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Credit Index Options

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CDS index options as macro hedges or directional overlays

Extensive spread volatility during the credit and more recently sovereign crisis has highlighted the importance of tail risk scenarios, in our view. As a result, options referencing CDS indices have been used extensively to hedge extreme spread moves. At the same time, investors have also used such options to customize their spread and volatility view. In this publication, we describe the key payoff and pricing attributes of CDS index options, with special attention on liquidity and market conventions.

Trading volumes highest in short-dated options

Although the market for single-name options has never truly developed, index options on 5y credit indices are liquid. Today, quotes for options on iTraxx Main, Crossover, FinSen and SovX WE, as well as CDX IG and HY, are quoted. In general, liquidity today is focused on short-dated options (< 9 months).

The building blocks: CDS index payer and receiver options

CDS index options provide investors with a right (but no obligation) to buy or sell protection on the index at a future date at some specified spread (known as the option's strike). The two fundamental types of options are payers (or puts, providing the right to buy protection) and receivers (or calls, providing the right to sell protection). Market convention is to quote options at an upfront premium to be paid by the option buyer (Chart 1). Investors can construct other structures using combinations of payers and receivers depending on their specific view or need. Likewise, credit options can also be traded against other products, including indices, single-names, index tranches, or equity options.

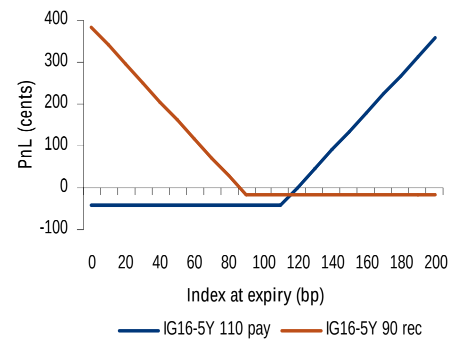
Credit Volatility: the ins and the outs

The price of a given option is affected by various factors, including the index spread, strike, time to maturity and rates. With all of these typically pre-specified, the option's value depends on its *implied volatility* (typically inferred from the option premium using standard pricing models). We can also compute realized or historical volatility using actual market closes. Due to a bias towards buyers of credit options, implied volatility in credit tends to trade at a premium to historical. However, during periods of significant distress we have seen implied vol trading inside realised.

Risk metrics and modelling

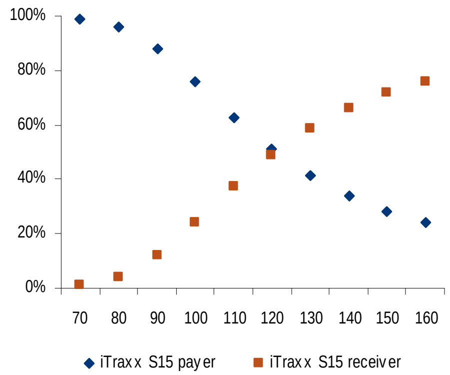
In contrast to the index, options provide exposure to risks such as convexity and volatility (Chart 2). We define the key risk terminology used in the options world, also describing how these are affected as market parameters change. In conjunction with this, we provide a summary of how index options are modelled, including how models incorporate the options' *no-knockout* feature.

Chart 1: CDX IG Sep'11 options: expiry payoffs



Source: BofA Merrill Lynch Global Research; As of 27th June 2011, ref=100

Chart 2: ITX S15 Sep'11 options: Deltas



Source: BofA Merrill Lynch Global Research; As of 23rd June 2011, ref 109.25

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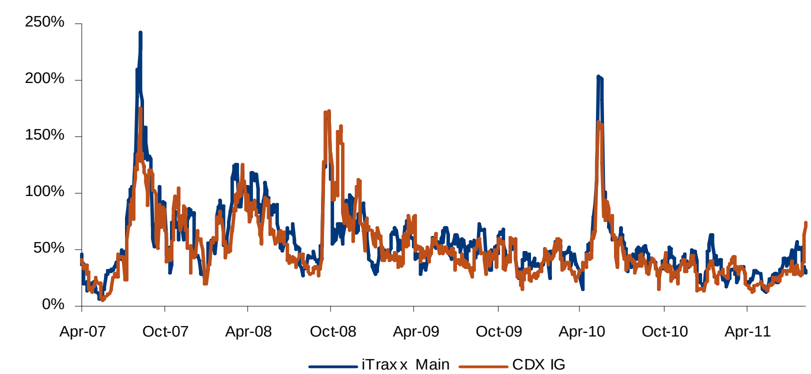
Credit Index Options – A Guide

Extensive spread volatility during the credit and more recently sovereign crisis has highlighted the importance of tail risk scenarios. From the acceleration of credit losses post Lehman to the Greek debt-fuelled widening seen in 2010 and 2011, realised volatility in CDS indices have surged (Chart 3). Given the experiences of the last 4 years, credit index options can help protect against downside risks, as well as provide efficient macro overlays to trade general spread direction and/or volatility. In this publication, we describe the key payoff and pricing attributes of basic index options, discuss liquidity and market conventions, and we explore the modelling of option-based products.[1]

Chart 3: 1month realised volatility for the on-the-run EU and US credit indices



Source: BofA Merrill Lynch Global Research; We ignore spread moves owing to index rolls for the above analysis; As of 10th Aug 2011

A brief history lesson on credit options

The market for CDS options is nothing new. In the early days of the CDS market, there was an attempt to provide liquidity on certain single-name CDS options; however this was largely unsuccessful with muted investor interest. It was only when CDS index products were launched that volumes truly began to grow.

Chart 4: iTraxx Crossover on-the-run spreads reached a low ~ 170bp in Feb 2007

Source: BofA Merrill Lynch Global Research, Markit Partners; As of 10th Aug 2011

Particularly when the iTraxx Crossover index in Europe flirted with its historic lows in early 2007 (Chart 4), dealers and investors that were uncomfortable with HY valuations searched for a downside hedge. As a result, demand for Crossover options increased dramatically. The underperformance of financial names in 2007-H2 as the sub-prime crisis took hold and the corresponding increase in spread volatility for high-grade names saw the start of a shift in options liquidity towards iTraxx Main. Today, index options in Main are more liquid than those on iTraxx Crossover, FinSen and SovX. However, 2-way markets are readily available across these credit indices from most dealers.

Naturally, the success of index options in Europe fuelled interest in similar products in CDX indices in the US. Especially in 2007-8, liquidity in CDX IG options grew extensively, with a pickup in HY options as well. Currently, on the 5y CDX/iTraxx indices, options with maturities up to 9 months are available with liquidity concentrated on the shorter end. In general, as more indices have found liquidity, investors have looked for ways to express index views via options. Since mid-2010 market makers have started trading also options referenced to SovX WE and Financial Senior credit indices as more investors wanted to hedge their portfolios against sovereign and senior financial risk.

[1] We assume that readers are aware of the basic workings, conventions and liquidity of the underlying CDS indices. If not, please contact us for a copy of our Credit Derivatives Primer

Option Structures: Payers and Receivers

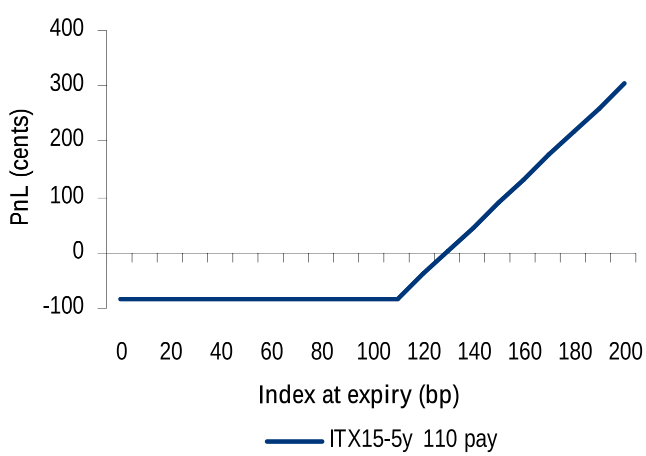
In the credit world, there are two vanilla options along the same lines as the naming convention adopted in the rates market:

i) ***Payer Option:*** the holder has the right (but not the obligation) to **buy** protection on the reference index at a pre-specified spread on a given future date. This is like a put option on the market.

ii) ***Receiver Option:*** the holder has the right (but not the obligation) to **sell** protection on the reference index at a pre-specified spread on a given future date. This is like a call option on the market.

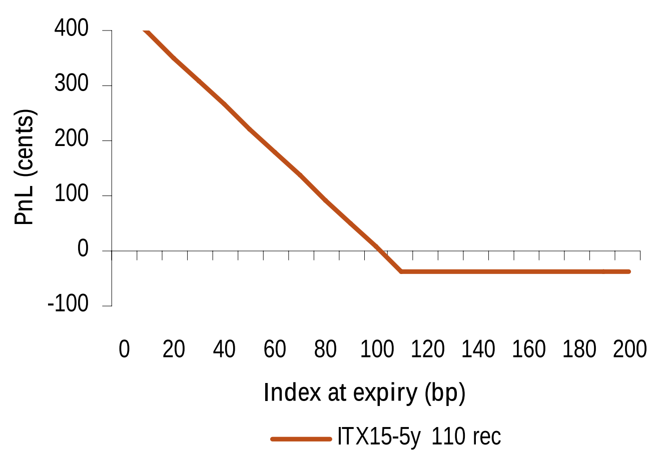
The pre-specified spread referred to above is also known as the option's *strike*, whereas the future date on which protection may be bought/sold is called the option *expiry*. Assuming the holder of the option behaves rationally, he/she will only exercise their payer (receiver) if the reference index spread is above (below) the strike on the date that the option expires. Due to the asymmetric nature of this payoff (i.e. holder only exercises when the option is 'in-the-money'), the option buyer is required to make an upfront payment to the seller at trade inception. Inclusive of this initial option cost[2], the payoff of long payer/receiver option at expiry is as follows (Charts 5 and 6):

Chart 5: Long Payer Swaption Payoff (with upfront cost of 83c*)



Source: BofA Merrill Lynch Global Research; * = 83c was rough cost of a 110bp struck iTraxx Main September'11 payer; as of 27th June; Assume a fixed forward risky duration for the index; ref=115

Chart 6: Long Receiver Swaption Payoff (with upfront cost of 36c*)



Source: BofA Merrill Lynch Global Research; * = 36c was rough cost of a 110bp struck iTraxx Main September'11 receiver as of 27th June; Assume a fixed forward risky duration for the index; ref=115

Credit index options are quoted in cents upfront. So if an investor were to purchase a payer option on a given index at 100c on a $100mm notional, he/she would be required to pay $1mm upfront to the option seller (simply $100mm * 1%). In addition, options on CDS indices only trade in *European* form. In other words, the option holder can only take the decision whether to exercise or not on the expiry date. Clearly, should the investor want to realize any mark-to-market gains on the trade ahead of expiry they may do so only by exiting their position.

We also need to consider how losses on the underlying portfolio are treated at the option level. Although we discuss this in more detail later in the report, it is worth distinguishing at an early stage between conventions for single-name and index-based option contracts. For single-name options, should the Reference Entity

[2] We exclude the effect of defaults for now.

default before the option reaches expiry, the historical convention has been to terminate the option contract. In other words, options on single name CDS provide exposure to MtM moves in credit spreads, but "knock out" in the event of default. Hence, single name options can be used to hedge spread movements but not default risks.

Table 1: Credit Index Options - Back to basics

	Payer		Receiver	
	Buyer	Seller	Buyer	Seller
Option Type	Buy the right to buy protection at expiry	Sell the right to buy protection at expiry	Buy the right to sell protection at expiry	Sell the right to sell protection at expiry
Upfront Premium	Paid	Received	Paid	Received
Spread view	Bearish	Stable/Bullish	Bullish	Stable/Bearish
Spread Volatility view	Long	Short	Long	Short
In-the-Money if	Spreads widen above strike	Spreads widen above strike	Spreads tighten below strike	Spreads tighten below strike
If exercised	Buy index protection at strike (lower than market level)	Sell index protection at strike (lower than market level)	Sell index protection at strike (higher than market level)	Buy index protection at strike (higher than market level)
Positive MtM	Spreads widening	Spreads tightening	Spreads tightening	Spreads widening
Negative MtM	Spreads tightening	Spreads widening	Spreads widening	Spreads tightening

Source: BofA Merrill Lynch Global Research

However, in the index world, once the loss amount has been settled (typically through a CDS auction) and the defaulted name is removed from the pool, the market continues to trade the index, albeit on a new version to reflect the reduced number of names. Thus, options on the index have also been designed *not* to terminate upon a default – this is referred to in the market as the 'no-knockout' feature.

