European Credit Research
28 March 2007

An Introduction to Credit Options and Credit Volatility

- **In this document we bring together the research we have done on the credit option market for a more comprehensive introduction**. It is divided into two main sections, which cover topics from basic CDS option descriptions to advanced trading of credit volatility.

- **The first section starts with the basics of CDS options and moves on to look at how to express market directional and volatility views using options**. Additionally, we look at the practical side of option trading including calculating breakevens, understanding the adjusted-forward and dealing with defaults.

- **Section 2 looks in greater depth at trading credit volatility.** We show how delta-hedging allows investors to trade credit volatility, what profits an investor can expect from such a strategy and how to estimate delta-hedging costs.

- **The Appendices provide analytical confirmation of much of the analysis of** this document along with a detailed example of the P&L of a delta-hedged option. The final appendix provides a glossary of commonly used option terms.

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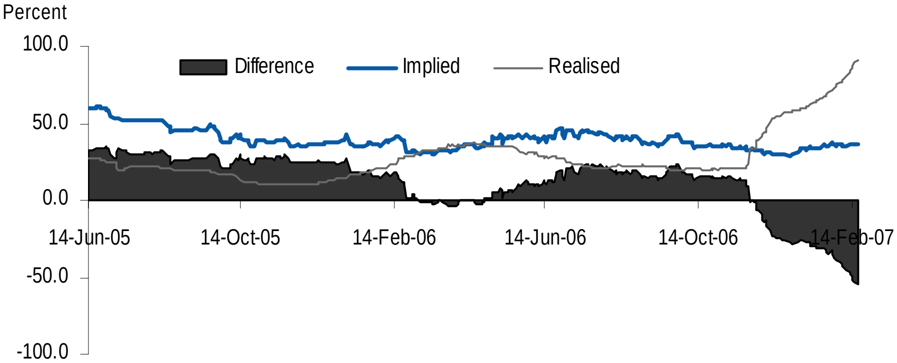
Figure 1: Three-Month Implied versus Realised Volatility



Source: JPMorgan

J.P. Morgan Securities Ltd.

See page 42 for analyst certification and important disclosures, including investment banking relationships.

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Section 1: Introduction to CDS Options

Product description

A CDS option is an option to buy or sell CDS protection on a specified reference entity at a fixed spread on a future date. Offered on both CDS indices and single-names, call options provide investors with the right to buy risk (receive spread) while put options provide investors with the right to sell risk (pay spread) at the strike spread. We therefore often refer to calls as receivers and puts as payers. Investors use options to trade credit volatility or tailor their directional spread views.

We use cents to denote the upfront value of a running spread in units of 0.01%. E.g. using a risky annuity of 4, 1bp would be equal to 4c (4×1bp).

CDS options have a European-style expiry and are quoted in cents upfront.
CDX and iTraxx options have a fixed expiry that usually coincides with the index coupon dates (March 20, June 20, September 20 and December 20), although other maturities are available. All options are European-style in that an investor can only exercise them on the expiry date. At inception, the option buyer pays an upfront premium to the option seller (T+3 settlement).

Most CDS options are quoted as spread options.
In both Europe and North America, we usually quote the strike of an option as a basis point spreads amount. The notable exception is CDX.NA High Yield, which is quoted with a strike price, since the index trades on a price rather than spread basis.

Table 1: CDX and iTraxx Option Standard Terms

Option Style:	European
Premium:	Quoted in cents upfront
Premium payment date:	Trade date + 3 business days
Expiration time:	11am New York time, 4pm London time
Settlement:	Physical
Settlement terms	Expiry + 3 business days
Settlement amount	
a. if no credit events before expiry	Settlement by buying or selling the index at strike at expiry
b. if one or more credit events before expiry	Settlement by buying or selling the index at strike at expiry. Subsequently, protection buyer triggers the contract in regard to any defaulted credits under the standard procedures.

Source: JPMorgan

Standard CDS option contract calls for physical rather than cash settlement.
If an option is In-the-Money at expiry, then the investor will enter the index contract at the strike spread. However, since the indices trade with an upfront fee, he will pay or receive this upfront and will then pay or receive the index coupon over the life of the CDS. An investor can immediately exit the contract and realise the difference between the strike and the prevailing market spread.

Index options do not “Knockout” if there is a default on an underlying name.
Standard CDS options do not roll onto the "on-the-run" index, but remain with the referenced series. If a name defaults, an investor’s contract is on the original series that includes the defaulted name. An investor who bought a payer option would be able to exercise on the defaulted name, once they were entered into a long protection position on the index at the option expiry. Investors typically use the CDS settlement protocol (reviewed in Part I) to settle the defaulted name.

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Express Views Through CDS Options

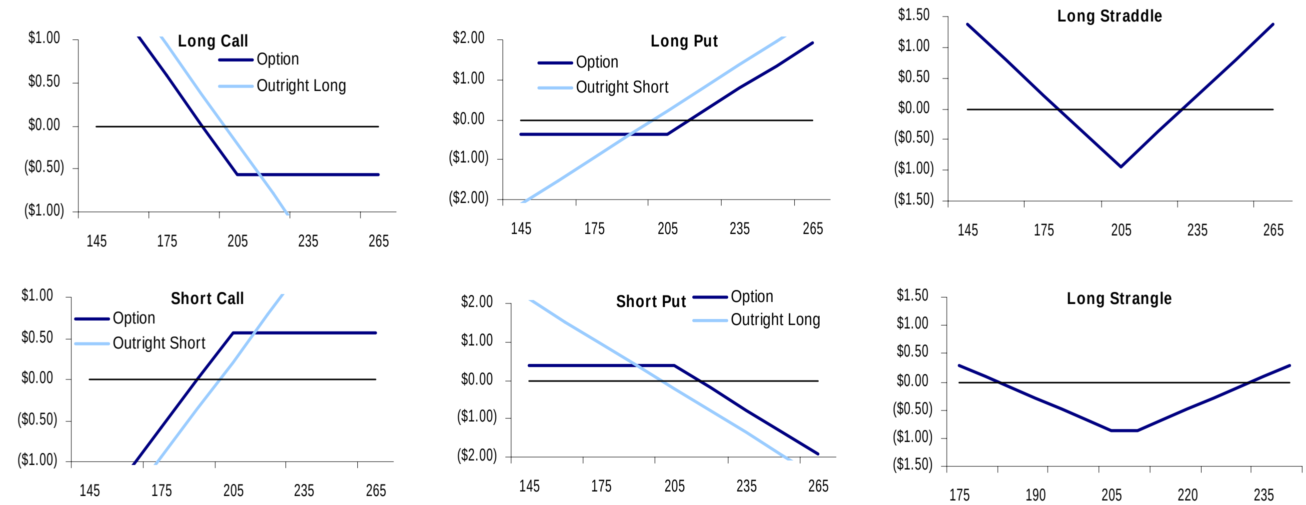
Basic option strategy payoff diagrams

Below we show the payoff diagrams for six common option strategies. Note that the "hockey stick" diagrams are reversed compared to equity option graphs because spreads, not dollar prices, are plotted on the x-axis. The charts plot the dollar gains and losses at expiry (y-axis) against the final index spread quoted in basis points (x-axis).

In the following paragraphs, we look at how to use these payoffs to express a spread or volatility view.

Figure 2: Payoff diagrams

The charts plot the dollar gains and losses at expiry (y-axis) against the final index spread in basis points (x-axis).



Source: JPMorgan.

Using options to express a spread view

Options can be used to express either a directional or range-bound market view. An investor who is Bullish on credit and expects the index to tighten can sell index protection or buy a receiver option. If he chooses to buy the option, he cannot lose more than his initial outlay, but will only benefit if spreads tighten past the strike.

Alternatively, the same investor may wish to sell a payer option, thereby receiving an upfront premium. So long as spreads remain below the option strike, the option seller will keep the full premium.

Straddle and Strangle are used for range-bound views

Investors can also express the view that spreads will remain range-bound by selling straddles or strangles (discussed in the next section). So long as spreads remain between the breakevens at expiry, an investor will keep all or part of the premium, irrespective of whether spreads move wider or tighter. However, an investor will lose on the trade if spreads widen past the breakevens at expiry.

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Using options to express a volatility view

Expressing the view that realised volatility will exceed option-implied volatility. Investors can also express a view that spreads will fluctuate without defining the direction of the move, i.e. trade implied volatility. The simplest way to buy volatility is to buy an At-the-Money (ATM) straddle. This position is initially spread neutral in that we would make an equal amount of money if spreads widened or tightened. We are therefore neutral to the direction of the spreads, but will benefit from a change in spreads.

However, in order to profit, we need spreads to move more than a breakeven amount. This breakeven is defined by the cost of the option, which in turn is defined by the implied volatility used to price the option. If the actual spread move (realised volatility) is greater than the breakeven (implied volatility) then the trade will be profitable. Equation 1 shows our daily Breakeven from Volatility.

Equation 1: Daily basis point volatility assuming 252 business days in a year

$$DailyVol(bp) = \frac{ForwardSpread \times AnnualVol(\%)}{\sqrt{252}}$$

where:
ForwardSpread = Adjusted Forward Spread on the index in basis points[1]
AnnualVol = Annualised percentage volatility

Combining spread and volatility views

Investors with a view on volatility can optimize their spread view. The Delta of an option measures how much the value of an option should change if the underlying asset moves by one unit. Since ATM options have a delta of 50% (i.e. a 1% change in the index P&L equates to a 0.5% change in our option P&L) we could buy two options in order to have the same exposure as one index.

In Exhibit 15.3 we show the payoff at expiry from buying two ATM options. Here, we take a directional view, outperforming the index if volatility is high; the options outperform if the final spread of the index is very high or low. In Exhibit 15.4 we have sold two ATM payer options and outperform the index if volatility is low.

