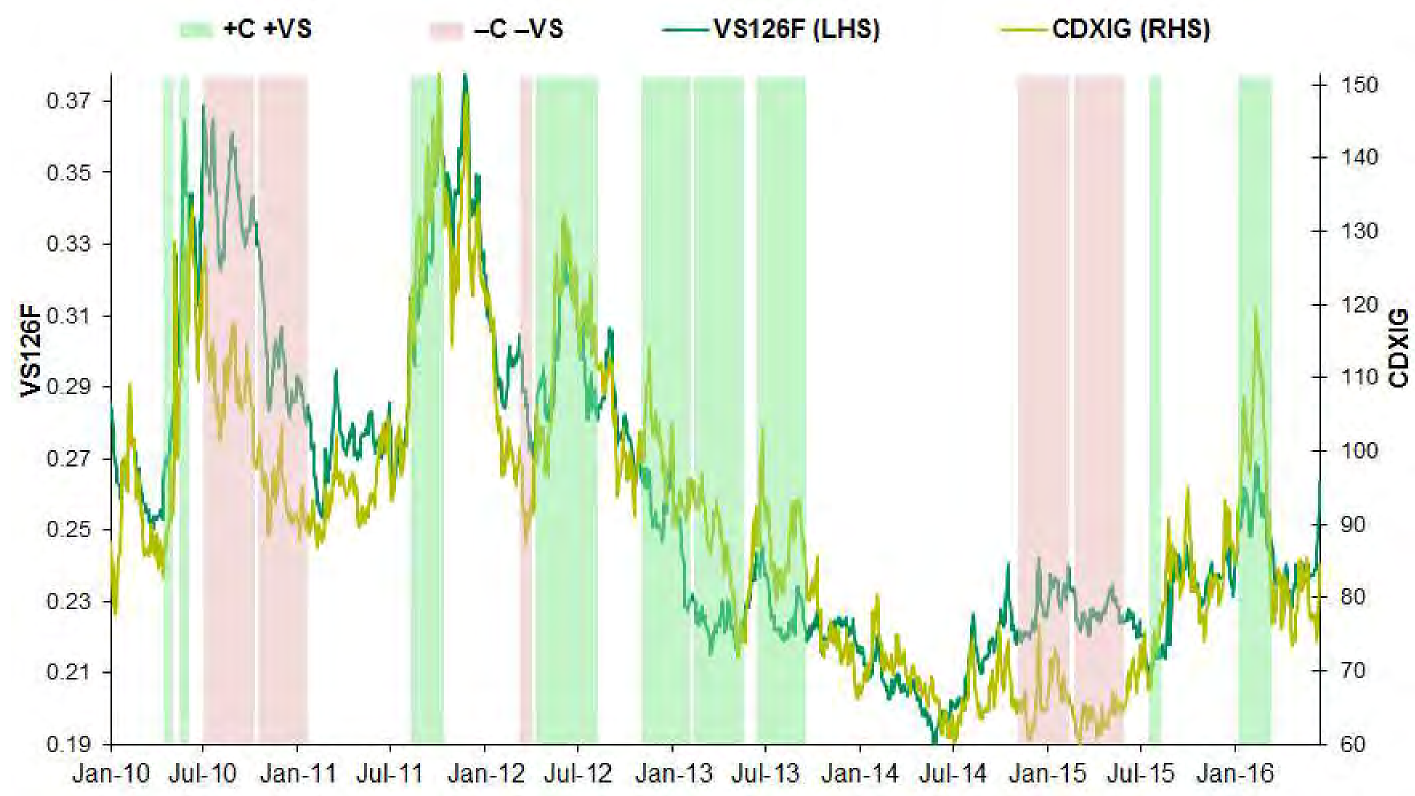
Other Notable Considerations

- Opportunities often arise due to the CDX IG “skew”, which represents the spread between the index and the average credit spread of its underlying constituents. The skew tends to trade in a narrow range most of the time (-6 to +6 bps), but can deviate significantly at times due to the make up of the market participants (the CDX IG index is a preferred instrument for Macro Credit investors, who often trade in and out quickly as they switch from risk-on to risk-off positioning). For example, the skew reached -17bp in Jan/Feb 2016.