Table 2: Sensitivity of Credit Index Options

	Effect on Option price if Factor increases	
Option Pricing Factors	Option Buyer	Option Seller
Underlying	+	-
Strike	-	+
Time to expiration	+	-
Volatility	+	-
Rates	-	+

Source: BofA Merrill Lynch Global Research

In general, the cost of an option will depend on a number of different factors:[3]

- **Index spread:** Since payers (receivers) are options to buy (sell) protection at a future date, a widening in the index today, ceteris paribus, would increase (decrease) the option premium.
- **Strike spread:** The payer (receiver) option will be exercised if the index on the option expiry is trading wider (tighter) than the pre-determined strike. So, payer (receiver) options struck at a higher spread will be cheaper (more expensive).
- **Time:** Longer-dated options have a higher probability that the option will expire 'in-the-money'. Thus, the premium of both payer and receiver options (all else constant) increases as we increase the time to expiry.
- **Rates:** Higher discount rates reduce the present value of the option payoff at maturity, and thus the upfront premium.
- **Volatility:** More volatile moves in the underlying index also increase the probability that the option will expire in-the-money, hence pushing the cost of both payer and receiver options higher.

[3] Later in the report, we define and describe the sensitivity of option premiums to each of these variables.

Liquidity and Conventions

Table 3: Credit Index options Markets...

Index	Bid/Offer	Standard Strikes every...
iTraxx Main	6c	10bp
Crossover	10c	25bp
Financial Snr	12c	10bp
SovX WE	16c	10bp
CDX IG	6c	10bp
CDX HY	30c	1pt

Source: BofA Merrill Lynch Global Research; Bid/Offer and standardised strikes as of 12th August 2011 for Sep'11 expiry contracts; During less distressed markets bid/offer is usually tighter

Today, index options referencing iTraxx Main and CDX IG are the most liquid, followed by markets on iTraxx Crossover, Financial Senior, SovX WE and CDX HY. Standard strikes for the iTraxx Main/CDX IG and also FinSen/SovX are usually set 10bp apart, with a typical bid/offer premium of around 6c for the high-grade corporate index referenced options. In the high-yield space, transaction costs are normally higher for Crossover and CDX HY options, largely due to the fact that indices are trading at wider bid/offer and spread levels (Table 3).

Notably, index options only on the underlying 5y maturity are available at the present time. Volumes are concentrated in options with quarterly expiries, although quotes are also provided to alternative maturities. For instance, today the most liquid index options are those on August, September and December 2011 expiry, although levels even for Mar'12 (for some indices) are also available. The standard expiry dates have now converged and do not anymore vary by region. The expiry date is always the 3rd Wednesday of the expiration month, for all European and US credit index options.

Types of investors

In terms of the user base, index option clients can be bracketed into three main categories, as listed below:

1. ***Spread-hedgers:*** Generically buyers of payer options to hedge widening of spreads. Includes generic credit portfolio managers, CVA and loan desks, amongst other types of investors.

2. ***Convexity-hedgers:*** Investors using options to hedge negative convexity to spread moves. Includes correlation and ABS desks/clients.

3. ***Volatility/Direction players:*** Investors taking a view on the volatility and/or direction of the underlying index, often using more than one option (including those from other asset classes).

Thinking forward

Since the index option is assessing the value of entering into an index position at some future date, investors need to be aware of the *forward* spread on the index. In this context, the forward spread refers to the spread of an index contract from option expiry to index maturity. In fact, from a modelling perspective, it is the forward spread (rather than the current or spot index quote) that is relevant.[4] Thankfully, calculation of the forward spread is relatively straightforward:

$$IndexForward = \frac{IEL(T) - IEL(T_e)}{RBPV(T) - RBPV(T_e)} \quad (1)$$

where:

- IEL(t) is Index Expected Loss to time t
- RBPV(t) is the risky duration[5] (or risky basis point value) of the index to time t

[4] This is discussed further in our report in the chapter on modelling, where we use a variation of the forward.

[5] For those unfamiliar with this term, the risky BPV indicates the mark-to-market in cents were a CDS trading at par to move by 1bp. The risky BPV measure is thus used to convert between running and upfront quoting conventions for CDS-based products.

- t=T is the maturity of the underlying index
- $t=T_e$ is the option expiry

The numerator in equation 1 above describes the total loss projected by the index between the option expiry T_e and the index maturity T. This is converted into a spread by dividing through by the risky annuity of the index between these same two dates – this is represented in the denominator. This in turn is known as the forward risky duration (or the forward risky BPV). In the special case where the index curve is completely flat, the forward spread of the index will be the same as the spot index spread.

Had an investor bought such forward protection (assuming the product was available), he/she would not be required to pay any premium to the forward start date, but would also *not* benefit from defaults occurring before that same day. However, in the index options world, an investor that eventually exercises a payer option *does* benefit from defaults in between option inception (i.e. t=0) and expiry (i.e. $t=T_e$). Hence, the index forward spread as calculated in equation 1 needs to be adjusted for the value of losses between now and the option expiry. In essence, we simply add back the index expected losses to option expiry.

$$AdjustedIndexForward = \frac{IEL(T)}{RBPV(T) - RBPV(T_e)} \qquad (2)$$

As mentioned earlier, this no-knockout feature is a direct result of the way in which the index market operates. Since the index option is based on the original index version, any defaults on the underlying need to be reflected by payouts/losses on any **exercised** options. Consider the following example:

- Client A buys a CDX IG payer option to protect against spread widening.
- 2 months prior to expiry, credit ABC in the underlying portfolio files for Chapter 11 and a Credit Event is declared.
- 1 month prior to expiry, the defaulted name recovers 40% in a CDS auction. The CDX IG index begins trading ex-ABC the day after the auction is held (under version V2).
- On the expiry day, the option is well in-the-money and Client A exercises.
- Client A enters into a long protection position in the V2 index at the strike spread.[6] He also receives cash representing the value of ABC's loss.[7] Please refer to Appendix #4 for more detail.

Crucially, while the index notional related to ABC is settled on the day of the auction, the cash settlement for the option does not take place till the expiry date.

[6] Note that there will be some accrued coupon on the index position on any exercised option due to i) the option expiry not falling on an index coupon date and/or; b) defaults in the index prior to expiry.

[7] In this example, the cash received is IndexNotional * (1 – 40%) * ABC_IndexWeight

Understanding a Bloomberg run

Chart 7: Example Run: CDX IG Series 16 options

GRAB CurncyMSG

1<GO>DEL 2<GO>REPLY 3<GO>FWD 11<GO>NEXT 12<GO>PREV 99<GO>OPTIONS

6/28 12:39:47 Page 1 / 2

From: AMIT AGRAWAL (MERRILL LYNCH) 1-646-855-6745

Subject: IG16 Sep Options Ref 100 -open-

91)☆ 92) Move 94) Tags

Credit Index Options M:917 355 8514

Ref:100.0 Fwd:105.2 Fwd Bpv:4.5 Expiry:21-Sep-11

Strike	Sep-Rec	Delta	Sep-Pay	Delta	Vol	Gamma
80	3.00 / 7.00	9%	116.75 / 120.75	91%	47%	0.7%
85	7.25 / 11.25	15%	98.25 / 102.25	85%	48%	1.0%
90	13.50 / 17.50	22%	82.00 / 86.00	78%	49%	1.2%
95	21.75 / 25.75	30%	67.50 / 71.50	70%	50%	1.4%
100	32.25 / 36.25	37%	55.50 / 59.50	63%	51%	1.5%
105	45.50 / 49.50	45%	46.50 / 50.50	55%	53%	1.5%
110	59.75 / 63.75	52%	38.25 / 42.25	48%	55%	1.4%
115	75.50 / 79.50	58%	32.00 / 36.00	42%	57%	1.4%
120	92.50 / 96.50	63%	27.00 / 31.00	37%	58%	1.3%
125	110.50 / 114.50	68%	22.75 / 26.75	32%	60%	1.2%
130	129.00 / 133.00	72%	19.50 / 23.50	28%	62%	1.1%
140	167.75 / 171.75	78%	14.50 / 18.50	22%	65%	0.9%

Australia 61 2 9777 8600 Brazil 5511 3048 4500 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
Japan 81 3 3201 8900 Singapore 65 6212 1000 U.S. 1 212 318 2000 Copyright 2011 Bloomberg Finance L.P.
SN 642494 0 28-Jun-11 16:37:22 GMT+1:00

Source: BofA Merrill Lynch Global Research; Prices shown as of opening markets on 28th June 2011

As an example, we display a run for CDX IG options above to September 2011 expiry.

A few basic comments can be made:

- The option quotes are valid assuming a specific spread for the index. In our example, the reference index spread for CDX IG S16 is 100bp. In the case of CDX HY options, the index ref would be in price terms, consistent with quotation of the underlying.
- **The option quote assumes that the client "exchanges the option's delta" with the dealer** (see Example #1 below). At a basic level, the delta is the amount of index hedge required to make the option trade neutral to (small) spread movements. The delta (or sensitivity of the option prices to index moves) will differ across options for various reasons as explained later in the report.
- The forward spread for a longer expiry is higher than for a short one and both are higher than the index ref. This is to be expected given that in the calculation of the (adjusted) forward, we are using the forward duration (smaller for longer-dated forwards) to convert the index EL into a spread, as per equation 2.
- **Longer-dated options are more expensive**, as noted previously, as are payers (receivers) with lower (higher) strikes.

Below, we provide a couple of examples of **hypothetical** trades, which can provide more clarity on expiry breakevens and how to look at defaults.

Example #1: Client concerned about spread widening on macro outlook

- Client wants to buy \$100mm September IG payer at a strike of 120bp.
- Option as per above run is offered at 31c. However, this assumes that the Client also sells \$37mm of index protection (i.e. \$100mm * 37% delta).

- However, Client wants to buy protection outright without the index hedge (i.e. trade *no-delta*). This would leave the dealer needing to buy index protection to hedge his short option position.
- Suppose Dealer can only buy IG16 index protection at 100.5bp (vs. original option ref of 100bp). Dealer increases the offer to ~32c to reflect the additional cost of hedging the spread risk. [8]
- At expiry, Client exercises the option if the index closes above 120bp. If the index closes below 120bp, Client does not exercise and the option expires worthless.
- Use the forward risky BPV of the index to convert the upfront outlay today into a breakeven spread for the index at expiry.

  → Payer Breakeven[9] = Option Strike + (Option Premium / Forward BPV)

  → Payer Breakeven = 120 + (32/4.5) ~ 127.1bp

  → Client expected to break-even if the index closes > 127.1bp at expiry[10]

  Thus, overall, the Client is expected to make money if the index closes above 127.1bp at expiry.

Example #2: Client bullish on European HY spreads

- Client wants to buy €100mm September iTraxx XO S15 receiver at strike of 400bp.
- Inclusive of bid/offer, the client buys the option for 75c *no-delta* (offered at a price of 72c, we assume 3c delta cost).
- Breakeven close of index at expiry is 380bp (as shown below)

  → Receiver Breakeven = Option Strike - (Option Premium / Forward BPV)

  → Receiver Breakeven = 400 - (75/3.75) = 380bp
- Entity XYZ in XO S15 defaults before expiry, recovering 0% in CDS auction. Since XO S15 is a 40-name basket, entity XYZ has a 2.5% weight (and loss).
- Index ex-XYZ (V2) closes at 350bp at expiry – ***should the Client exercise***?
- **NO – Client's receiver is on the ORIGINAL index** (i.e. with XYZ in the pool). By exercising client would enter into a position selling V2 index protection at 400bp (booking a MtM gain), but would have to pay out €2.5mm (or 2.5% notional) for the default of XYZ.

  → Effective V1 Index spread = V2 Index + (SingleNameLoss / New DV01)

  → Effective V1 Index spread = 350 + (250 / 3.75) ~ 416.67bp[11]

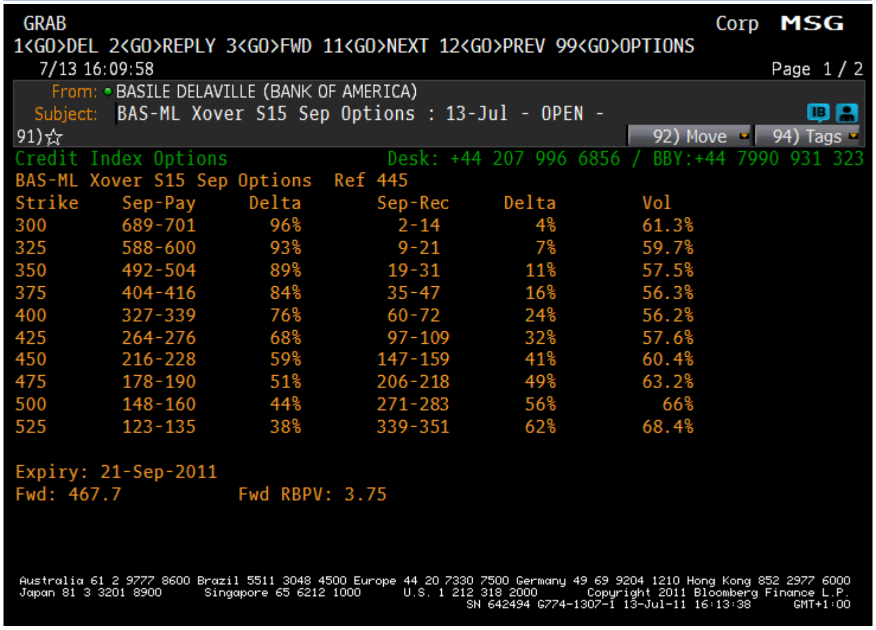
[8] The additional cost will be approximately equal to (100.5bp – 100bp) * FwdDV01 * OptionDelta ~ 0.83c here

[9] Likewise Receiver Breakeven = Option Strike – (Option Premium / Forward BPV)

[10] Note this is a break-even only for today – if the index does not move over time, the index breakeven spread will be higher since the duration of the forward will have fallen.