Figure 3: Buying Two Payer Options Outperform if Volatility is High

y-axis: P&L (cents); y-axis: Final Spread (bp)

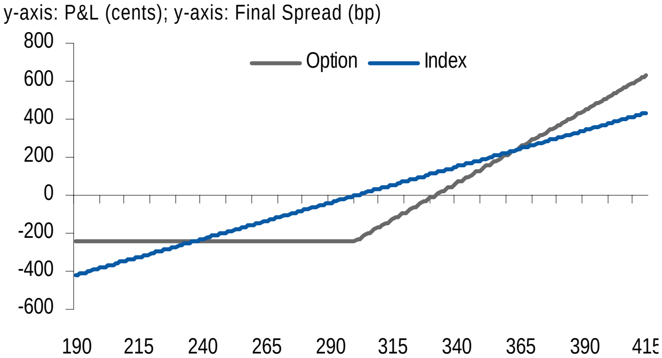
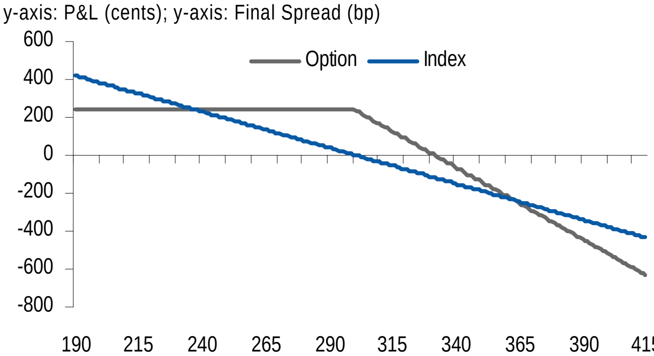


Figure 4: Selling Two Payer Options Outperform if Volatility is Low

y-axis: P&L (cents); y-axis: Final Spread (bp)



Source: JPMorgan.

[1] CDS index options are priced using the Black formula on the CDS forward. The forward is approximately equal to the spot plus the carry over the option term.

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Option trading strategies

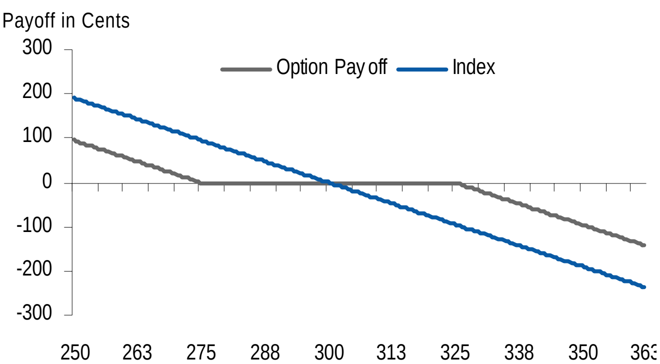
Having looked at how we can express views using payers and receivers, we look at expressing views by combining payers and receivers.

Bull Cylinders—spreads likely to move substantially tighter, but unlikely to widen. We form these by selling a put/payer option and buying a call/receiver option. Between the two strikes of the trade, the cost is close to zero and the trade will perform if spreads tighten. On the downside, if spreads move much wider, the trade will lose money, although it outperforms an outright short protection position (Exhibit 15.5). Variations on this strategy involve increasing the notional on one or both legs of the trade versus the index. Bear Cylinders are formed by selling a call and buying a put.

Bull Spreads – spreads likely to drift tighter, protection against wider spreads.

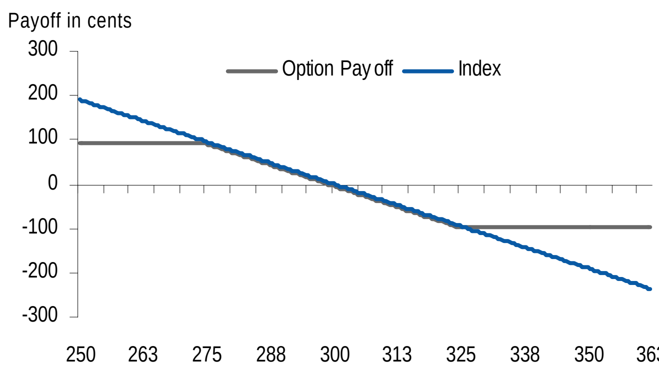
We form these by selling a low strike call and buying a high strike call (we can also form these with puts) (Exhibit 15.6). Between the strikes of the trade, the position performs inline with the index while if spreads widen, the losses are capped above the upper strike. The downside is that we lose, inline with the index, if spreads widen, however, we can only lose up to the higher strike of the trade. At this point we cap our loss. Bear spreads are also formed using different strike puts or calls.

Figure 5: Comparing a Cylinder to the Index



Source: JPMorgan

Figure 6: Comparing a Bull Spread to the Index



Source: JPMorgan

Market neutral strategies

There are three common market neutral strategies available when using options:

Straddles and Strangles – spreads to remain in a range.

These are formed by selling a payer and receiver either at the same (Straddle) or at different (Strangles) strikes. Between the breakevens, the position will make money. The downside is that we lose if spreads widen or tighten past the breakevens (Exhibit 15.7).

Butterfly– spreads likely to remain in a range.

These are formed by selling a straddle and buying a higher strike payer option and a lower strike receiver option. Between the breakevens, the position will make money. Our loss is capped if we move above or below the extreme strikes, although we don't make as much as an outright straddle.

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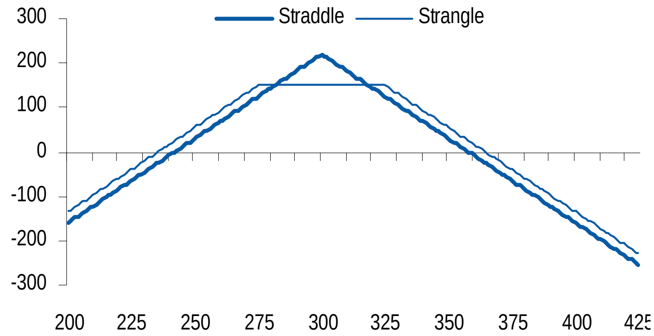
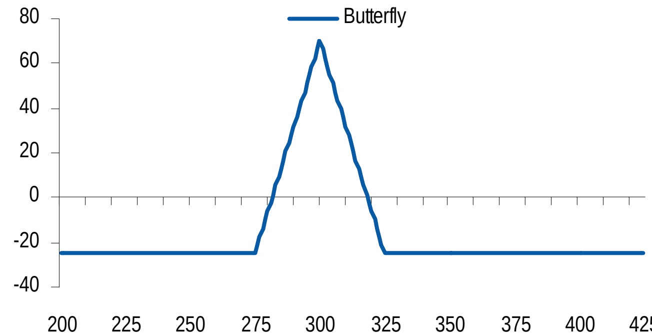
Figure 7: Straddles and Strangles



Source: JPMorgan

Figure 8: Butterfly



Source: JPMorgan

Other option trading strategies

Calendar Spreads –trading the difference between volatility for different expiries.
These are most commonly formed by trading straddles for different expiries. An investor who believes volatility will be low in the short term, but will pick up in the longer term may sell short-dated straddles and buy long-dated straddles. The notionals traded can be scaled to be Vega neutral, insensitive to changes in implied volatility, or Gamma-neutral, insensitive to changes in the index spread.

Skew Trading- trading the difference between options at different strikes
Skew measures the difference in implied volatility at different strikes. Although the index can have only one realized volatility, supply and demand dynamics often cause options at different strikes to trade with different levels of volatility. We tend to see options with higher strikes trade with higher implied volatility as investors buy cheap Out-of-the-Money payer options as portfolio protection. This causes positive skew.

Investors can trade options of different strikes to express the view that skew will increase or decline.

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The Practical Side to Trading Options

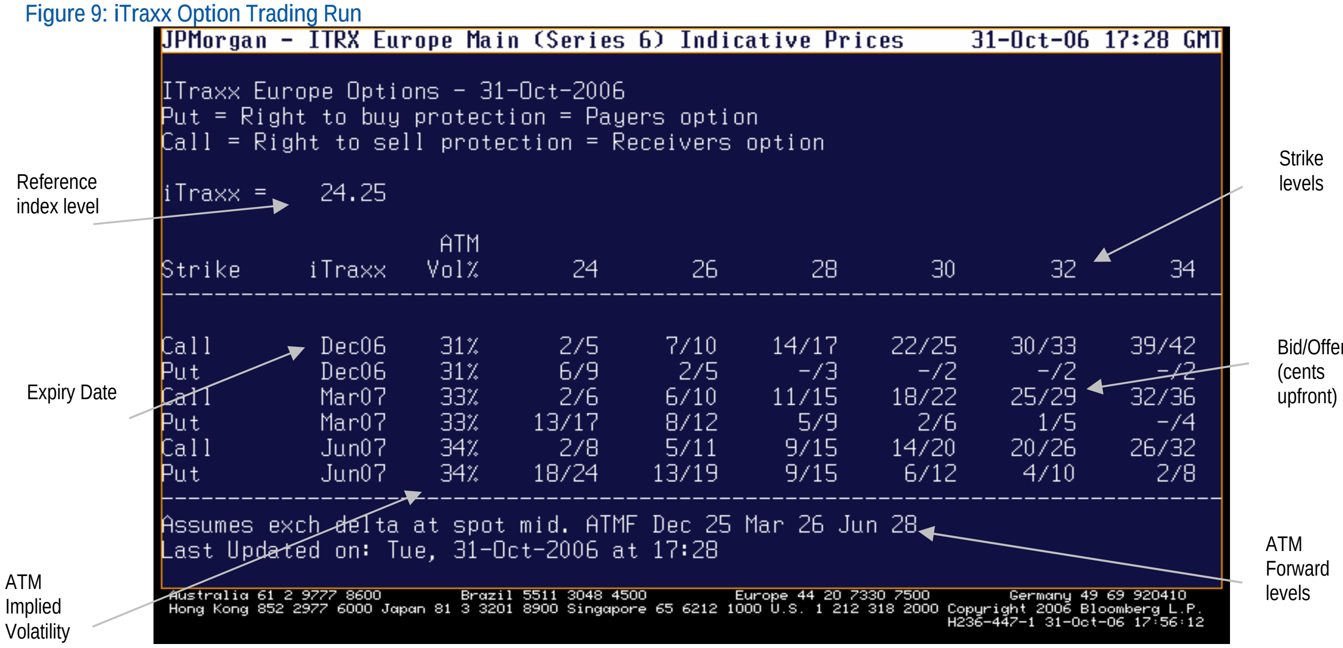
Having looked at the strategies we can use credit options for, we now look at the practical side of trading credit options. Exhibit 15.9 shows a typical Bloomberg screen we would see for iTraxx options (JITO <GO> on Bloomberg). Similar screens are available for CDX and runs are send out daily from option traders.