Risks

- The trading strategy presented here is rather simplistic, and serves only to highlight that the relative value between CDX IG and equity vol presents attractive opportunities when there are significant dislocations in both markets.
- In our opinion, it is difficult to completely automate this strategy (as seen by some of the large drawdowns in Table 1). For each trade opportunity, it is imperative to analyze the macro and technical factors that are causing those dislocations.
- A particular trade in the trading strategy can lose money should the residuals move against the trade after trade initiation.
- Additionally, the investor will be further at risk if the relationship between CDX IG and variance swap moves into a different regime (i.e. a new relative relationship).
- Variance swaps have a convex exposure to volatility, while our regression function analyzes CDX vs variance swaps using a linear function. If volatility levels change considerably, the P&L of a relative value trade can deviate significantly from what the residual might suggest.

Chart 7: IG CDX and Variance Swap History and simulated strategy positioning



Source: BNP Paribas.

Table 1: Details of Simulated Trading Strategy

Trade No.	Enter Trade Date	Exit Trade Date	Duration (Days)	Residual @ Initiation	Trade Type	CDX Entry Level	CDX Exit Level	Varswap Entry Level	Varswap Exit Level	Total P&L	Drawdown	IG Leg P&L	VS Leg P&L	Trade Notional (VS)
1	02-Jul-09	27-Jul-09	25	18	+C +VS	138	115	31.6	30.4	920,893	-91,619	1,108,020	-187,127	2,632
2	15-Sep-09	28-Oct-09	43	-13	-C -VS	104	118	30.3	29.3	629,366	-202,595	468,678	160,688	2,693
3	16-Dec-09	21-Jan-10	36	-14	-C -VS	90	91	29.4	25.3	594,124	-88,592	-68,320	662,444	2,924
4	06-May-10	10-May-10	4	20	+C +VS	129	99	30.2	31.1	1,551,742	0	1,382,772	168,970	2,870
5	09-Jun-10	17-Jun-10	8	14	+C +VS	132	114	33.0	31.8	658,426	0	861,500	-203,075	2,583
6	09-Jul-10	12-Oct-10	95	-14	-C -VS	110	92	34.7	30.9	-497,426	-433,613	-1,103,011	605,585	2,464
7	13-Oct-10	14-Jan-11	93	-20	-C -VS	96	83	32.5	25.6	283,369	-53,818	-838,006	1,121,374	2,796
8	12-Aug-11	27-Oct-11	76	13	+C +VS	116	109	29.8	32.2	942,851	-284,930	525,889	416,962	2,859
9	20-Mar-12	05-Apr-12	16	-13	-C -VS	88	97	28.4	26.7	715,578	0	405,177	310,400	3,240
10	14-May-12	15-Aug-12	93	16	+C +VS	115	103	28.7	25.9	350,921	-275,086	826,687	-475,767	3,109
11	08-Nov-12	11-Feb-13	95	14	+C +VS	105	90	26.3	20.4	25,428	-402,068	970,270	-944,841	3,439
12	12-Feb-13	07-May-13	84	15	+C +VS	88	60	22.5	19.3	931,659	-509,181	1,447,329	-515,670	3,833
13	20-Jun-13	23-Sep-13	95	16	+C +VS	93	72	23.5	20.2	694,229	-110,465	1,239,405	-545,176	3,744
14	25-Nov-14	26-Feb-15	93	-14	-C -VS	61	61	21.6	19.6	217,762	-132,177	-130,694	348,455	4,180
15	27-Feb-15	02-Jun-15	95	-15	-C -VS	61	63	22.1	19.6	355,260	-110,507	-73,924	429,183	4,099
16	25-Aug-15	11-Sep-15	17	17	+C +VS	87	80	21.4	23.2	733,963	0	384,385	349,578	4,234
17	15-Jan-16	10-Mar-16	55	15	+C +VS	110	91	25.6	22.3	456,178	-498,171	1,020,886	-564,708	3,527
Average			58.7			108	95	29.3	26.9	**600,089**	**-188,613**	**495,708**	**44,213**	**3,014**
Median			76.0			105	97	29.8	26.7	**658,426**	**-110,465**	**525,889**	**160,688**	**2,870**

Source: BNP Paribas Past performance is not indicative of future performance, which may be better or worse than prior results.

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