[11] For simplicity in this example, we assume that the index DV01 at expiry is the same as the original forward DV01 at option inception. In practice, this is unlikely to be the case.

Chart 8: Example Run: iTraxx Crossover Series 15 options


GRAB Corp MSG
1<GO>DEL 2<GO>REPLY 3<GO>FWD 11<GO>NEXT 12<GO>PREV 99<GO>OPTIONS
7/13 16:09:58 Page 1 / 2
From: BASILE DELAVILLE (BANK OF AMERICA)
Subject: BAS-ML Xover S15 Sep Options : 13-Jul - OPEN -
91) 92) Move 94) Tags
Credit Index Options Desk: +44 207 996 6856 / BBY:+44 7990 931 323
BAS-ML Xover S15 Sep Options Ref 445

Strike	Sep-Pay	Delta	Sep-Rec	Delta	Vol
300	689-701	96%	2-14	4%	61.3%
325	588-600	93%	9-21	7%	59.7%
350	492-504	89%	19-31	11%	57.5%
375	404-416	84%	35-47	16%	56.3%
400	327-339	76%	60-72	24%	56.2%
425	264-276	68%	97-109	32%	57.6%
450	216-228	59%	147-159	41%	60.4%
475	178-190	51%	206-218	49%	63.2%
500	148-160	44%	271-283	56%	66%
525	123-135	38%	339-351	62%	68.4%

Expiry: 21-Sep-2011
Fwd: 467.7 Fwd RBPV: 3.75

Australia 61 2 9777 8600 Brazil 5511 3048 4500 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
Japan 81 3 3201 8900 Singapore 65 6212 1000 U.S. 1 212 318 2000 Copyright 2011 Bloomberg Finance L.P.
SN 642494 G774-1307-1 13-Jul-11 16:13:38 GMT+1:00

Source: BofA Merrill Lynch Global Research; Prices shown were from 13th Jul 2011

Thus, the 400bp-strike receiver is actually *out of the money*, thus the option buyer should not exercise the option.

Finally, we note that any declaration of a Restructuring Credit Event (only applicable to iTraxx indices) is likely to complicate the settlement procedure for index options. For more details, we refer to our literature around the time of the Thomson CDS Restructuring (see *Situation Room: Summing up Small Bang*)

Moneyness of options

Market participants often refer to the *moneyness* of options. In basic terms, the moneyness of an option refers to whether the intrinsic value (i.e. its value if exercised today) of the option is positive or negative. The intrinsic value depends on where the strike of the option is set relative to the underlying (forward) spread:

- For ***at-the-money (ATM)*** options, the strike of the option is equal to the forward spread. As explained in detail later in the piece, long ATM option positions tend to benefit from large swings in the index spread due to their positive convexity.

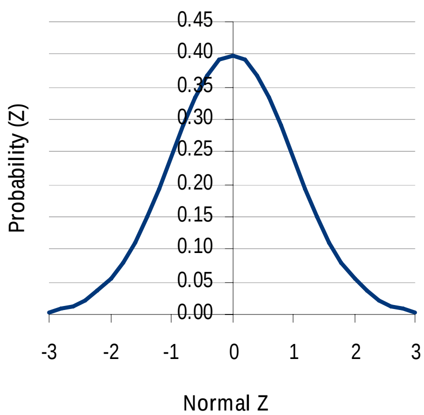
- ***Out-of-the-money (OTM)*** options are those where the investor is holding the right to buy (sell) protection above (below) the forward spread. In other words, a payer (receiver) option whose strike is above (below) the forward is considered out-of-the-money. Deep OTM options usually have a *low* sensitivity to index spread movements.

- ***In-the-money (ITM)*** options are those where the investor is holding the right to buy (sell) protection below (above) the forward spread. In other words, a payer (receiver) option whose strike is below (above) the forward is considered in-the-money. Deep ITM options usually have a *high* sensitivity to index spread movements.

What is Volatility?

In basic terms, volatility is simply a measure of how much the underlying index spread has or is expected to move. For credit options, we refer to the moves in the index *forward* spread, rather than the current (spot) level. To elaborate:

Chart 9: Standard Normal distribution



Source: BofA Merrill Lynch Global Research

- Volatility is calculated by looking at the standard deviation of % changes in the index forward spread. This is principally done because option models assume that % changes in the forward are normally distributed (Chart 9).

- **Volatility** (measured in %) is usually annualized to ease comparisons between options of different maturities.[12]

$$Annualized\ \ Vol\,(\%)\ = Vol\,(\%)\ * \sqrt{\frac{1}{T_e}} \qquad (3)$$

  where T_e is the time to expiry quoted in years. For example we need to double the volatility of a 3-month option to annualize it.[13]

- With all other parameters for a given index option known (spread, strike, time, rates), we can *imply* the volatility being priced into the market. We infer the ***implied volatility*** using standard market models, such as the modified Black model for swaptions. Modelling of credit index options is discussed in later chapters.

- Since the market often thinks in absolute moves, ATM volatility is typically converted into a daily basis point move using the following:

$$DailyVol(bp) = \frac{AdjustedIndexForward * AnnualizedVol(\%)}{\sqrt{252}} \qquad (4)$$

  where the expressions in the numerator are as defined in equations 2 and 3, with volatility taken as that of the ATM option (Strike = Forward).

Participants in the index options market often use the above daily bp conversion to ascertain whether they think volatility is “expensive”. In fact, under certain modelling assumptions, it can be shown that buyers of delta-hedged ATM options (who continuously rebalance) require the forward spread to move by this amount per day to break even on their strategy, so as the positive gamma/vega to pay for the negative theta (more details on greeks will be discussed more extensively later on). Whenever investors use this information to infer investment decisions, though, we think it is important that they consider breakeven index moves relative to their desired hedging frequency (also bearing in mind rebalancing costs).

A simple example

- Supposedly a 3-month option on iTraxx Main is priced using ~60% ATM vol (annualized), with the index forward spread currently at ~110bp.

- De-annualizing (dividing by 2) gives a 30% implied volatility over 3-months.[13]

[12] The annualization is done in this way as the variance of the underlying is defined per unit time. In other words, 1-year variance is 12x 1-month variance. Since we are dealing with volatility (the square root of variance), we annualize using the square root of the time factor.

[13] This is as T_e for a 3-month option is 0.25, meaning sqrt(1/0.25)=2

- Assuming a standard normal distribution for % changes in the forward, we can be circa 95% confident that the index spread at option expiry will be within 2 standard deviations of the mean (0%). Thus, we can be 95% certain that the index forward spread at maturity (3 months from now) will be within the +/- 60% (2 * 30%) range i.e. between 42bp and 166bp at maturity (remember volatility measures a 1 standard deviation move).[14]

Implied vs. Realized volatility relationship

So far, our discussion has centred around *implied* volatility i.e. that which is inferred from the option price. Market participants also look at *realized* volatility from historic data to observe how much the underlying has moved on a % basis over time. Calculation of realized volatility (also known as historical or delivered volatility) is as follows:

$$RVol(\%) = \sqrt{\frac{[\ln(f_t / f_{t-1})]^2 * 252}{n}} \qquad (5)$$

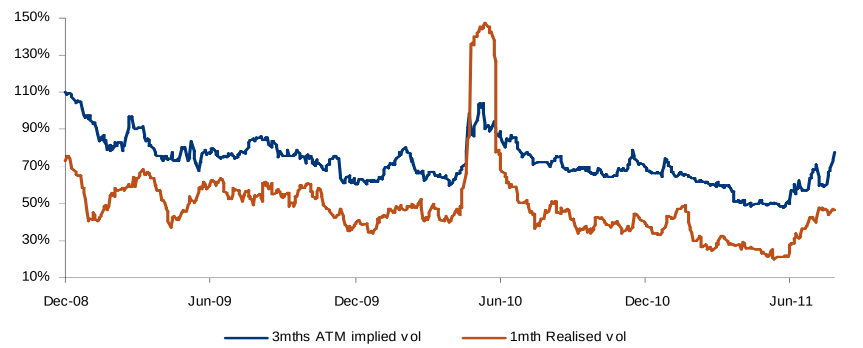
where:

- f_t is the index (default-adjusted) forward spread at time t (as per equation 1)
- n is the number of (daily) observations for that particular period

In words, realized volatility is computed using the average squared % (or log) changes in the forward spread. [15]

Below, we compare implied vs. historic (realised) volatility for iTraxx Main, using a 1 month period for the latter. As is evident, implied volatility has been usually traded above realized, indicating that credit volatility is generally expensive. This is likely to do (at least in part) with the fact that users of credit index options (as detailed earlier) to date have typically been buyers of options (due to hedging and/or convexity needs). However, at the spike of sovereign fuelled uncertainty in May last year we have seen implied trading inside realised vol.

Chart 10: iTraxx Main on-the-run index implied vs realized volatility



Source: BofA Merrill Lynch Global Research; As of 10th Aug 2011

Large moves in implied volatility often coincide with shifts in realised vol (in the same direction), a trend we have also experienced over the last months. This is particularly true for shorter-dated options, whose implied volatility is typically more sensitive to movements in realized vol.

14 To elaborate: 104bp * [1+(2*30%)] = 166bp; 110bp * [1 – (2*30%)] = 42bp, assuming current iTraxx Main 5y cds levels at 104bp and the forward at 110bp.

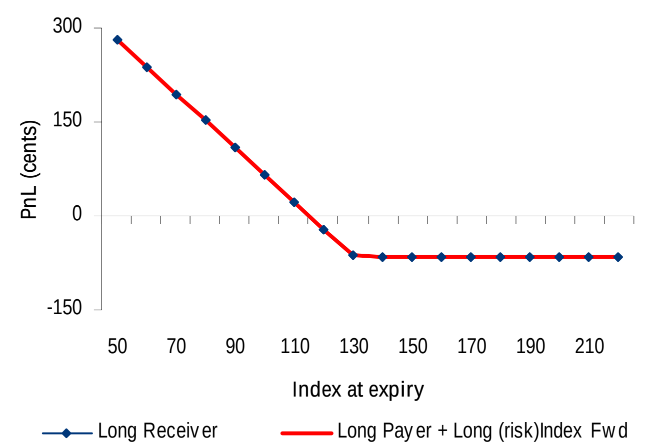
15 Although technically we should be using the forward spread to calculate realized volatility, it is common to use the actual index spread as a proxy (particularly when forward spread data is not available).

Piecing it together: Put-Call parity

Looking back at the example Bloomberg runs (on pages 8 and 10), readers may notice that the implied vol shown is the same for both payers (puts) and receivers (calls) for a given maturity at the same strike. To understand why this is the case, we need to first understand how index payers and receivers are priced versus one another, as defined by the ***put-call parity*** principle.

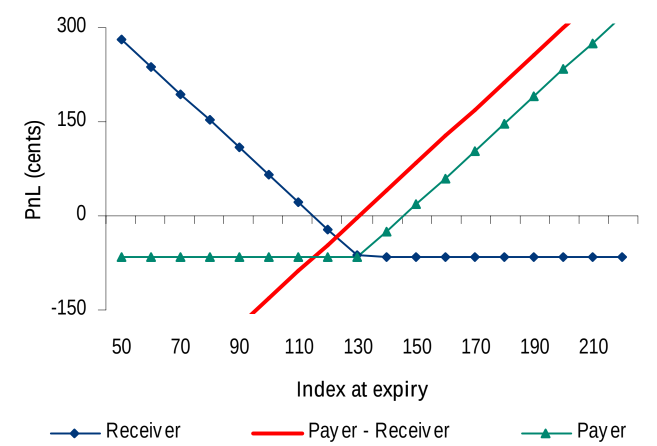
Put-call parity is predicated on the fact that the expiry payoff of a call (put) option can be exactly replicated using a portfolio of a put (call) option, the underlying asset (forward), and cash. In terms of credit indices, let us assume an investor buys a receiver (call) option at a given strike K. Instead of doing this, the investor could have instead purchased a payer (put) option struck at K and sold protection on the forward index. In Chart 11, we show how looking purely at expiry payoffs, the payoff of an at-the-money (ATM) long receiver is identical to that of a long ATM payer + long forward strategy. Since the end payoffs of both portfolios are the same in all states, they should also be priced identically today. We note that when replicating options that are not struck ATM, there will also be a requirement to lend/borrow some cash to the option expiry.[16]

Chart 11: ATM receiver can be replicated by payer and index forward



Source: BofA Merrill Lynch Global Research; Using forward BPV of 4.3 for iTraxx Main Sep'11 options and Fwd Spread of 130.55bp; Both options are struck @ Index Fwd Spread (12th Jul 2011) and have a price of 65.71cents.

Chart 12: Payoff of a long payer and short receiver at K=131bp



Source: BofA Merrill Lynch Global Research; Using forward BPV of 4.3 for iTraxx Main Sep'11 options and Fwd Spread of 130.55bp; Both options are struck @ Index Fwd Spread (12th Jul 2011) and have a price of 65.71cents.