When using index options to express a spread view, there are three aspects we consider:

1. **Cost** – This is the upfront cost of an option and is the amount we pay if we buy an option, or receive if we sell an option. This amount is quoted in cents and is an upfront amount. Suppose an investor is concerned about spread widening and wants to buy the option to buy protection at 26bp out to 20 March 2007. From Exhibit 15.9 we can see that the cost of this option is 12c. On a notional trade of $10,000,000, an investor will pay $12,000.

2. **Breakeven** – the trade breakeven tells us the level spreads need to be at expiry in order to recoup the initial cost of buying the option. Continuing with our example above, if spreads are wider than 26bp at expiry, our option will be in-the-money. For each basis point above 26bp we will make approximately 1bp × duration. So assuming a duration of 4, we will make 4c for each bp the index is wider than 26bp at expiry. Therefore if the index is above 29bp, we will recoup the full cost of the option. We call 29bp the breakeven.

Figure 9: iTraxx Option Trading Run


JPMorgan - ITRX Europe Main (Series 6) Indicative Prices 31-Oct-06 17:28 GMT

ITraxx Europe Options - 31-Oct-2006
Put = Right to buy protection = Payers option
Call = Right to sell protection = Receivers option

iTraxx = 24.25

Strike	iTraxx	ATM Vol%	24	26	28	30	32	34
Call	Dec06	31%	2/5	7/10	14/17	22/25	30/33	39/42
Put	Dec06	31%	6/9	2/5	-/3	-/2	-/2	-/2
Call	Mar07	33%	2/6	6/10	11/15	18/22	25/29	32/36
Put	Mar07	33%	13/17	8/12	5/9	2/6	1/5	-/4
Call	Jun07	34%	2/8	5/11	9/15	14/20	20/26	26/32
Put	Jun07	34%	18/24	13/19	9/15	6/12	4/10	2/8

Assumes exch delta at spot mid. ATMF Dec 25 Mar 26 Jun 28
Last Updated on: Tue, 31-Oct-2006 at 17:28

Australia 61 2 9777 8600 Brazil 5511 3048 4500 Europe 44 20 7330 7500 Germany 49 69 920410
Hong Kong 852 2977 6000 Japan 81 3 3201 8900 Singapore 65 6212 1000 U.S. 1 212 318 2000 Copyright 2006 Bloomberg L.P.
H236-447-1 31-Oct-06 17:56:12

Source: JPMorgan

Equation 2: Calculating the Breakeven of an Option

$$Breakeven = Strike + \frac{Upfront}{ForwardAnnuity}$$

$$Forward\ Annuity = Annuity\ of\ for\ a\ forward\ trade$$

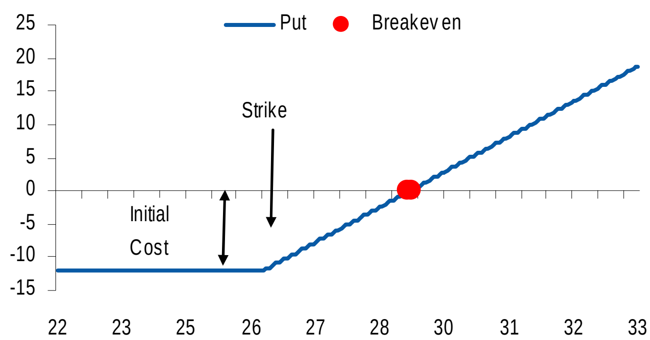
3. **Final P&L** – lastly, we look at our expected P&L in the case that spreads reach a certain level. If we buy a payer option and spreads remain below the strike at expiry, we will lose our upfront premium. For each basis point above our strike we will make 1bp × duration. Therefore, our P&L is shown in Equation 3.

Equation 3: Calculating the Final P&L of an Option

$$Final\ P\ \&\ L = [(FinalSpread - Strike) \times ForwardDuration - Upfront] \times Notional$$

Figure 10: Trade Analysis

y-axis: Final P&L (cents); x-axis: Final Spread (bp)



Source: JPMorgan

Delta-Exchange – The cost of trading outright

Another aspect to consider when trading options is that prices are usually quoted with delta-exchange. This means that an investor who purchases an option with a delta of 30% will also acquire an index position equal to 30% of the notional of the trade. This happens because option traders need to hedge their spread exposure. A trader who sells a $10,000,000 notional payer option with a delta of 30% and simultaneously buys index protection on $3,000,000 notional, will initially be neutral to spread changes in the index.

Therefore, investors who want to trade options outright and do not want this delta-exchange will need to exit their delta position. The cost of this is just the cost of exiting an index trade on the delta notional, Equation 4.

Equation 4: Cost of Exiting Delta

$$Cost = \frac{1}{2} \times (Bid, Offer) \times Annuity \times Notional$$

Source: JPMorgan

Suppose we want to buy the March payer option with a strike of 26, quoted in Exhibit 15.9, as an outright trade. The option is quoted as 8/12, so would cost us 12c to enter. If we assume that our delta is 50% and we wish to trade outright, then we would need to unwind our delta. If the bid/offer on the index is 0.25bp and the annuity is 4, then the cost of this unwind is 0.5c (= 1/2×0.25bp×4). Therefore, on a notional of $10,000,000 we would pay $12,000 for the options and $500 for the delta unwind giving a net cost of $12,500.

The Adjusted-forward – Accounting for "No Knockout"

We price CDS options using the forward rather than spot CDS spread. This is because the model we use is a Black model that relies on lognormal distribution of spreads at maturity. This forward is calculated in the usual fashion (Equation 5).

Equation 5: Calculating the Forward between time s and t

$$F_{s,t} = \frac{S_t A_t - S_s A_s}{A_t - A_s}$$

where
S_t = *Spreads for Maturity t*
A_t = *Risky Annuity for Maturity t*

However, we adjust the forward to account for the "No Knockout" feature of index options. If a name in the index defaults before the expiry of the option, we will be entered into an index with a defaulted name at expiry of the option. If we had bought a payer option, we could trigger the contract and collect on the defaulted name. Therefore, we have received protection from today, even though the forward only offers protection from the option expiry.

We account for this additional protection by increasing the forward spread by the cost of protection. This makes payer options more expensive and receiver options cheaper because payer buyers receive protection on the spot and receiver buyers forgo this protection.

Equation 6: Calculating the Adjustment

$$Adjustment = \frac{S_s A_s}{A_t - A_s}$$

Our adjusted-forward, which we use for pricing CDS options, is the sum of Equation 5 and Equation 6. It is roughly equal to our spot plus carry as a running spread.

Equation 7: Calculating the Adjusted Forward

$$\begin{aligned} AdjustedForward &= \frac{S_t A_t - S_s A_s}{A_t - A_s} + \frac{S_t A_s}{A_t - A_s} \\ &= S_t + \frac{S_t A_s}{A_t - A_s} \\ &\approx Spot + \frac{Carry}{ForwardAnnuity} \end{aligned}$$

Exercising an option with a defaulted name in the portfolio

We present below an example on expiry mechanics for options on the Dow Jones CDX.NA.HY Swaps. The expiry mechanics for options on CDX.IG and iTraxx work similarly.

Expiry mechanics of options: The option contract is not directly affected by credit events prior to the expiry date of the option. The option holder continues to have the right to buy or sell the "old" CDX.HY product (the product with the original reference entities) at the agreed strike price. After exercising the option, the buyer of protection can trigger the contract under the standard procedures if he chooses.

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An example below demonstrates the expiry mechanics:

- Strike = $102
- Price at expiry of "new" CDX.HY Swap (with 99 underlying credits) = $101
- Price at expiry of bonds of the credit that defaulted (recovery rate) = $0.25

Settlement process at expiry

- Investor exercises the call: he buys the "old" contract for a price of $102 (the strike)
- The seller of the contract then triggers the defaulted name: investor pays $1.00
- Investor receives default bond worth $0.25

The net result suggests an equation that can be used to evaluate whether to exercise the option. Exercise a long call option if:

	Strike on "old" CDX.HY contract		$102.00
+	Defaulted credit notional value		$1.00
-	Recovery value of defaulted credits		($0.25)
	Cash cost to buy "new" DJ CDX.NA.HY through the option		$102.75

Source: JPMorgan

In this example, the cash cost to buy new CDX.HY in the market is $101.00 * a factor of 0.99 = $99.99. The investor would not exercise the option, as it is $2.76 out of the money.

In practice, the recovery rate of the defaulted bond is determined by the CDS Settlement protocol auction process, described in Part I.

Accrued interest

An outright position pays accrued interest on a defaulted credit up to the credit event date. At expiry, the settlement amount for an option on the index will be adjusted to reflect the same economics.

Option pricing model

We use option pricing models either to calculate option prices from volatility levels, or to calculate implied volatility levels from input prices.

Two such models are easily accessible to investors; JPMorgan's Excel based model and the CDSO Bloomberg screen. Both models use the Black pricing formula on the forward and return very similar results. The reader is referred to Bloomberg's own documentation on their model or to our previous note *Credit Option Pricing Model October 2004*.