A second important conclusion from put-call parity relates to how index payers and receivers should price on a relative basis. Imagine that an investor purchases an index payer and sells an index receiver at the same strike K. At expiry:

- If the index > K, the investor exercises the long payer position, but the receiver is not exercised by the counterparty (as it is out-of-the-money).
- If the index < K, the investor's payer option expires worthless, but the counterparty on the receiver exercises their option.

An example payoff of this structure is shown in Chart 12 – since the investor makes (loses) money when the index is above (below) K, the structure is in effect

[16] In the case where the index forward is OTM, i.e. selling (buying) forward protection below (above) the ATM forward spread, then cash will have to be lent out. In the case when the index forward is ITM (opposite to prior scenarios), option replication will require cash to be borrowed. The amount of cash that is lent / borrowed is the PV difference between this OTM / ITM forward and the ATM forward, by definition equal to the difference between payer and receiver option premiums.

a forward index short at K. Thus the difference between payer and receiver premiums should reflect the value of this forward.[17] Taking this further, we can highlight some powerful results from the relation:

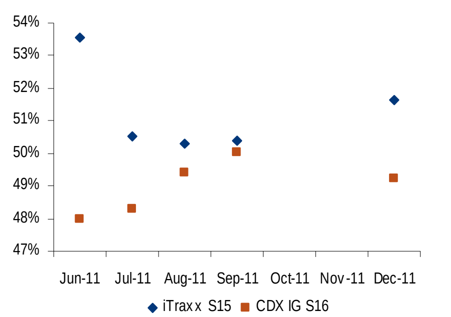
- **ATM payers and receivers must have the same premium.** This has to be the case due to the above conclusion that a long payer and short receiver strategy is equivalent to being short the index forward. If, for instance, the ATM payer was more expensive than the ATM receiver, an investor could hypothetically earn a riskless profit by: i) selling the payer; ii) buying the receiver; and iii) buying forward index protection (all with strikes of K).

- **The implied volatility of payers and receivers at the same strike must be identical.** This is due to the fact that we can replicate a long payer (receiver) through long receiver (payer) and short (long) forward index positions.

- **The value of a long payer (receiver) and short receiver (payer) position changes circa 1:1 with the index MtM.** This is as this structure is the same as a short (long) index forward, whose own delta (or sensitivity) to the index is close to 1. This outcome can be seen from the previous Bloomberg examples, where the difference between (positive) receiver deltas and (negative) payer deltas for options of the same strike equates to 1.

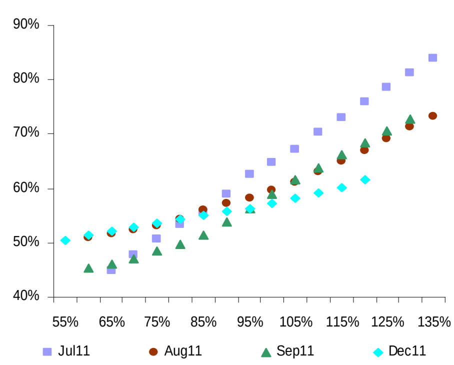
- **Deep ITM options can be exited through replication.** Generally speaking, liquidity in credit index options is concentrated in OTM options. For example, if an investor buys a 80bp-strike payer option that becomes heavily in-the-money (ITM) as spreads widen, he/she may be concerned that quotes on this become difficult to source. However, since this option can be replicated using a 80bp receiver and an index forward struck at 80bp, the dealer should be able to hedge the option and therefore provide pricing for the client's unwind.

Chart 13: IG16 and ITX15 ATM term structures



Source: BofA Merrill Lynch Global Research; As of 10th Jun 2011; ref for iTraxx Main is 108 and CDX IG is 99bp

Chart 14: iTraxx Main volatility surface



Source: BofA Merrill Lynch Global Research; Strike as a % of Index fwd; As of 24th Jun 2011

Volatility Term Structure

- ***Term structure*** is defined as the difference in annualized implied volatility for options with the same strike (or % strike) but different maturities, as shown in Chart 13.

- Term structure is often used as a measure of risk across different time horizons (analogous to credit curves in this way).

- In distressed markets, the term structure can often become heavily inverted, as the short-dated implied volatility is higher vs the long-dated (iTraxx S15 – Chart 13)

- Likewise, in recovering or more normal markets, the term structure is often upward sloping, as the short-end implied vol is lower compared to the long-dated (CDX IG S16 - Chart 13).

- Moves in short-dated volatility, in particular, tend to be closely linked to realized volatility in the market. Should index moves become subdued, for instance, then owning volatility via short-term options can appear expensive, leading the term structure to steepen.

- Investors often take a view on the relative pricing of volatility across options to different maturities, trading the term structure, **employing structures called calendars**.

[17] A reminder that the forward we are referring to is always referencing the no-knockout (i.e. original) index.

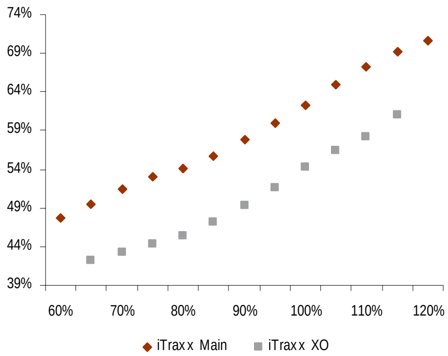
Volatility Skew

- Skew is defined as the difference in annualized implied volatility for options with the same maturity, but with different strikes. Similar to the term structure calculation, this is usually normalized to be a % of the index forward, as shown for iTraxx Main and XO options in Chart 15. Note that as displayed, volatility for iTraxx Main (a high-grade basket) is actually higher than that for Crossover (a high-yield basket). Although this may seem initially counterintuitive, this pattern persists since volatility measures % changes in spread, which tend to be *higher* for tighter-spread portfolios (even if absolute changes are much smaller for Main).

- ***Skew*** is a measure of the relative value between out-of-the-money (OTM) options and their ATM / ITM counterparts. Investors can keep track of different skew metrics through our Weekly Publication.

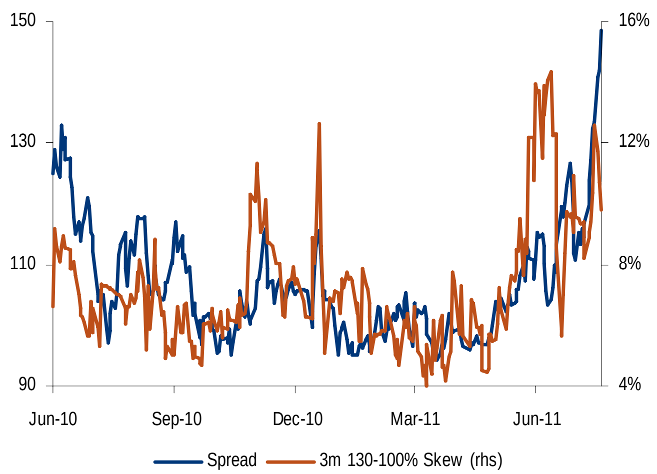
- In general, skew tends to steepen (OTM payer vol increases relative to ATM vol) at times of higher macro uncertainty as the market prices in a higher probability of a fast index move tighter or wider. We have experienced such a trend lately in iTraxx Main OTM payer options, on the back of uncertainty around Greece. More specifically, investors were willing to buy "expensive" (in vol-terms) OTM payers, pushing the skew steeper in an attempt to own tail-risk hedges for their credit portfolios (Chart 16).

Chart 15: iTraxx Main vs XO Sep'11 vol skew



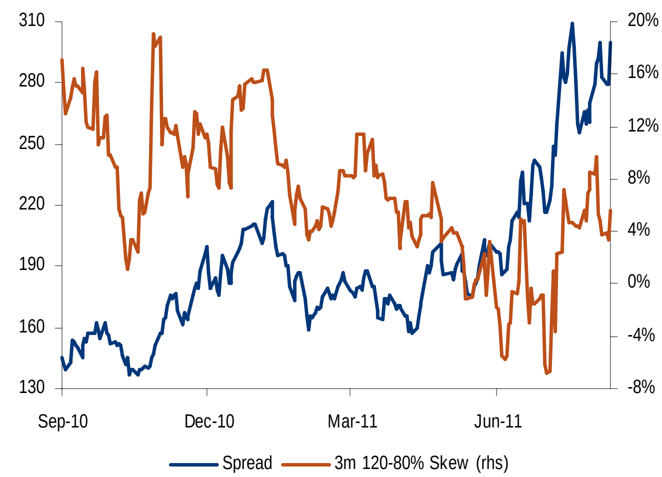
Source: BofA Merrill Lynch Global Research; Strike as a % of Index fwd; As of 27th Jun 2011

Chart 16: OTM Main payers better bid, on credit market weakness...



Source: BofA Merrill Lynch Global Research; As of 10th Aug 2011

Chart 17: not for SovX, as recent widening was considered overdone



Source: BofA Merrill Lynch Global Research; As of 10th Aug 2011

However, there may be specific instances where this relationship does not hold, such as:

a) Volatility for deep OTM payers on tight spread portfolios may remain elevated if investors see these options as "cheap" due to their low absolute premiums.

b) At times of extreme distress (e.g. in May 2010), premiums for ATM options may reach astronomical levels. Hence, investors may only be able to finance ATM hedges by selling OTM options (payer spreads), having the effect of actually *flattening* the skew.

- Moreover, on some occasions, despite market weakness we have seen skew flattening as market participants were expressing the view that such a move was overdone. Quite notably, payers vs receivers skew has flattened (till late June), as we saw better buyers of OTM receivers vs sellers of OTM payers in SovX options (Chart 17).

Option Trading Strategies

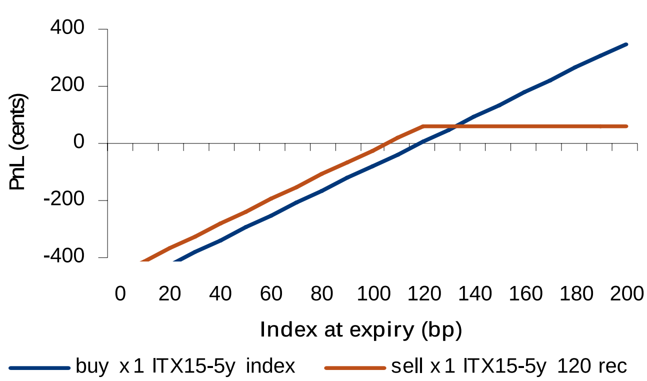
Generally a set of plain vanilla options are combined together to devise a desired payoff profile. Here we discuss some of these combinations that are popular among investors because of the desirability of their risk profiles.

- Options with 1x Index Strategies: These are analogous to the "covered call" strategy in the equity markets. These are typically income generation strategies that cap the upside in the index position for an upfront fee. For example:

  i) *Buy Protection on Index + Sell out of the money Payer* (Chart 18): In case the payer is exercised at maturity, the seller of the option is fully hedged because of his index position. The investor is essentially giving up his upside partially (any move above the strike the payer contract has been sold) until option maturity for a fixed fee. The option premium can be used to fund/offset the coupon payment on the index leg. Therefore, this strategy can be viewed as a cheap index short with capped upside.

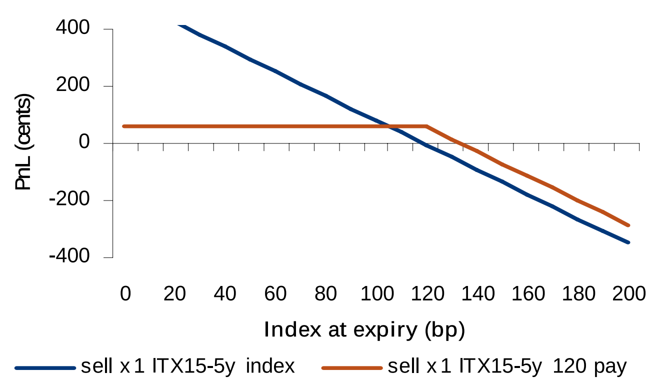
  ii) *Sell Protection on Index + Sell out of the money Receiver* (Chart 19): If the option is exercised at maturity, the seller of the option is fully hedged because of his index position. The investor is essentially giving up his upside partially (any move below the strike the receiver contract has been sold) until option maturity for a fixed fee. The option premium in this strategy can be used to enhance returns and accordingly this is a strategy to enhance returns on a long position in the index.