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Section 2: Trading Credit Volatility

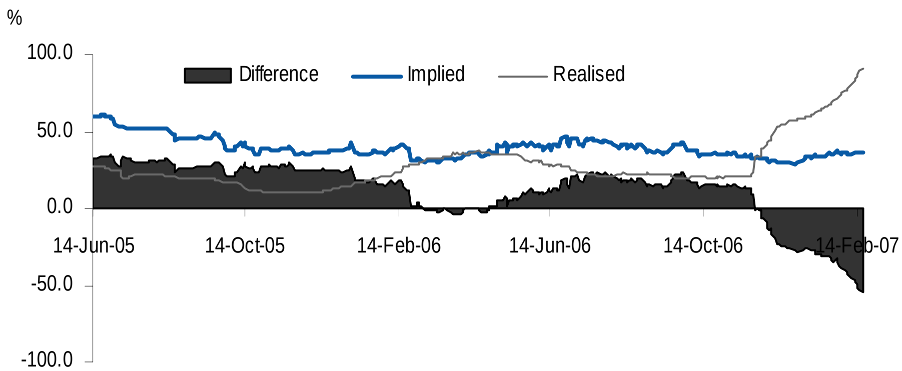
Trading Credit Volatility allows investors to generate alpha by expressing a view about the volatility of credit spreads. The introduction of a liquid market in CDS index options has allowed investors to trade credit volatility. By doing so, investors are able to gain the benefits of exposure to an asset that is not perfectly correlated to the level of spreads.

We think that there are profits to be made from trading volatility. This section explains what credit volatility is and how investors can trade it. Investors can actively manage their option exposure through expedient delta-hedging.

The cost of trading volatility through expedient delta-hedging can be estimated and is not prohibitive. Furthermore, as more investors and dealers enter the underlying index as well as the option market, we expect these costs to decline further. An investor should carefully consider how much he expects to make from a trade and how much it may cost him in transaction costs.

In credit, implied and subsequent realised volatility frequently trade apart, meaning that investors are able to take advantage of this dislocation. The last eighteen months have shown two distinct periods when trading volatility would have been profitable. These profits are available to investors who wish to express a more nuanced view on the credit market, which is not necessarily market directional.

Figure 11: iTraxx Crossover Implied versus subsequent Realised Volatility



Source: JPMorgan

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Section Description

In Section 1, **The Basics**, we define volatility for the credit market and discuss the difference between realised and implied volatility. By converting percentage volatility into daily basis point volatility, we present a rule-of-thumb measure for assessing volatility and deciding in an intuitive manner whether volatility is cheap or expensive.

We describe the two driving factors of the P&L of volatility trades, namely changes to implied volatility (vega trading) and the difference between implied and realised volatility (gamma trading). These allow us to take exposure to an asset that is less than perfectly correlated with the credit market.

In Section 2, **Delta-Hedging**, we look at the strategy employed in volatility trading. When we buy an option and a delta amount of the underlying asset, we are neutral to small changes in the underlying. However, as the price of the asset changes, our delta changes and we will need to adjust our position in the underlying in order to remain delta-neutral. This process of adjusting our position, along with the changing price of the option will result in our P&L from delta-hedging.

Investors looking to trade volatility can either buy ATM options and delta-hedge these, or they can buy ATM straddles. We explain why these are equivalent and why an investor might choose one over the other. Since credit spread options are priced using the forward spread, delta-hedging requires that we own a delta amount of the forward. Since this is not possible, we explain why owning the spot is a good approximation for this.

Once we have seen how to trade volatility, Section 3, **The Returns from Delta-Hedging in Credit**, shows how to calculate our expected returns from a volatility trade. Returning to the two P&L drivers we introduced earlier – vega trading and gamma trading – we show how to estimate the returns from these factors. We explain that we may not achieve this expected amount since we cannot trade continuously but must do so in discrete time. The upside of this is that it gives successful investors the opportunity to outperform their expected return.

Section 4, **Transaction Costs,** describes the factors we need to look at in order to estimate the cost of trading volatility. The two costs we look at are the bid/offer of the option and the bid/offer cost of adjusting our delta position. We look at these costs for an index trade and conclude that while they are substantial they are not inhibitive.

This section, combined with the Section 3, tells us the net returns from trading volatility. An estimate of our returns, combined with an estimate of our cost will tell us how much we expect to make over the life of the trade.

Finally, in Section 6, **Historical Analysis**, we look at whether trading volatility has been a profitable strategy. Over the last 12 months, we have seen two distinct periods when buying and selling volatility would have been profitable.

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The Basics

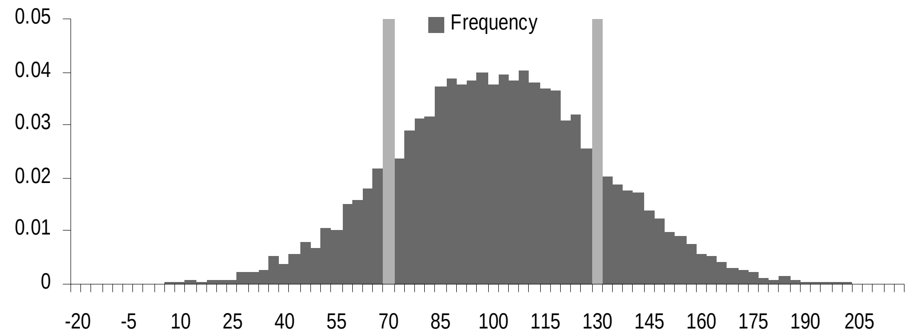
- Volatility in credit is a measure of the standard deviation of spreads
- Volatility trading aims to take advantage of changes to implied volatility, or implied volatility differing from realised volatility
- Our daily basis point volatility tells us how much spreads need to change in order to offset the cost of an option

What is Volatility?

Before describing volatility trading we should settle on a definition of volatility. Volatility is defined as the annualised standard deviation of percent change in the underlying price or spread[2]. For example, a volatility of 30% can be interpreted as a 68% chance (1 standard deviation) that the asset will be +/- 30% of the current level a year from now.

Figure 12: Standard Normal Distribution

Bars Indicate 1 Standard Deviation From The Mean. 68% of the distribution lies in this area.



Source: JPMorgan

We generally talk about two types of volatility:

- **Historical** (also called actual, delivered or realised) volatility is the volatility of a particular asset as measured by its past price movements.
- **Implied** volatility is the volatility that is forecast by the pricing of options on the asset. This volatility is an output from the Black pricing formula for options.

Implied volatility tends to be somewhat higher than realised, as sellers of volatility, who cannot hedge themselves in continuous time, are exposed to spread jumps, which may leave them under-hedged.

[2] $Vol = \sum \sqrt{\frac{\left(x_i - \bar{x}\right)^2}{n-1}}$, where $x_i = \ln\left(\frac{s_t}{s_{t-1}}\right)$ and s_t = CDS spread on day t

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In Credit, it is often more convenient to talk in terms of daily volatility in basis points (basis point volatility) rather than annualised volatility in percentage terms. We can convert annualised volatility into daily volatility in basis points using the following formula:

Equation 8: Daily basis point volatility assuming 252 business days in a year

$$DailyVol(bp) = \frac{ForwardSpread \times AnnualVol}{\sqrt{252}}$$

where:

ForwardSpread = Adjusted Forward Spread on the index in basis points[3]
AnnualVol = Annualised percentage volatility

In Appendix II we show that this amount is our daily breakeven from volatility. In a long volatility trade, our daily spread move needs to be greater than this amount in order for the trade to be profitable. This daily volatility amount gives an intuitive feel for whether options are expensive or not. **If we think it will be exceeded by realised spread moves over the option term it is worthwhile buying volatility. The reverse holds if we think daily spread moves will be less than this amount.**

Profiting from Volatile Markets

Volatility trades seek to benefit either from changes to implied volatility or to realised volatility differing from implied volatility

Trading volatility allows investors the possibility to generate alpha through views that are not market directional. Pure volatility trades seek to benefit from exposure to volatility and are designed to be neutral to market direction. In particular, volatility positions seek to benefit from the following:

- **Changes in implied volatility**: an increase in implied volatility benefits a long option position as the options become more valuable
- **Differences between implied and realised volatility over the trade horizon**: realised volatility that is higher than implied should benefit a long volatility position

A dynamically delta-hedged position, also known as a gamma position, is designed to take advantage of the two trading characteristics above. For example, a long delta-hedged option position should make money if implied volatility rises or if the index realised volatility is greater than the volatility implied by the original cost of the options. (See Appendix I for a reminder of the greeks.)

The simplest way to construct a long gamma position is to buy ATM options on an index and dynamically delta-hedge (see section below) by regularly trading the index in appropriate amounts in order to maintain a net market-neutral (i.e. delta-neutral) position.

[3] CDS index options are priced using the Black formula on the CDS forward. The forward is approximately equal to the spot plus the carry over the option term.

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Delta-Hedging

- The initial cost of an option is the cost of replication
- Trading straddles may be cheaper than delta-hedging a payer or receiver
- The forward is equal to the spot plus carry

What is dynamic delta-hedging?

The delta of an option measures how much the theoretical value of an option should change if the underlying asset moves by 1 unit. **A positive delta means the option should rise in value if the underlying spread widens**. In credit, call deltas range between -1 and 0 while put deltas range between 0 and 1.

An investor can **replicate** the payoff from an option by establishing and regularly adjusting a position in the underlying index asset (CDX or iTraxx). The amount of the index that an investor needs to own is given by the delta of the option (See Appendix I for a recap of delta and the greeks).

As the spread on the index changes, the delta of the option will change and the investor will need to adjust his position for the replication to work. In order to replicate the payoff from a long call/receiver (short protection) an investor will have to sell protection when spreads tighten and buy protection when spreads widen. He will therefore buy protection at a higher spread and sell it at a lower spread. This process of selling low and buying high is the cost of replicating an option.