Chart 18: Buy Protection on Index + Sell out of the money Payer



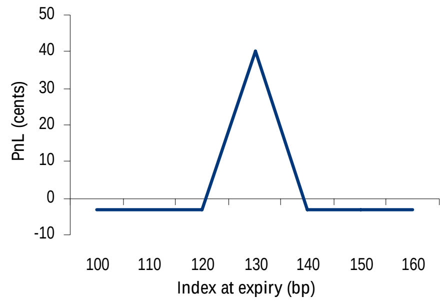
Source: BofA Merrill Lynch Global Research; as of 28th June 2011; ref=115

Chart 19: Sell Protection on Index + Sell out of the money Receiver



Source: BofA Merrill Lynch Global Research; as of 28th June 2011; ref=115

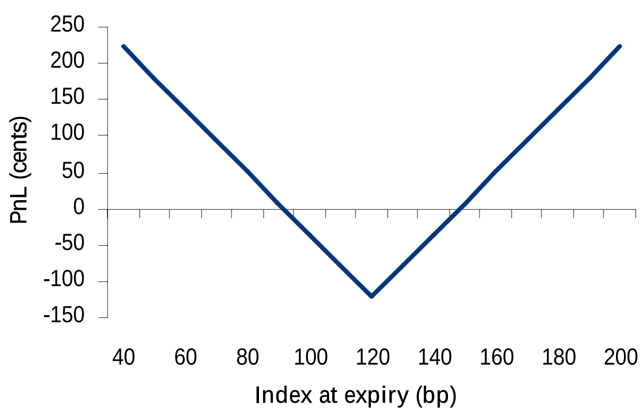
Chart 20: iTraxx Main Sep'11 Butterfly option



Source: BofA Merrill Lynch Global Research; as of 28th June 2011; ref=115

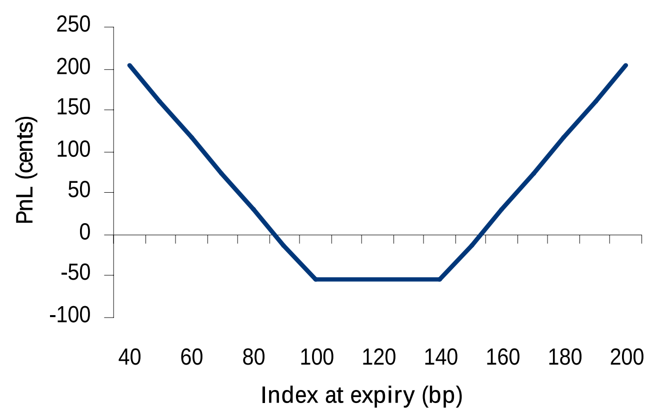
- Butterfly: A butterfly option strategy involves buying an option at a certain strike, selling 2x options at a higher strike and buying 1x option at an even higher strike. A butterfly can be constructed with either Payer options ("Put Butterfly") or Receiver options ("Call Butterfly"). The payoff at expiry of a long butterfly structure (Chart 20) is always positive or zero and hence a butterfly structure always has some cost associated with it. The cost of a butterfly also indicates the convexity (or gamma) around the middle strike, implying that butterflies are most expensive around at-the-money strikes.
- Straddle: A long straddle position (Chart 21) involves buying both a receiver and a payer at the same strike. This position ensures that there is a positive payoff (or zero in case the index level at expiry is equal to the strike) on the structure regardless of the direction of the index move, as one of the options will be exercised at expiration, making these structures expensive. Therefore, selling straddles is viewed as a short volatility strategy geared towards income generation. To take a view on implied volatility, straddles need to be dynamically delta-hedged.

Chart 21: Payoff of a Sep'11 Straddle on iTraxx Main



Source: BofA Merrill Lynch Global Research; as of 28th June 2011; ref=115

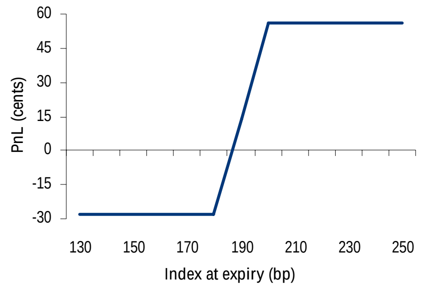
Chart 22: Payoff of a Sep'11 Strangle on iTraxx Main



Source: BofA Merrill Lynch Global Research; as of 28th June 2011; ref=115

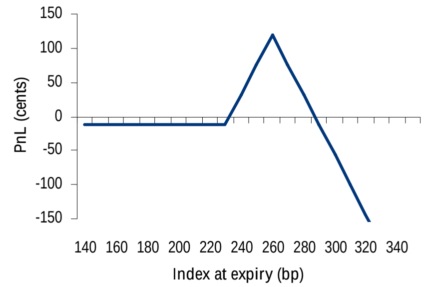
- Strangle: A long strangle position (Chart 22) typically involves buying an OTM payer and an OTM receiver. This can be viewed as a way to cheapen the straddle and still get the volatility exposure, although with wider breakevens.
- Option Spreads: An option spread involves buying and selling the same type of option (payer or receiver) at two different strikes. Option spreads have a limited upside and downside and hence are cheaper. 1x1 payer spreads (Chart 23) are structures where investor buys a payer and sells an out-of-the money payer to reduce the cost. 1x2 payer spreads, on the other hand, can be structured as zero cost structures but expose the investor to unlimited downside as spreads go much wider. (Chart 24). Structures that involve buying and selling multiple options of the same type (payer/receiver) are known as *ladders*.
- Risk Reversal (RR): A bullish (bearish) risk reversal involves buying (selling) an OTM receiver and selling (buying) an OTM payer. Investors are usually employing such strategies by selling (buying) the steep/expensive (flat/cheap) skew (Chart 25).

Chart 23: 1x1 Sep'11 Fin Senior Payer Spread



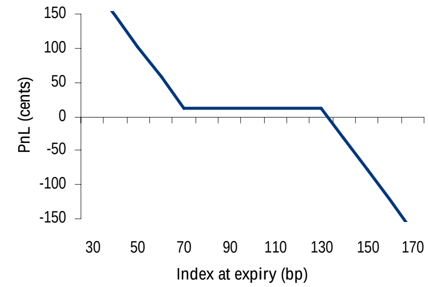
Source: BofA Merrill Lynch Global Research; as of 28th June 2011; ref=115

Chart 24: 1x2 Jul'11 SovX WE Payer Spread



Source: BofA Merrill Lynch Global Research; as of 28th June 2011; ref=115

Chart 25: Bullish Jul'11 iTraxx Main RR



Source: BofA Merrill Lynch Global Research; as of 28th June 2011; ref=115

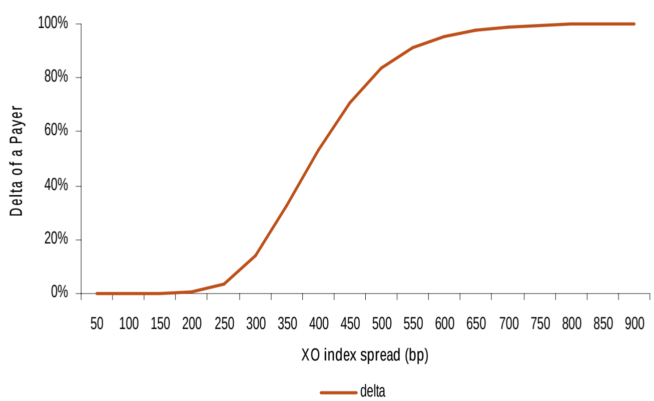
Option Greeks

In this section we look at risk profiles (greeks) of index options that are critical in understanding and formulating trading strategies in options. While we show the risk profiles for iTraxx XO options, these characteristics hold for all options when looked at from the moneyness (strike relative to the forward spread on the respective index) perspective.

Delta

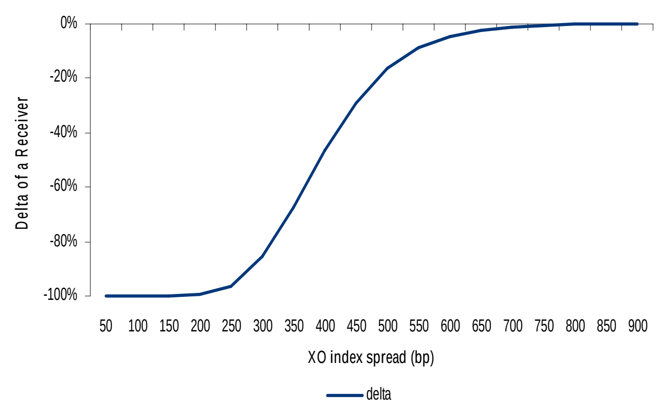
Delta is defined as the change in the price of an option relative to the change in index PV for a 1 bp move in the index spread. It also represents the notional amount of index required to hedge the option against any spread moves in the index.

Chart 26: Delta of a XO Sep'11 Payer increases as spreads widen



Source: BofA Merrill Lynch Global Research; Ref - 425bps, Fwd – 451.5 bps, Vol – 52%

Chart 27: Delta of a XO Sep'11 Receiver drops as spreads widen



Source: BofA Merrill Lynch Global Research; Ref - 425bps, Fwd – 451.5 bps, Vol – 52%

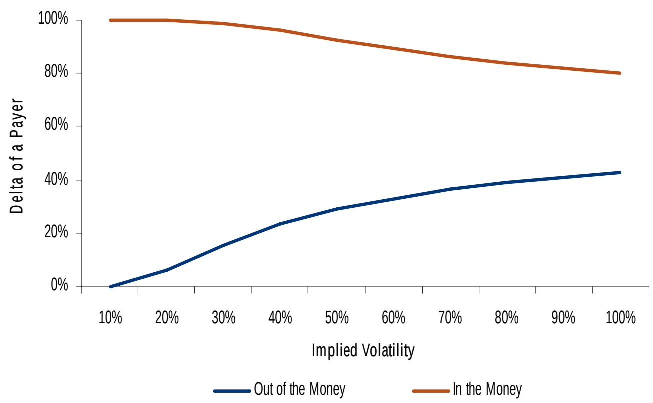
Assuming there are no jumps in the index spread and everything else (like volatility, time to maturity, rates and losses) stays the same, a dynamically delta-hedged option position should be flat. Roughly speaking, delta represents both the 1) likelihood of a given option being exercised and 2) the extent to which the option could be in the money if exercised. Therefore, currently deep in-the-money (ITM) options have a delta close to 1, deep out-of-the-money (OTM) options have a delta close to 0 and at-the-money (ATM) options have a delta close to 0.5, reflecting the likelihood of the option exercise. Chart 26 and Chart 27 show the variation of delta of a XO payer and receiver respectively as index spread changes. The delta of a receiver drops and that of a payer increases as index spreads increase and vice-versa.

Chart 28 shows the impact of implied volatility on the delta of Sep'11 payers. As volatility increases, the probability of currently OTM options being in the money at expiry increases (and vice versa for ITM options). **Therefore, the delta increases for OTM options and decreases for ITM options with increasing volatility.**

Chart 29 shows the impact of time to maturity on option delta. A longer time to maturity has a similar impact on option deltas as volatility – **OTM option deltas are higher and ITM option deltas lower for longer dated options.**

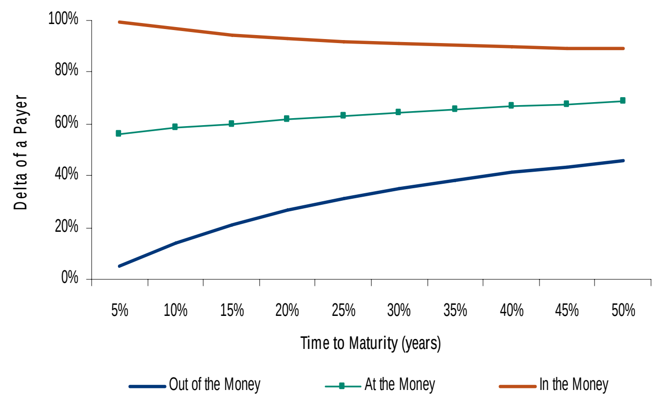
It is also interesting to note that Chart 28 and Chart 29 look very similar, indicating that volatility and time to maturity both have similar impacts on the option delta. This is an artefact of the way volatility is priced in an option. As volatility priced in an option is equal to $\sigma * \sqrt{T}$, an increase in either of them increases the net volatility impact. Accordingly, ATM option deltas increase above 50% with increasing time to maturity, reflecting the greater possibility of the option being in-the-money.

Chart 28: XO Sep'11 Payer Delta versus Implied Volatility



Source: BofA Merrill Lynch Global Research; +/-100 bps OTM and ITM strikes were used

Chart 29: XO Sep'11 Payer Delta versus the maturity of the option



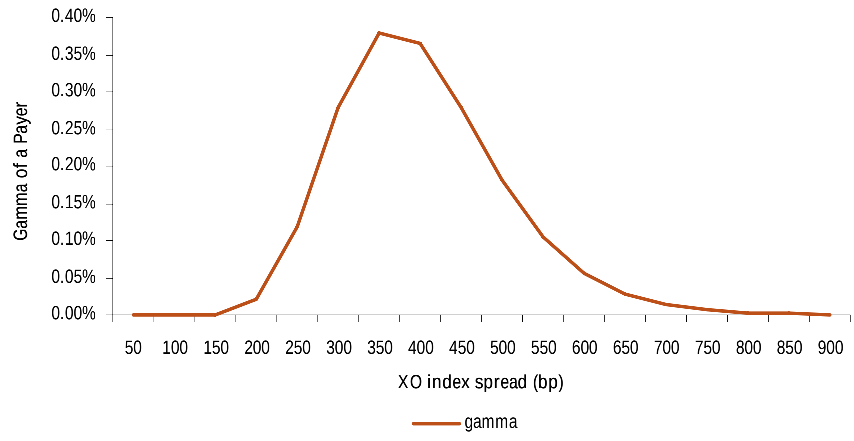
Source: BofA Merrill Lynch Global Research; +/-100 bps OTM and ITM strikes were used. Vol – 52%

Please note that in the case of gamma, vega, theta and rho, while we show risk profiles for a payer option below the same risk profiles hold for a receiver option too.