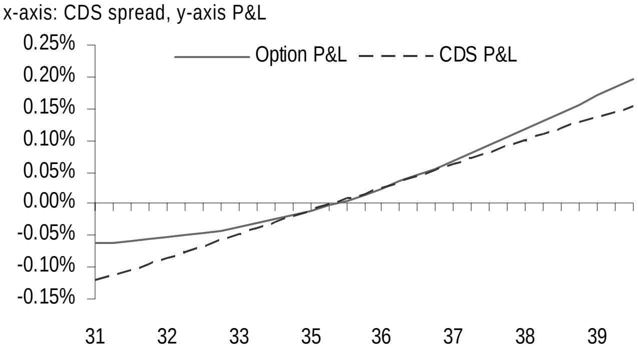
Reminder:

Call = Receiver, Put = Payer

Essentially, **the initial cost of an option should be equal to the cost of replicating it**. If the cost of replicating an option is more expensive than the initial cost, an investor should buy the option and delta-hedge it. This means that he should take the opposing position in the underlying index. An investor who buys a payer option (long protection) should therefore sell protection on the index in the delta amount and adjust this hedge as the index spread moves.

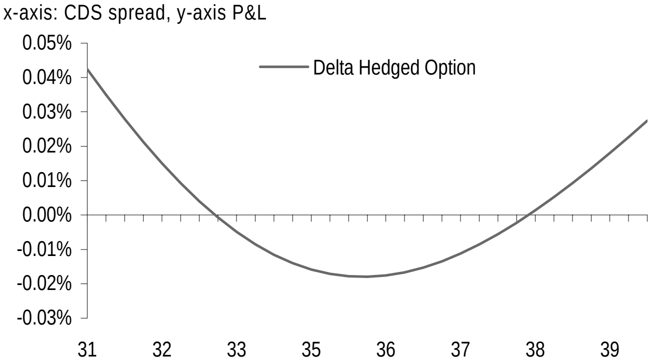
Since the initial cost of an option is given by the implied volatility, and the cost of replicating the option is given by the realised volatility, an investor who buys a delta-hedged option will make money if realised volatility is higher than the initial implied volatility.

Figure 13: Instantaneous P&L on Option and Delta Replication
x-axis: CDS spread, y-axis P&L



Source: JPMorgan

Figure 14: P&L on Delta-Hedged Option over a period of time
x-axis: CDS spread, y-axis P&L



Source: JPMorgan

In Figure 14 we show the P&L from two positions – an ATM payer and a delta amount of the index (both long protection). We can see that these two trades differ due to the convex nature of the option P&L. A long payer combined with a delta short index protection trade gives us the payoff in Figure 14. Our P&L dips below the x-axis as our option loses value over time. As we show in Appendix II, the loss over this period is given by our implied basis point volatility. In order to recoup this loss we therefore need the index spread to move more than our basis point volatility over the period we consider.

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How to Trade Volatility in Credit

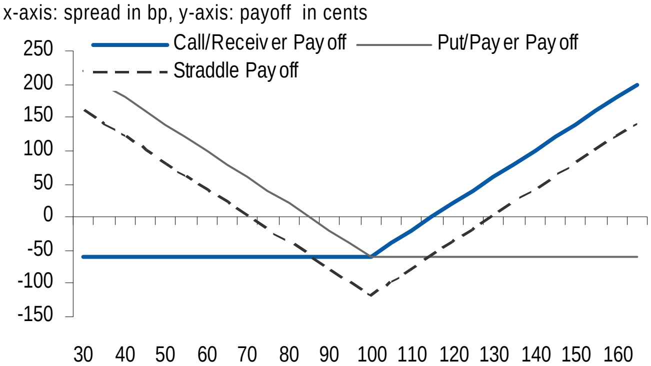
Now that we have seen that delta-hedging involves buying an option and taking an opposing position in the underlying, we consider how this is most commonly done in practice.

Trading Straddles rather than Calls or Puts

Rather than buying a single option and delta-hedging this over the term of the option, a common strategy for trading volatility is to buy an ATM straddle (a call and put at the same strike) and delta-hedge this over the option term. In this way, the delta of our call and put net off against each other (our initial delta should be close to 0) and we need only purchase a lower amount of the underlying index, than had we bought a call or put and delta-hedged these. Essentially **a long straddle is equivalent to purchasing two delta-hedged calls or puts**[4] (Figure 15 and Figure 16). If, however, the cost of an ATM put and call differs, it may be preferable to buy two of the cheaper options and delta-hedge these.

Figure 15: Forming a Straddle from a Payer and Receiver

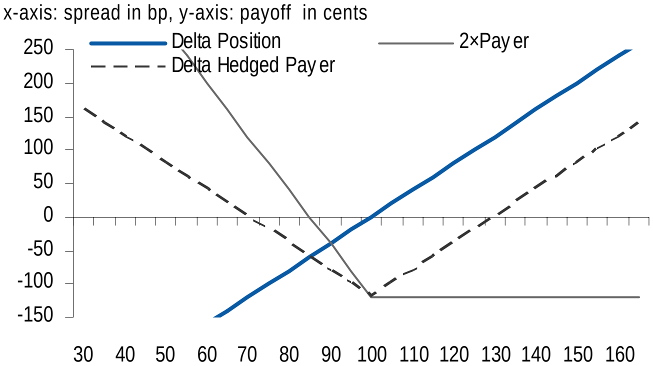
x-axis: spread in bp, y-axis: payoff in cents



Source: JPMorgan

Figure 16: Forming a Straddle from Two Delta-Hedged Payers

x-axis: spread in bp, y-axis: payoff in cents



Source: JPMorgan

Spot versus Forward

Since we price credit options using the forward spread rather than the spot, our delta-hedging strategy demands that at all times we own a particular amount of the underlying index forward. Since the forward does not trade, owning the forward is not possible in practice. However, since index options have a "no knock-out" feature[5] and are short-dated, trading the spot is equivalent to trading the forward. Essentially**, the forward is just the spot plus the carry to the option expiry**. So trading the forward is similar to trading the spot and paying the carry at the option expiry.

Having seen how we can delta -hedge credit options to isolate the volatility component, we look at the returns and costs of such a strategy.

[4] The payoff from a delta-hedged call is 1/2×|underlying-strike|×Notional×Duration, while the payoff from a straddle is |underlying-strike|×Notional×Duration

[5] CDS index options do not knock out if there is a default in the underlying portfolio of names. Conversely, single name CDS options do knock out on default as the two legs of the forward trade cancel each other.

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The Returns from Delta-Hedging in Credit

- Our expected return from vega trading is the change in volatility times the vega
- Our expected return from gamma trading is the difference between implied and realised volatility times our vega
- Longer-dated options are better for vega trading, while shorter-dated options are more suited to gamma trading

So far, we have shown how to trade volatility through buying or selling delta-hedged options. We now look at our expected return from such a strategy in order to assess whether it is a worthwhile trade to employ. In this section we will show how to estimate the returns from gamma and vega trading and explain why we may not achieve our expected returns. Throughout this section, we assume that there are no costs to delta-hedging the option – we will deal with these costs in the next section.

Gamma Trading and Vega Trading

As we noted earlier, a long volatility trade aims to profit from two factors:

4. Rising implied volatility – which increases the value of an option

5. Realised volatility exceeding implied volatility – which means more delta-hedging and therefore more profits

We often refer to the first of these a *Vega trade* and the second a *Gamma trade* since the first aims to take advantage of rising volatility and the second of changes to the option delta – i.e. gamma.

The Expected Returns from Vega Trading

A delta-hedged option is neutral to small spread changes in the underlying index. However, the P&L of such a position will change as implied volatility changes. Higher implied volatility will generally lead to higher option prices and an investor who is long volatility through buying a delta-hedged option will benefit from this. We call the sensitivity of option prices to changes in volatility the Vega of an option.

For an ATM option, the price of the option can be approximated by:

Equation 9

$$Price \approx \frac{1}{\sqrt{2\Pi}} \times \sigma_{Implied} \times \sqrt{OptionTerm} \times Forward \times Annuity$$

where:

$\sigma_{Implied}$ = *Implied Volatility of the Option*
OptionTerm = Time to option expiry
Forward = Forward spread of the underlying index
Duration = Forward duration of the index

Therefore the Vega of the option is:

Equation 10: Vega for an ATM Option

$$
\begin{aligned}
Vega &\approx \left(\frac{1}{\sqrt{2\Pi}} \times \sigma_{Implied} \times \sqrt{time} \times Forward \times Annuity\right) \\
&\quad - \left(\frac{1}{\sqrt{2\Pi}} \times (\sigma_{Implied} + 1) \times \sqrt{time} \times Forward \times Annuity\right) \\
&\approx \frac{1}{\sqrt{2\Pi}} \times \sqrt{time} \times Forward \times Annuity \\
&\approx \frac{Price}{\sigma_{Implied}}
\end{aligned}
$$

Therefore, each percentage point rise in volatility of an ATM option, will make a profit proportional to the option cost divided by the implied volatility. If the index forward trades away from the ATM point, this relationship will no longer hold. As we move away from the ATM point, our sensitivity to changes in implied volatility will decline.

Vega trading is best performed with longer dated options as these have a higher price sensitivity to changes in implied volatility and have a lower gamma (and theta) since the delta of the option changes less with a spread change in the underlying.

The Expected Returns from Gamma Trading

Now that we have seen our expected returns from changes in volatility, we turn to the other driver of our P&L - the difference between implied and realised volatility. In what follows, we show that the expected return has a distribution that is dependent on the frequency of adjusting our delta-hedge.

In Appendix IV we show that a linear approximation for the expected P&L from delta-hedging an option to expiry is:

$$P\&L \approx \frac{1}{\sqrt{2\Pi}} \times \sqrt{time} \times Forward \times Annuity \times (\sigma_{Realised} - \sigma_{Implied}).$$

We call this an expected P&L because in reality a number of factors may mean that we do not actually realise this P&L. The primary reason for this is that the Black pricing formula gives us a price for an option in a world where we can continuously buy and sell an asset in order to be delta-neutral. In reality, continuous hedging is not feasible and we must content ourselves with weekly, daily or inter-day hedging. The more frequently we hedge, the more likely we are to earn our expected return.