Gamma (or convexity)

By definition, Gamma (or convexity) represents the amount the delta of an option would change for a 1 bp move in the index. From a practical standpoint, gamma represents the magnitude of PnL that can be made by dynamically delta-hedging the option as the index spread moves. Therefore, positive gamma is beneficial and gamma is positive for long option positions and vice versa. However, gamma is not cheap, as options with positive gamma have negative theta. Therefore, generally speaking, gamma is what we are getting paid for in an option if we delta-hedge out the spread moves. For example, for an out-of-the money (OTM) long payer option, that has been traded with delta (so the trader has sold protection via the index) as the market moves wider, the option's delta is increasing as it becomes more in-the-money (ITM). Thus the holder of the option (traded with delta), in order to remain delta neutral, needs to sell more protection at the wider spread level. By analogy, as the underling index tightens, the option becomes more OTM and its delta decreases. In that instance, so the investor can rebalance and remain delta neutral he/she needs to buy some protection on the index at lower level. All in all, every time the positive gamma delta-neutral option holder is rebalancing whenever the index moves, this results in positive PnL.

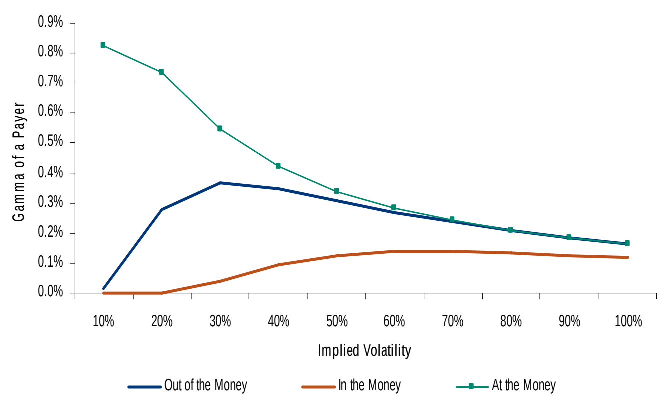
Chart 30: Gamma of a long position in XO Sep'11 425 Payer option vs XO index spread



Source: BofA Merrill Lynch Global Research; Ref - 425bps, Fwd – 451.5 bps, Vol – 52%

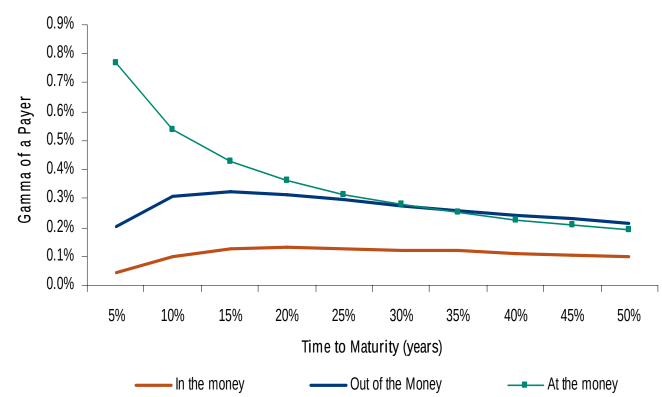
It is noteworthy that *gamma trading* is optimal when executed employing short-dated options, as gamma is more sensitive the closer we move to the contract's expiry. Consequently, an ATM option closer to maturity can be the vehicle in order to try to benefit from gamma trading if rebalancing is done frequently enough to capture the market volatility. It is widely considered that gamma is the "short-term" volatility of an option.

Chart 31: XO Sep'11 Payer Gamma versus Implied Volatility



Source: BofA Merrill Lynch Global Research; +/-100 bps OTM and ITM strikes were used

Chart 32: XO Sep'11 Payer Gamma versus the maturity of the option



Source: BofA Merrill Lynch Global Research; +/-100 bps OTM and ITM strikes were used. Vol – 52%

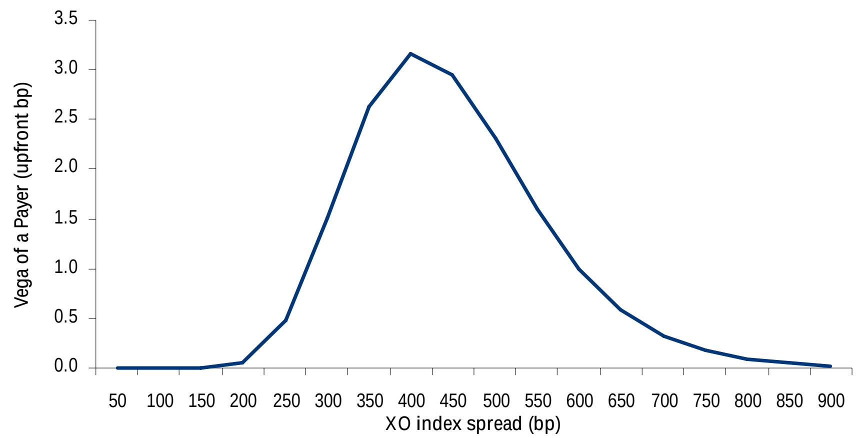
Chart 30 shows that **gamma is the highest for an ATM option and reduces as the option becomes more in the money or out of the money**. This can be understood intuitively by thinking of gamma as being analogous to the amount of optionality in the payoff diagrams in Chart 5 and Chart 6. Clearly, ATM options have a lot of optionality – positive upside versus no downside depending on where the index spread is at maturity. On the other hand, deep ITM and OTM options have more balanced upside and downside with respect to any spread moves, implying that the gamma is very low.

Chart 31 & Chart 32 show the variation of option gamma with volatility and time to maturity and the two charts are similar because of the reason mentioned in the previous section. Chart 31 shows that gamma is the highest for short dated ATM options – if you were to think of an ATM option with a few minutes left to maturity, it has very high gamma as it will have a delta of 1 if it ends in the money or a delta of 0 if it ends out of the money at maturity. On the other hand, short dated OTM and ITM options have very little gamma. Also, the **gamma of ATM options falls drastically with greater time to maturity.**

Vega

Vega is the change in price (in cents or basis points upfront) of an option for 1% change in implied volatility. Option prices increase as implied volatility increases and vega signifies the rate of this increase for options at different strikes. Vega has a similar profile with gamma, **with ATM options having the highest vega** (Chart 33).

Chart 33: Vega of a long position in Sep'11 XO 425 Payer option vs XO index spread

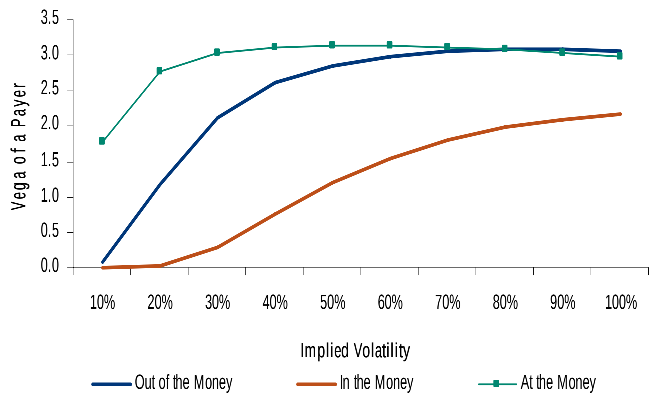


Source: BofA Merrill Lynch Global Research; Ref - 425bps, Fwd – 451.5 bps, Vol – 52%

Chart 34 shows that vega of an ATM payer is almost insensitive to implied volatility. This indicates that the cost of an ATM payer is more or less linear in implied volatility. The vega of OTM and ITM options goes higher as implied volatility goes up, indicating the convexity of option price to a rise in implied volatility. Chart 35 shows that the **vega of an option increases with maturity**. Therefore, long dated option have higher vega and are more sensitive to volatility moves than short dated ones.

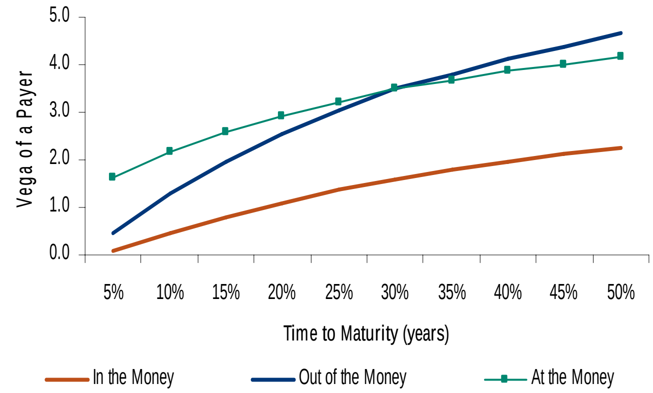
However, in contrast to what we have seen in gamma trading, it is noteworthy that *vega trading* is optimal when executed employing longer-dated options, as vega is more sensitive the longer the time to the contract's expiry. Consequently, an ATM option with longer time to maturity can be the vehicle in order to try to benefit from vega trading if rebalancing is done frequently enough to capture the market volatility.

Chart 34: XO Sep'11 Payer Vega versus Implied Volatility



Source: BofA Merrill Lynch Global Research; +/-100 bps OTM and ITM strikes were used

Chart 35: XO Payer Vega with respect to the maturity of the option

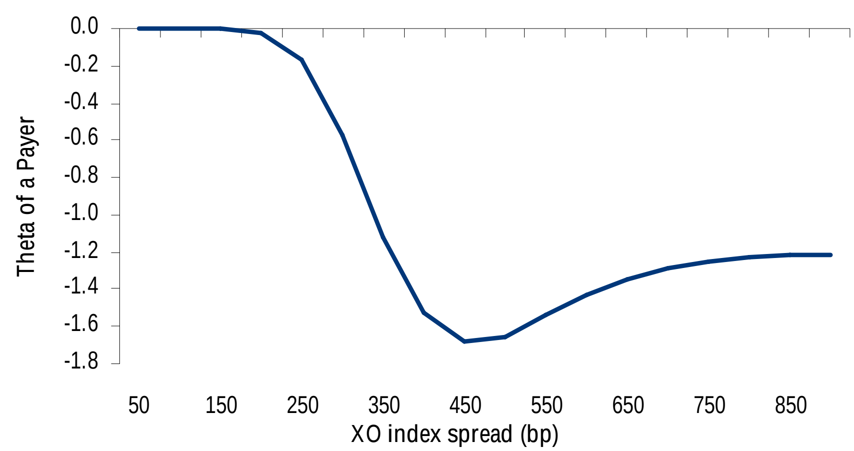


Source: BofA Merrill Lynch Global Research; +/-100 bps OTM and ITM strikes were used. Vol – 52%

Theta

Theta is defined as the rate of change in the option price with passage of time. Theta is negative (option loses value with passage of time) for an option buyer and positive for an option seller. It is also commonly considered the "gamma rent", as the holder of a long credit option has to "pay" theta for the positive gamma of the structure. Chart 36 shows theta of a payer option with respect to the index spread. It shows that **ATM options have the highest theta while OTM options have relatively little theta.** Theta is the cost of optionality (or gamma) and hence is the highest for ATM options. OTM options have low theta as the option price itself is so low. On the other hand, ITM options have theta greater than OTM options as a 1bp move in the index has a bigger impact on their option price and hence the time value is so much more. Finally, short dated options have the highest theta as the non-intrinsic value of the option declines drastically towards maturity.

Chart 36: Theta of a long position in Sep'11 XO 425 Payer option vs XO index spread



Source: BofA Merrill Lynch Global Research; Ref - 425bps, Fwd – 451.5 bps, Vol – 52%

Rho

Rho defines the sensitivity of the option price to change in interest rates. The expected value of the option payoff at maturity is discounted back to the present time to compute the option price. Therefore, as interest rates go higher the value of the option drops and vice-versa. Further, high cost options (ITM and/or on extremely wide-spread portfolios) have a higher rho because of a bigger payoff being discounted (Table 2).

Jump Risk

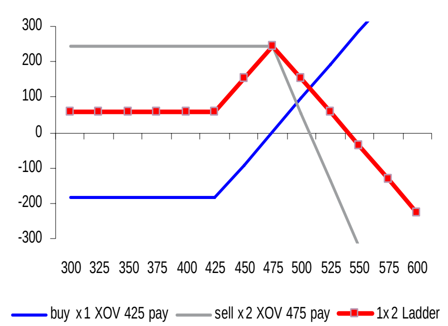
A default in one of the index constituents will push the overall spread of the no knockout index wider, assuming all other spreads stay the same. Therefore, the potential change in option price resulting from a default in one of the names can theoretically be hedged by delta-hedging with the index. However, this jump in the spread because of a default is hard to dynamically delta-hedge.