In order to illustrate this we have performed a Monte-Carlo simulation of delta-hedging a three-month option to expiry with realised and implied volatility equal. Figure 17 shows the distribution of P&L at expiry. Our mean return is 0, as expected, although there is a distribution around this mean. As we move from daily to weekly hedging, our mean remains at 0, however our distribution flattens meaning the chance of out or underperforming this mean increases.

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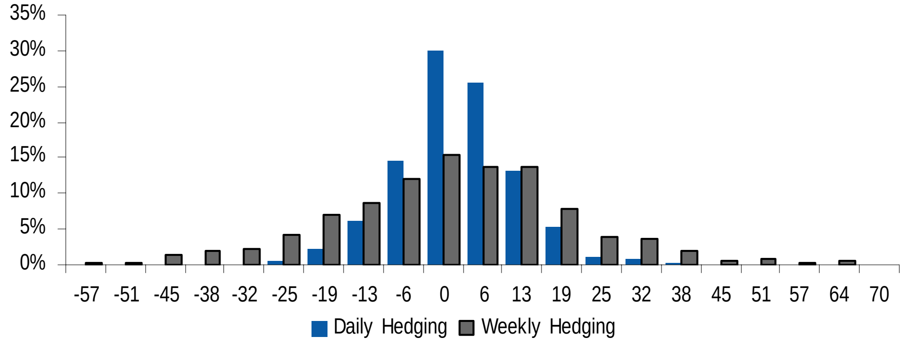
Figure 17: P&L Distribution for Weekly and Daily Hedging

x-axis: P&L in cents, y-axis: Frequency



Source: JPMorgan

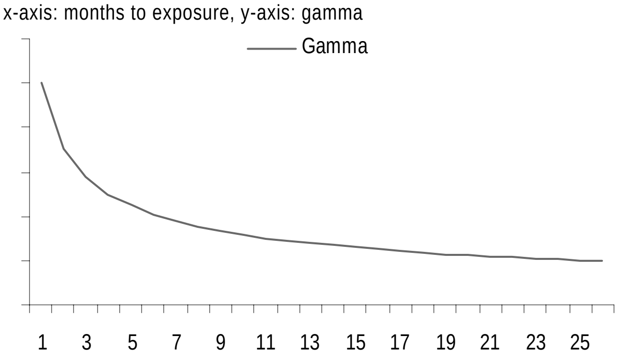
Option traders will likely use an alternative strategy to just hedging weekly or daily. Sometimes, they may wish to be under-hedged in order to profit from changes in the option price and not pay this away through their delta-hedge. A volatility trader hopes not only to make his expected P&L, but to make more than this through expedient delta-hedging.

In Appendix IV we examine the relationship between our expected P&L and the path that our spread takes over the life of the option. We find that if the spread remains around the ATM point the opportunity to outperform our expected P&L increases, while as we move away from this point, we will make our expected P&L with greater certainty. Therefore investors who want to take advantage of expedient delta-hedging should look to trading ATM options as there provide the highest gamma and opportunity for outperformance.

Gamma trading is best performed with shorter dated options since out P&L from gamma increases as we move closer to expiry (Figure 18). The higher the gamma of our option, the more frequently we will have to adjust our delta-hedge and the more we will be able to sell high and buy low. Higher gamma will be accompanied by higher theta as we move towards option expiry (Figure 19).

Figure 18: Gamma Exposure with Time to Expiry

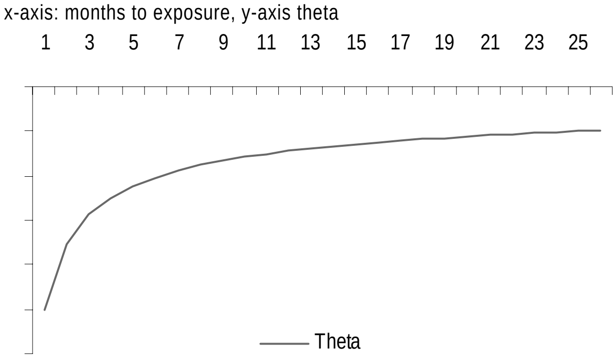
x-axis: months to exposure, y-axis: gamma



Source: JPMorgan

Figure 19: Theta Exposure with Time to Expiry

x-axis: months to exposure, y-axis theta



Source: JPMorgan

Outright Straddles versus Delta-Hedging Options

An investor who buys an ATM straddle (assuming a delta of zero) is hoping that at maturity of the trade, the spread on the index is above or below the breakevens of the trade. I.e. the index spread has moved more than the initial implied volatility predicted. Essentially then, a straddle is a delta-hedged option which only has an initial delta-hedge. The expected payoff is then the same as a delta-hedged option, but the standard deviation around this mean will be large. Longer dated straddles will have a less variable delta and are therefore suitable for trading views on implied volatility.

An Example

In Appendix III we show a detailed example of delta-hedging an option over a one month period. The reader is referred here for a more detailed understanding of how delta-hedging works.

Having seen the returns from different frequencies of delta-hedging, we turn analysing the cost of delta-hedging.

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Transaction Costs

- We need to account for the bid/offer cost of trading volatility both for entering/exiting the trade and delta-hedging
- These costs can be substantial, but are not inhibitive
- We present a formula for estimating these costs

We now turn to the final part of the story, the transaction costs involved in trading volatility. We have so far ignored these costs as they depend on the liquidity of the iTraxx and CDX options and the underlying indices. We expect these costs to decline over time as the market matures. Essentially, there are two aspects to this:

- Bid/Offer cost of entering/exiting an option trade
- Bid/Offer cost of adjusting a delta position

In the following analysis we show that while the cost associated with delta-hedging can be substantial, they are not overly onerous and can be minimised through expedient hedging. For a six-month option, we find that to cross the full bid/offer of the option would cost us 2.4 vegas. (We would only pay half of this if we held the option over the full term.) Additionally, the cost of weekly delta-hedging is expected to be around 1.9 vegas.

Bid/Offer cost of entering/exiting an option trade

The first of these costs is easy to see; it is just the bid/offer cost of an option as quoted from a trading run. At present JPMorgan quotes bid/offer cost approximately equal to those shown in Table 2. Since the vega of an ATM option is roughly equal to the ratio of price to volatility [6] (see Equation 10), we can estimate the cost of trading in and out of options in terms of volatility (Vegas). From Table 2 we can see that on iTraxx Crossover, the option bid/offer cost in terms of volatility is around 2.4%. This means that if we had bought options and delta-hedged them, implied volatility would need to increase by 2.4% in order for us to breakeven on the trade (excluding any P&L from delta-hedging).

This, of course, assumes that we trade out of the option prior to expiry. If we held the option and delta-hedged to expiry, we would only have to pay half the bid/offer, in order to enter the trade. If the option ended OTM at expiry, then we would not be delivered an index contract and would have no index delta position. If the option ended ITM, then our delta position would net off with our delivered index.

Table 2: Estimating Bid/Offer Cost for a Six-Month Option

Index	Bid/Offer (c)	Price (ATM Option) (c)	Bid/Offer as % of Price	Volatility (%)	Bid/Offer in Vols (%)
Main	4	18	23%	40%	9.0%
HiVol	5	34	15%	40%	6.0%
Crossover	8	135	6%	40%	2.4%

Source: JPMorgan

[6] An option priced at 20c with a volatility of 30% will increase in price to 30c if volatility increases to 45%.

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Bid/Offer Cost of adjusting delta position

The second cost we need to take into account is the cost of adjusting our delta-hedge as the spread on the index moves. We do this in order to ensure that we own enough of the underlying index to match the option delta. Unfortunately, there is no way of knowing *a priori* what the cost of adjusting our delta is since it is dependent on a number of factors. We can however calculate the *expected* cost of hedging, which we show in Appendix V. It turns out that for an ATM option, our cost of delta-hedging is equal to:

Equation 11: Average Cost of Delta-Hedging over Option Term

$$Cost = \frac{1}{2} \times BidOffer \times Annuity \times \frac{\sqrt{n}}{\Pi}$$, where n is the number times we hedge.

Our cost is therefore dependent on three factors:

- **Bid/Offer:** Clearly the higher this cost, the more expensive it will be each time we trade. More important than the absolute bid/offer cost is the cost as a percent of the option price. The higher this is, the more we need to make from volatility trading in order to cover this.
- **Frequency of hedging**: As we increase the number of times we hedges, n, our cost increases by a factor proportional to $\sqrt{n}$, so if we quadruple the term of our option, or quadruple the frequency of hedging, we will double the cost of hedging. Less frequent hedging is therefore more cost efficient, however, as we saw earlier, the cost of this is that while our expected P&L from the trade remains the same, our distribution around this P&L increases (Figure 17).
- **Spread path:** The spread path will determine how much we need to adjust our delta. As the spread moves away from the strike, we will need to adjust our delta less frequently as our gamma declines (gamma is highest ATM).Therefore the further we move from the strike, the less we need to adjust our delta. Figure 27 shows the sum of our delta changes against our final spread (a proxy for the spread path). The further we move from our strike, the lower this sum.

Interestingly, we find that the following factor does not affect our delta-hedging cost for an ATM option:

- **Volatility:** On the one hand, the volatility will determine the distribution of our spread and hence will impact the size of our delta change. A more volatile index is more likely to move away from the ATM point, thus reducing our daily delta change. However, higher volatility will also result in bigger spread changes, meaning that our delta will have to be adjusted more frequently or by a larger amount. These two factors balance each other to reduce the effect of volatility on our costs.

In Table 3 we show the cost of delta-hedging a three month option in each of the three iTraxx indices given different frequencies of re-hedging. We arrive at these costs by using Equation 11 and the tables shown in Appendix V. If we assume a realised and implied volatility of 40%, then we can calculate the hedging cost as a percent of the option price. We can then convert this into a Volatility amount as shown in the last three columns of Table 3. These tell us our hedging costs in volatility points ie how much we need to make from volatility in order to cover the hedging costs. For example we can see that weekly delta-hedging of iTraxx Crossover would cost 1.9% in volatility terms.

Table 3: Expected Cost of Delta-Hedging a Six-Month Option

	Cost (c)							Delta Trading Cost in Vols (%)		
	Daily	Weekly	Fortnightly	Duration	Bid/Offer (c)	ATM Volatility	Option Price	Daily	Weekly	Fortnightly
Main	2.0	0.9	0.6	4.5	0.25	40%	18	4.6%	2.1%	1.5%
HiVol	3.9	1.7	1.2	4.3	0.5	40%	34	4.6%	2.1%	1.5%
Crossover	14.6	6.5	4.6	4.0	2	40%	135	4.3%	1.9%	1.4%

Source: JPMorgan

We have seen in this section that the cost of trading volatility can be significant. An investor who weekly delta-hedges a six-month option on iTraxx Crossover will need to pay 1.2 Vegas (bid/mid) in option costs and 1.9 Vegas in hedging costs (Table 2 and Table 3). He would therefore need to make more than this from either a rise in volatility over the option term, or the difference between implied and realised volatility. The rise in volatility would only help if he closed out the option earlier than the expiry date. This would involve crossing the full bid/offer, but would mean that he doesn't need to delta-hedge over the remaining term.

What we have presented is a maximum cost of delta-hedging through a programme trading method – delta-hedging at set periods. A volatility trader will likely base his re-hedging periods on the term to maturity and the spread change experienced. This is essentially a utility function and the frequency of hedging will depend on a traders comfort with a minimum spread change before re-hedging. We will revisit this hedging in a later note.

Now that we have seen the returns and costs of delta-hedging, we finally examine how profitable this strategy would have been in practice.

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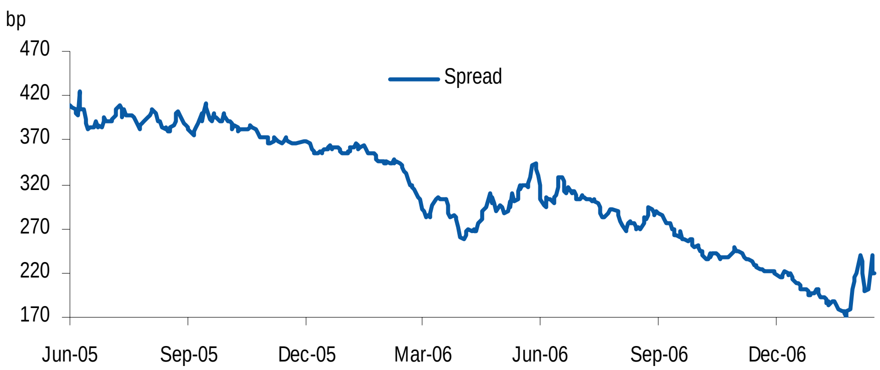
Historical Analysis

- Trading volatility has been profitable in ten of the last twelve months
- These profits exceed the costs involved

We have so far seen what credit volatility is, how to trade it, the profits we can expect and what it may cost. We now turn to the final chapter of the story and look at when it has been profitable to buy or sell volatility. In order to do this, we look at the iTraxx Crossover index over the last two years. This is the most commonly traded index option and, as we saw in the last section, the cheapest to hedge.

The spread history of the index over the last year is shown in Figure 20. Here we have formed an adjusted spread history that adjusts for the jump in spread normally seen on the roll date. This gives us a smoothed spread history to analyse.

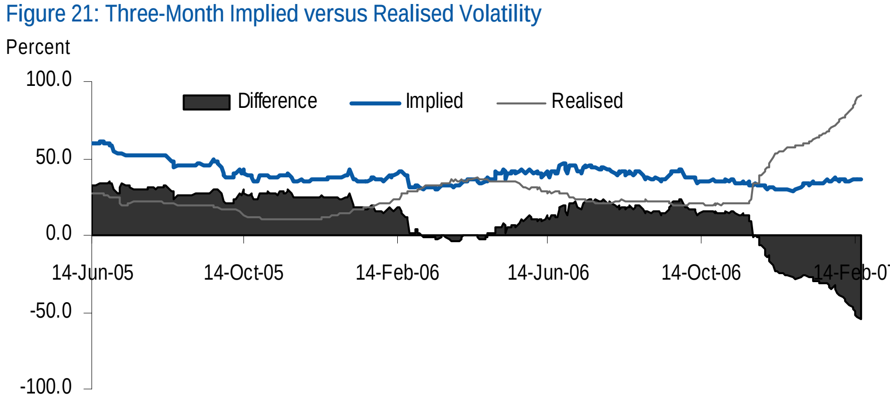
Figure 20: iTraxx Crossover Adjusted CDS spread



Source: JPMorgan

Next, we look at the difference between implied and realised volatility over this period. In periods when implied was at a premium to realised, selling volatility would have been a profitable trade and vice-versa. This is shown in Figure 21, where we have plotted three-month implied volatility versus lagged three-month realised volatility[7].

Figure 21: Three-Month Implied versus Realised Volatility

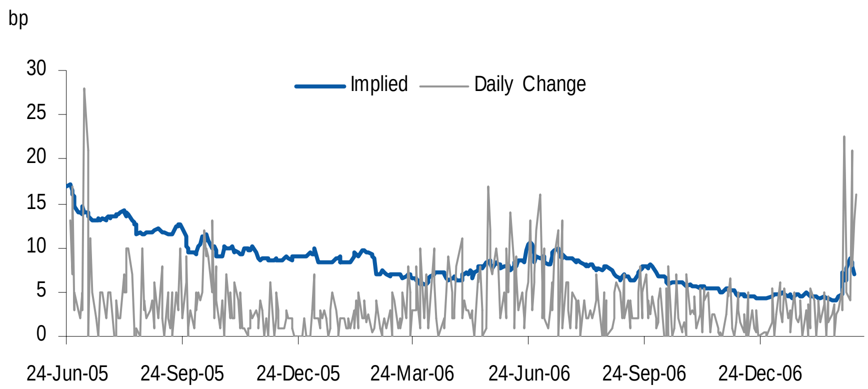


Source: JPMorgan

[7] Since we trade fixed maturities, we have interpolated between the three and six month options to calculate a running three-month volatility. For realised volatility we have looked at a rolling three month volatility, lagged by three months.

Clearly the last six months of 2005 would have been profitable times for selling volatility, while the first six months of 2006 as well as the start of 2007 would have been profitable for buying volatility. Another way to look at this is shown in Figure 22, where we look at the daily implied volatility versus the absolute change in spreads. As we saw in Appendix IV, if the daily moves are bigger than the daily implied volatility, then buying volatility would be a good trade. The results we see are similar to those in Figure 21.

Figure 22: Daily Implied Volatility versus Daily Move



Source: JPMorgan

As we saw in the last section, we would expect to pay around 3.85 vegas for buying and delta-hedging an option over three months (2.5 vegas for buying the option and 1.35 vegas for delta-hedging the option). Figure 21 shows us that the difference between implied and realised volatility has been greater than 3.85 over most of the last twelve months. In fact, only between January 2006 and March 2006 was implied volatility equal to realised volatility. **This shows that trading volatility has historically been a profitable strategy.**

See Appendix III for a detailed example of delta-hedging over a period of time.

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Appendix I: The Greeks

In this section we discuss the Greeks - the sensitivities of options - from the perspective of a product that trades on spread (i.e. the CDX High Grade index as opposed to the CDX High Yield index which trades in price terms).

- **Delta** of an option measures how much the theoretical value of an option should change if the underlying asset moves by 1 unit. A positive delta means the option should rise in value if the underlying spread widens. Call deltas range between -1 and 0 while put deltas range between 0 and 1. Delta can be thought of as the approximate probability that the option ends up in the money. At-The-Money options have a delta of 0.5 and around 50% chance of ending in-the-money. Far ITM options are likely to remain ITM and therefore have a delta close to 1.

  Since the delta of an option is dependent largely on the price of the underlying asset relative to the strike, the delta of an option changes as the price of the asset changes. The rate of change of delta is known as gamma.

  Delta-hedging of an option is a process whereby we replicate the value of an option by owning a delta amount of the underlying. Since the delta of the option tells us the change in option price for a 1 unit move in the underlying, by owning a delta amount of the underlying, we can synthesize the behaviour of the option.

- **Gamma** estimates how much the delta of an option changes for 1 unit move in the price of the underlying asset. A large gamma means that the delta of an option can change very quickly for a small move in the underlying asset. Long calls (puts) have positive gamma which means that as the underlying spread tightens (widens), the delta of the call (put) increases. Gamma is highest for ATM options and ATM gamma increases as we move closer to expiration.

  An investor who owns a delta-hedged option will have positive gamma and will benefit from fluctuations in the underlying asset. In order to remain delta-hedged, he will buy low and sell high thus making money on this position. Alternatively, an investor who is short gamma will buy high and sell low and therefore lose money on this position. However, the long gamma position which allows the investor to buy low and sell high comes with a cost. That cost is theta.

- **Theta**, which is also known as time decay, estimates how much the theoretical value of the option will decrease as we move 1 day closer to option expiry, all else being equal. Options that have high gamma also have high theta. In other words, the option that affords an investor the best convexity also decays at the highest rate. Theta is highest for ATM options and increases closer to option expiry. By "all else being equal", we mean that spreads rather than forwards remain constant. Since the options are priced using the forward and the forward adjustment decreases as we move closer to expiry, we may find that keeping spot spreads constant actually give a long call position positive theta.

- **Vega** and **Rho** are option sensitivities to implied volatility and interest rates respectively.