Option Greeks on low cost trading strategies

In this section we look at risk profiles (greeks) of option structures similar to popular index options strategies investors have employed over the last months trying to benefit from steep skews in OTM payers. In an attempt to employ low cost structures that benefit from moderate widening, market participants have used payer ladders (usually at strikes were the buyer is getting paid) or butterflies (with high leverage in terms cost vs max payout). That is critical in understanding and formulating trading strategies employing more complicated option structures, and very important to understand the risk associated with structures were the risk sensitivities profiles are volatile.

For this exercise we will use iTraxx Crossover index referenced options

Chart 37: XO Sep'11 425-475 1x2 payer ladder



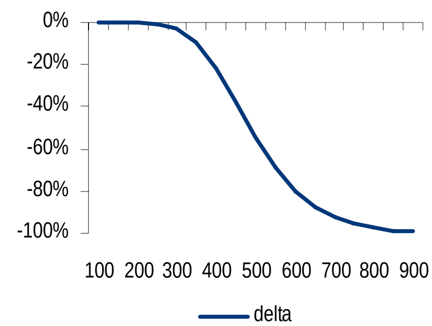
Source: BofA Merrill Lynch Global Research; as of 29th June 2011 (mid prices); ref=409

Payer Ladders (1x2 payer spreads)

As we have mentioned in a previous chapter, payer ladders are structures that involve buying a close to ATM option and selling multiple OTM options of the same type (payer/receiver). Ladders can be structured as zero cost but investors usually prefer to get paid a low fee to get in such a trade, so as to guarantee no losses in an adverse (tightening/widening) scenario. We will continue employing iTraxx XO options in our analysis, exploring how the structure's greeks behave vs the underline credit index spread changes.

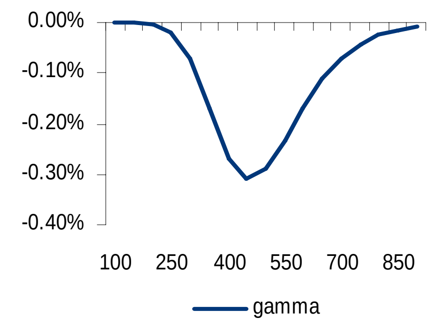
According to the following charts, a payer ladder is a long risk trade that has negative delta (Chart 38), negative gamma (Chart 39), negative vega (payout profile similar to gamma) but positive theta (Chart 40). In other words it is behaving in a very similar way to a short payer option. However it benefits from wider breakevens (425-475 ladder has wider breakevens vs the 475 payer) but comes with lower initial upfront receipt. Also the maximum payout can be reached at the level where the investor is selling the multiple of OTM payers, while for an OTM payer the initial receipt is the max payout and is lower than the ladder's. We have to underline that both trades are exposed to unlimited downside should markets widen significantly. Additionally, even a ladder reaches its maximum payout at a wider cds level vs entry levels, it does not have positive MtM as it moves to that point. That is the effect of a negative delta trade (traded no delta) on market weakness. Additionally, because of its negative gamma (Chart 39) the structure has negative convexity that results in negative PnL whenever delta is re-neutralised.

Chart 38: Payer ladder has: negative Delta...



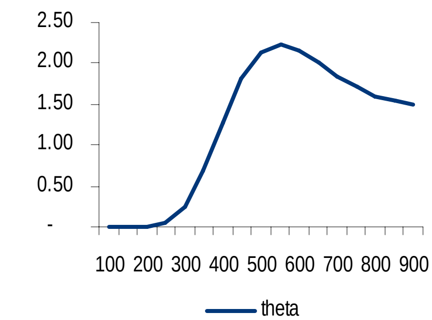
Source: BofA Merrill Lynch Global Research

Chart 39: ...negative Gamma but...



Source: BofA Merrill Lynch Global Research

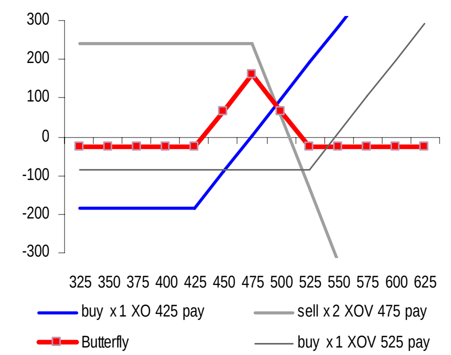
Chart 40: ...positive Theta



Source: BofA Merrill Lynch Global Research

Additionally, as time to maturity declines, gamma and delta become less negative if the market remains at original levels.

Chart 41: XO Sep'11 425-475-525 payer butterfly



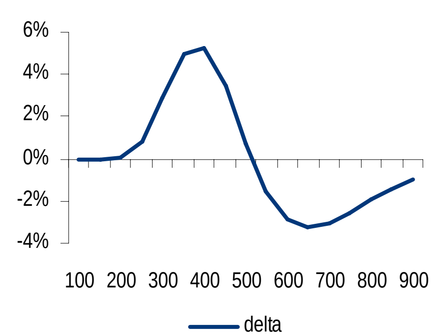
Source: BofA Merrill Lynch Global Research; as of 29th June 2011 (mid prices); ref=409

Butterflies

As we have mentioned in a previous chapter, a butterfly option strategy involves buying an option at a certain strike, selling 2x options at a higher strike and buying 1x option at an even higher strike. A butterfly can be constructed with either Payer options ("Put Butterfly") or Receiver options ("Call Butterfly"). The trade benefits from relative low cost and limited downside equal to the initial outlay. However the thinner the range (distance of strikes where investor bought the contracts) the lower the probability ending ITM at expiry, but the higher the potential max payout to initial cost ratio. That ratio of max payout vs cost is usually a common method to assess the structure attractiveness, always bearing in mind the implied probability that such a range can be reached.

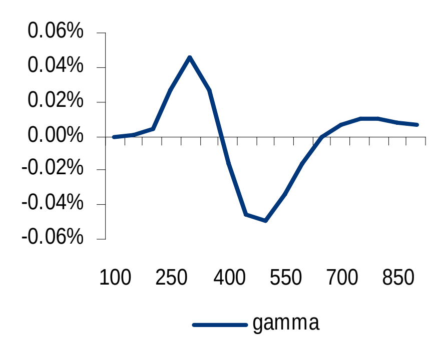
However the low cost to payout ratio does not come for free. Highly volatile risk sensitivities (greeks) can justify that. The trade has positive delta up to the level the high strike payer was bought, and negative from that point onwards (roughly). However, the gamma bounces from positive to negative and again positive. The trade has negative gamma (and vega) in the range of ~400-600bp. Finally, the trade benefits from positive theta at the same range (roughly).

Chart 42: Payer butterfly's: Delta...



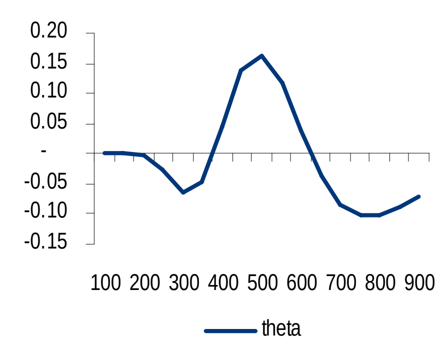
Source: BofA Merrill Lynch Global Research

Chart 43: Gamma...



Source: BofA Merrill Lynch Global Research

Chart 44: and Theta



Source: BofA Merrill Lynch Global Research

The payoff at expiry of a long butterfly structure (Chart 41) is always positive or zero and hence a butterfly structure always has some cost associated with it. The cost of a butterfly also indicates the convexity (or gamma) around the middle strike, implying that butterflies are most expensive around at-the-money strikes.

Options vs. Tranches: a comparison

As described above, credit index options provide access to risks such as convexity and volatility that cannot be isolated through the index underlying. However, the former is a term also commonly used in the index tranche market, so readers may wonder how these two products compare. In general, we distinguish between them as follows:[18]

- Index *options* are options on spread with typically short maturities.
- Index *tranches* are options on loss with typically long maturities.[19]

For example, both long equity tranche positions and long payer options are expected to be positively convex strategies. However, some of their other risks may be in opposite directions, as summarized in Table 4 below:

Table 4: Comparing 2 positively convex trades: Long junior tranche vs. long payer option

Sensitivity	Long (Risk) Junior Tranche	Long Payer Option
Convexity	positive	positive
Risk	long	short
Roll-down	positive	negative
Jump-to-default	negative	positive
Correlation	long	N/A
Volatility	N/A	long

Source: BofA Merrill Lynch Global Research

Although positive convexity is a desired property, there is a cost or trade-off associated with this. In the options world, long convexity positions are typically short theta (or decay), losing money when the index does not move. In the tranche market, long convexity positions are typically short jump-to-default, losing money if either names in the portfolio default or individual credits see extreme isolated moves.

In theory, an investor with differing views on each of the above attributes in Table 4 can use a combination of options and tranches to achieve certain risk characteristics. In more generic terms, options and tranches can be viewed as complements to credit portfolios depending on what risks the investor is attempting to hedge or gain exposure to.

In addition, due to the shorter tenor of index options, they tend to exhibit greater convexity on a % basis than tranches. As would be expected, the delta of payer options (equity tranches) increase (decrease) respectively as spreads widen.

Although our analysis has centred around the relative risk/reward characteristics of options versus tranches, index options can also be compared or directly traded against the following products:

- Underlying indices themselves e.g. as a view on volatility, convexity play
- Cross-Asset options e.g. taking a view on credit vs. equity volatility
- Single-name CDS to capture high conviction views and hedge downside risk.

[18] Note that both options and standardized tranches use the index as the reference portfolio. Since tranches refer to 2 different strikes (attachment point and detachment point) they can viewed as spread options whose end payoff is determined by loss (rather than spread).

[19] Investors may trade shorter maturity tranches too, particularly if they consider off-the-run index portfolios.

Appendix #1: Index Option Modelling

The credit index pricing model discussed herein was developed by Leif Andersen at Bank of America in 2003 and is similar to the one currently adopted by Bloomberg in their CDSO screen.

As stated earlier, index options provide front-end protection - protection on defaults up to the option maturity. Trying to model losses up to option maturity and the spread of the ex-defaulted names index could be cumbersome. Therefore, pricing index options requires using an underlying that consists of all the CDS constituents of the index at the time of option origination.

If there are defaults in the basket during the life of the option, all defaulted CDSs will be delivered at option maturity, with values of one minus recovery. We shall refer to this underlying as a no knockout index i.e. at option maturity the deliverable has all the names present at option origination. Therefore, the strike on an index option corresponds to the spread/price of this no knockout index (defaulted names marked at one minus recovery and the ex-defaulted names index trading at a certain spread).

Analytical description

The payout of a payer option at option maturity, to buy protection on an index with m names, with option maturity T will be

$$V_{opt}(T) = Max\left(\sum_{i=1}^{m} V^{i}(T) - K, 0\right) = Max\left(\sum_{i \notin D(T)} V^{i}(T) + \sum_{i \in D(T)} (1 - R_i) - K, 0\right) \quad (6)$$

where V^{i} (T) represents the value of the CDS on name i at option maturity and D(T) denotes the set of constituents that default by option maturity. Note that we assume \$1 notional for each constituent of the index.

The second term in the above representation shows the one minus recovery value for the defaulted names and the first term denotes the value of the index consisting of the remaining names. The option is worth exercising only if the sum of the two terms is greater than the strike value (in price terms).

Assuming deterministic interest rates under the risk neutral measure, we have at time 0

$$P(0,T)\, E\left(\sum_{i \notin D(T)} V^{i}(T)\right) = P(0,T)\, E\left(\sum_{i=1}^{m} 1_{\tau_i > T} A_i(T)\,(c_{par,i}(T) - c)\right) = \sum_{i=1}^{m} A_i(0)\,(c_{par,i}(0) - c) \quad (7)$$

where P(0,T) is the risk-free discount factor from time 0 to T, A_i (0) represents the time 0 expectation of the forward starting risky annuity for constituent i and $c_{par,i}(0)$ represents the time 0 expectation of the par spread on the forward starting CDS of constituent i. The left hand term represents the present value of the index protection consisting of names that did not default by option maturity.

In the above equation, we take the present value of expectation of the PV of surviving forward starting CDS to be today's PV of the forward starting index.

Also,

$$E\left(\sum_{i \in D(T)} (1 - R_i)\right) = \sum_{i=1}^{m} [1 - X_i(0,T)]\,(1 - R_i) \quad (8)$$

where the left hand term represents the expectation of the total value of payments on defaulted names or, in other words, the undiscounted expected loss till option maturity (T). X_i represents the survival probability of each name till time T.

If we were to think of (6) as $V_{opt}(T) = Max(\gamma(T) - K, 0)$ (9)

We now know that at time T:

E($\gamma(T)$) = $P(0,T)^{-1}\sum_{i=1}^{m} A_i(0)(c_{par,i}(0) - c) + \sum_{i=1}^{m}[1 - X_i(0,T)](1 - R_i)$ (10)

meaning that the expectation of the value of protection on the no knockout index at the option maturity is equal to the current PV of the forward starting index taken forward to option maturity plus the undiscounted expected loss on the index. It is important to highlight that the two right hand terms can be computed using the current spreads on the constituent names.

We define a default-adjusted forward spread on the no knockout index (including defaults) S (T), as a spread on a CDS starting at time T till index maturity and which is computed by equating the value of this CDS to the value of the no knockout index at option maturity. Please note the subtle difference of this spread from a conventional forward spread on the no-knockout index (the one discussed in the “Thinking Forward” section of this piece), which is implied from today’s spread curve. It is important to note that the resulting forward risky BPV from the option expiry to index maturity is different under these two definitions.

$\gamma(T)$ in (9) can also be defined in terms of the new forward spread we just defined, S (T)

$\gamma(T)$ = $\gamma(S(T))$ = m * A_S (T) (S (T) – c) (11)

where A_S (T) can be written as a function of S (T) assuming a flat hazard rate and 40% recovery

Revisiting our option payout from (4), we can rewrite it as

$V_{opt}(0) = P(0,T)\,E(Max(\gamma(S) - K, 0))$ (12)

If we know the density ϕ_S of S(T), we can compute this option value by numerical evaluation of the integral:

$V_{opt}(0) = P(0,T)\int_0^{\infty} Max(\gamma(S) - K, 0)\,\phi_S(S)\,dS$ (13)

From (5) and the distributional properties of $\gamma(S)$, we also have the following

E($\gamma(T)$) = $\int_0^{\infty}\gamma(S)\,\phi_S(S)\,dS$ = $P(0,T)^{-1}\sum_{i=1}^{m} A_i(0)(c_{par,i}(0) - c) + \sum_{i=1}^{m}[1 - X_i(0,T)](1 - R_i)$ (14)

Therefore, by assuming a lognormal distribution for S (T), such as

S (T) = $\mu \exp(-0.5\sigma_S^2 T + \sigma_S\sqrt{T}z)$ (15)

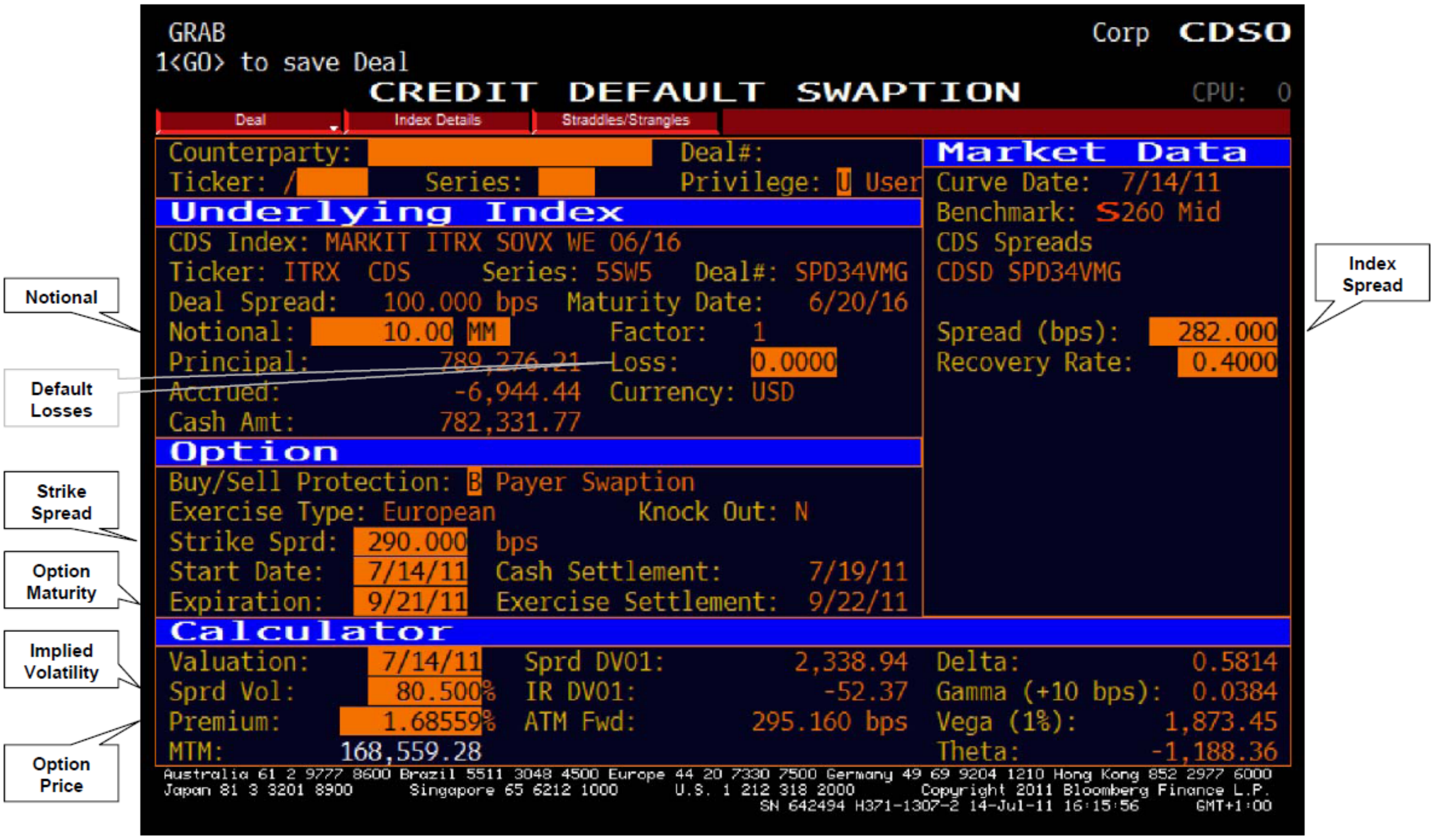
we can estimate μ from (15) using a root search algorithm and an assumption for spread volatility.

In the above derivation we assumed that the strike K is in price. However for most index options the strike is expressed in spread terms, for which we can use the standard methods of converting a spread into a clean price assuming a 40% recovery.

Appendix #2: CDSO Bloomberg

Below, we provide a basic guide of how to input information into Bloomberg's CDSO page, a basic tool by which to price options and imply risk parameters. The example illustrated below is for a SovX WE S5 September 2011 payer.

Chart 45: Using CDSO screen on Bloomberg



Source: Bloomberg, BofA Merrill Lynch Global Research

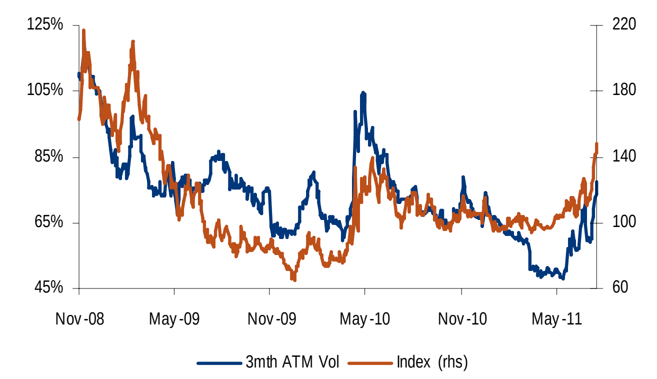
Appendix #3: Spread vs. Vol Historics

Investors using CDS index options are likely to have interest in the historic relationship between spreads and volatility. Below, we chart the two together for both iTraxx Main and CDX IG since late-2008. 2009 was a year that began with a sharp sell-off in spreads as the recession took hold, before a liquidity-fuelled retracement. However, since spring-2010, we have seen implied vol / index spreads spiking, amid increasing uncertainty around the European debt crisis. As it is evident, volatility and spreads were closely linked over this period, with both considerably lower at the end of the period relative to where they began.

We remind readers that since credit volatility is based off % changes in the forward spread, lower spreads and volatility together signify a sharp reduction in the average daily index move predicted by the options market (see earlier equation 4). Although in general one may expect credit spreads to be less volatile (even on a % basis) in lower-spread environments, this may not be the case in the interim period if spread tightening occurs quickly. See for instance the divergence between index spreads and volatility for iTraxx Main in summer 2009 (Chart 46). However, we have witnessed periods (spring 2011) were implied vol retreated even though the index remained relatively wider compared to implied vol levels.

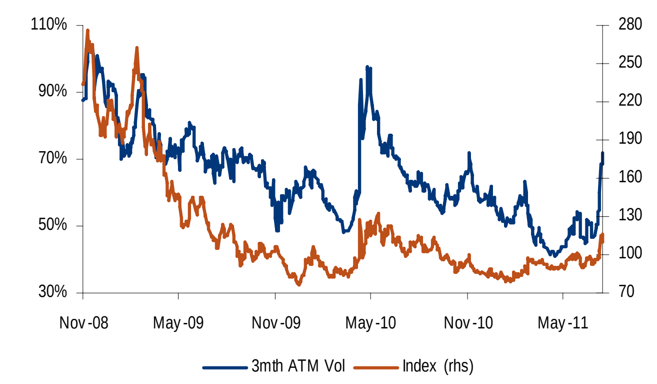
Finally, one may notice that the implied volatility for iTraxx Main is around 5-15% higher on average over this period vs CDX IG. This relationship was typical over 2009 - early2010 because of the tighter absolute spread on iTraxx Main, leading to a higher expectation of % moves on this index. However, over the last 18 months on the back of peripheral risk-fuelled uncertainty, CDX IG started trading inside iTraxx Main while implied vol remained elevated in Europe, highlighting the higher perception of risk in the European credit markets.

Chart 46: iTraxx Main: Spread vs. ATM implied volatility



Source: BofA Merrill Lynch Global Research; as of 10th of August 2011

Chart 47: CDX IG: Spread vs. ATM implied volatility



Source: BofA Merrill Lynch Global Research; as of 10th of August 2011

Table 5: Credit Index Options - Standardized Contract Terms

Options style	European Type (exercise on expiry date only)
Initial Premium Cash Settlement	T+3 (Trade date + 3 business days)
Exercise Cash Settlement	T+3 (Expiry date + 3 business day)
Settlement	Physical (into index if ITM)
Maturities	3rd Wednesday of the expiry month
Exercise Time	9am - 4pm LDN (EU index options) / 9am - 11am NYT (US index options)

Source: BofA Merrill Lynch Global Research

Appendix #4: Expiry Day Mechanics

Since CDS index options are in European options, all exercise decisions from the option holder are taken on the exercise date. We attempt to describe the exercise process for options below as per our understanding. However, we would encourage investors to discuss this in more depth with the dealer acting as counterparty on the option. A few simple points can be made, though:

- The holder of an in-the-money (ITM) option can only exercise their right between pre-designated times on the expiry date. For iTraxx options, the historical convention has been between 9am and 4pm London time. For CDX options, the time interval is shorter, between 9am and 11am New York time.

- The decision to exercise is usually done by electronic communication to avoid confusion and to ease the operational burden somewhat.

- Once an option is exercised, the holder of the option will be delivered a long or short protection position in the index at spread K (original strike). The direction of the trade (buy or sell protection) will depend on whether the initial option was a payer or a receiver. To clarify, if an investor is exercising a payer option, he will enter into a long protection index position at a spread of K, struck at the index coupon C. The investor will now pay/receive the difference in K and C upfront as per usual index convention.

- Clearly, the mark-to-market of this index position can be immediately realized through an offsetting trade. If the expiry date falls on a non-coupon date for the index, there will be accrued coupon to consider.

- From a mechanical perspective, investors long/short multiple option positions (with different degrees of moneyness) are likely to exercise all trades heavily ITM early on during the day (where they are long the option). If there are a large number of options very close to the ATM point in the market, there may be a flurry of exercise decisions just before the relevant cut-off time.

- Investors should also check with their dealer as to the treatment of partial exercise (i.e. not on the full notional). If an investor has a large notional exposure to an ATM strike, he/she may wish to reduce overall expiry day convexity (positive or negative) by exercising a proportion of this early on the day.

Link to Definitions

Credit

Click here for definitions of commonly used terms.

Analyst Certification

I, Ioannis Angelakis, hereby certify that the views expressed in this research report accurately reflect my personal views about the subject securities and issuers. I also certify that no part of my compensation was, is, or will be, directly or indirectly, related to the specific recommendations or view expressed in this research report.

Important Disclosures

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Issuer credit recommendations do not cover equity preferreds or CDS related to the issuer. Issuer credit recommendations do not cover capital securities of the issuer unless a statement to that effect is provided in the relevant research report.

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Equity Preferreds: Equity preferreds are recommended on an individual basis under the Credit Opinion Key. Issuer credit recommendations do not apply to equity preferreds.

Recommendation	Investor Action Points (Cash and/or CDS)	Primary Investment Return Driver
Overweight-100%	Up to 100% Overweight of investor's guidelines	Compelling spread tightening potential
Overweight-70%	Up to 70% Overweight of investor's guidelines	Carry, plus some spread tightening expected
Overweight-30%	Up to 30% Overweight of investor's guidelines	Good carry, but little spread tightening expected
Underweight-30%	Down to 30% Underweight of investor's guidelines	Unattractive carry, but spreads unlikely to widen
Underweight-70%	Down to 70% Underweight of investor's guidelines	Expected spread underperformance
Underweight-100%	Down to 100% Underweight of investor's guidelines	Material spread widening expected

Time horizon – our recommendations have a 3 month trade horizon

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