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Appendix II: Breakeven Volatility

Delta-hedging involves buying an option and selling a delta amount of the underlying asset. The change in value of our position, δV, from such a strategy is

$$\delta V = \delta V(Option) - \delta V(Delta - hedge)$$

If we assume that the forward spread, S, follows a Weiner Process, it can be shown from Taylor's expansion that:

$$\delta V(Option) \approx \left[\Delta \delta S + \Theta \delta t + \frac{1}{2}\Gamma(\delta S)^2\right] \times Annuity$$

Where:
Δ = Option delta
Θ = Option theta
Γ = Option gamma
δS = Change in spread
δt = Small time period

And since we own an amount Δ of the asset:

$$\delta V(Delta - hedge) \approx \Delta \delta S \times Annuity$$

Now for an ATM option, $\Theta = -\frac{1}{2} S^2 \sigma^2 \Gamma$, which implies:

$$\begin{aligned}
\delta V &\approx \left[\Delta \delta S + \frac{1}{2}\Gamma(\delta S)^2 - \frac{1}{2}\Gamma \sigma^2 S_i^2 \delta t\right] \times Annuity - \Delta \delta S \times Annuity \\
&\approx \left[\frac{1}{2}\Gamma \times (\delta S)^2 - \frac{1}{2}\Gamma \sigma^2 S^2 \delta t\right] \times Annuity \\
&\approx \frac{1}{2}\Gamma \times \left[(\delta S)^2 - \sigma^2 S^2 \delta t\right] \times Annuity
\end{aligned}$$

We can therefore calculate the breakeven spread move we need such that our $\delta V > 0$. From above, we can see that this amount is:

$$(\delta S)^2 = \sigma^2 S^2 \times \delta t$$

$$\begin{aligned}
&\Rightarrow \delta S = \sqrt{\sigma^2 S^2 \delta t} \\
&= \sigma S \sqrt{\delta t}
\end{aligned}$$

Now if we consider a one day period of time, we can see that our breakeven spread change is:

$$\delta S = \frac{\sigma S}{\sqrt{252}} \quad \text{since } \delta t = 1/252$$

This shows that in order for us to make money from a delta-hedged position, our breakeven spread move is equal to our daily absolute volatility.

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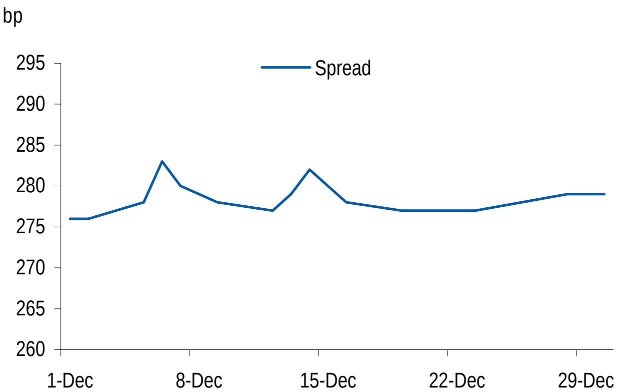
Appendix III: An Example

To illustrate the process of trading volatility through options, we choose two periods, and look at delta-hedging an options position over these:

1. December 2005, a relatively benign period for credit, and
2. Mid May 2006, the recent market sell-off.

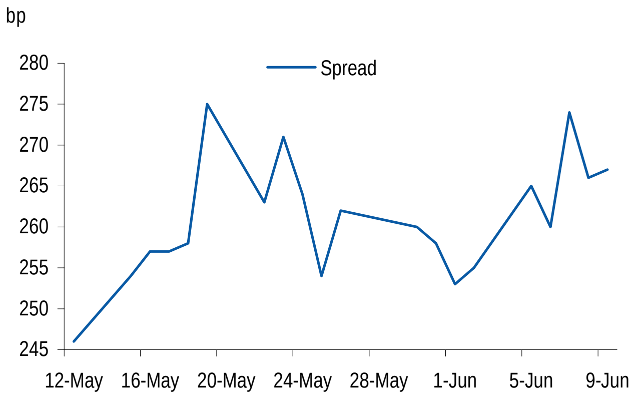
These two periods contrast well with each other as the former is a period when short volatility trades would have been profitable, while the later is a period when a long volatility trades would have been profitable. We plot the spread performance over these periods in Figure 23 and Figure 24.

Figure 23: iTraxx CDS Spread over Quiet Period



Source: JPMorgan

Figure 24: iTraxx CDS Spread over Volatile Period



Source: JPMorgan

In Table 4 we describe the process of delta-hedging over these periods. In both cases we take the perspective of an investor who is long volatility through the purchase of a delta-hedged straddle. We would expect that over the quiet December period, this trade would lose money, while over the volatile May period it would be profitable. Table 5 and Table 6 show the daily P&L and from delta-hedging a long straddle. In both cases, we present the P&L in two equivalent ways:

Method 1: The actual cost of entering the strategy and adjusting our delta
This way of looking at our P&L considers the costs of entering an option position, delta-hedging over the period and then exiting both the hedge and option (if we exit before option expiry). Initially we will pay the cost of the option and the cost of our initial delta-hedge, which may be positive or negative. Each day we buy or sell an amount of the underlying, as dictated by our new delta, in order to remain delta neutral. At expiry we completely exit our delta and sell the option. The sum of these costs will give us the P&L.

Method 2: The daily Mark-to-Market P&L
This Method looks at the daily Mark-to-Market of an option and delta-hedge. Initially we have no MtM, but as our underlying moves, we will have an MtM on the option and our delta-hedge. If implied and realised volatility are equal over a day, we will offset the loss/gain on our option with a loss/gain on our hedge.

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Both methods do and should yield the same results. In both cases, we assume a constant implied volatility over the life of the trade. In reality, a volatile market would likely lead to higher implied volatility, which would mean even greater profits from a long volatility position. The reverse is likely to hold over a period of low realised volatility.

In the quiet month of December, a long volatility position would have lost €24,700, while a short volatility would have made this amount. Over the volatile May period, a similar trade would have made €20,100 for a long volatility position and lost this amount for a short position.

Table 4: Description of Trades

	Trading Market	Trending Market
Position	Long	Long
Option Type	Straddle	Straddle
Trade Start Date	01 Dec 2005	12 May 2006
Trade End Date	28 De2005	07 June 2006
Notional	€10,000,000	€10,000,000
Option Term	3 Months	3 Months
Realised Volatility (%)	11	49
Implied Volatility (%)	35	35
Initial Spread (bp)	276	246
Initial Forward (bp)	293	260
Option Strike (bp)	293	260
Index Coupon (bp)	290	290

Source: JPMorgan

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Table 5: Delta-Hedging in a Quiet Market

						Cost			MTM Daily		MTM Cumulative	
	Spread	Dirty Price (c)	Delta	Option Price (c)	Action	Delta-Hedge	Option	Net Position	Delta-Hedge	Option	Delta-Hedge	Option
1-Dec-05	276	-115.1	6.2%	166.7	Sell Protection on €623,461 at -115c	-7,175	-166,661	Short Protection on €623,461 at -115c	0	0	0	0
2-Dec-05	276	-115.8	5.9%	165.7	Buy Protection on €33,196 at -116c	384		Short Protection on €590,265 at -116c	46	-972	46	-972
5-Dec-05	278	-109.9	8.3%	163.3	Sell Protection on €235,982 at -110c	-2,594		Short Protection on €826,248 at -110c	-348	-2,358	-301	-3,330
6-Dec-05	283	-90.1	16.3%	165.0	Sell Protection on €799,295 at -90c	-7,199		Short Protection on €1,625,542 at -90c	-1,641	1,620	-1,942	-1,710
7-Dec-05	280	-103.2	11.0%	162.1	Buy Protection on €526,769 at -103c	5,438		Short Protection on €1,098,773 at -103c	2,140	-2,839	198	-4,549
8-Dec-05	279	-108.1	9.0%	160.6	Buy Protection on €201,036 at -108c	2,174		Short Protection on €897,737 at -108c	539	-1,472	737	-6,021
9-Dec-05	278	-113.0	6.9%	159.3	Buy Protection on €204,661 at -113c	2,313		Short Protection on €693,076 at -113c	438	-1,373	1,175	-7,393
12-Dec-05	277	-119.5	4.1%	156.0	Buy Protection on €280,507 at -120c	3,352		Short Protection on €412,570 at -120c	450	-3,296	1,625	-10,689
13-Dec-05	279	-112.1	7.3%	155.4	Sell Protection on €317,067 at -112c	-3,553		Short Protection on €729,637 at -112c	-308	-539	1,317	-11,228
14-Dec-05	282	-100.5	12.2%	155.6	Sell Protection on €491,990 at -100c	-4,944		Short Protection on €1,221,627 at -100c	-844	192	473	-11,036
15-Dec-05	280	-109.5	8.4%	153.6	Buy Protection on €384,338 at -109c	4,208		Short Protection on €837,289 at -109c	1,102	-1,975	1,575	-13,011
16-Dec-05	278	-118.5	4.4%	152.0	Buy Protection on €393,977 at -118c	4,668		Short Protection on €443,312 at -118c	751	-1,612	2,326	-14,624
19-Dec-05	277	-125.0	1.4%	148.8	Buy Protection on €299,289 at -125c	3,740		Short Protection on €144,023 at -125c	287	-3,252	2,613	-17,876
20-Dec-05	277	-125.7	1.0%	147.7	Buy Protection on €40,546 at -126c	510		Short Protection on €103,477 at -126c	11	-1,040	2,624	-18,916
21-Dec-05	277	-126.5	0.6%	146.7	Buy Protection on €41,139 at -127c	520		Short Protection on €62,338 at -127c	8	-1,044	2,632	-19,960
22-Dec-05	277	-127.3	0.2%	145.7	Buy Protection on €41,751 at -127c	531		Short Protection on €20,586 at -127c	5	-1,047	2,637	-21,007
23-Dec-05	277	-128.0	-0.2%	144.6	Buy Protection on €42,382 at -128c	543		Short Protection on €21,795 at -128c	2	-1,051	2,639	-22,058
28-Dec-05	279	-123.8	1.5%	139.2	Sell Protection on €21,795 at -124c	-270	139,248		9	-5,355	2,648	-27,413
						-24,765			-24,765		-24,765	

Source: JPMorgan

Method 1: Cost

1 Dec
We buy the 293-strike straddle and pay €166,661 on our notional of €10,000,000.
Additionally, our option has a delta of 6.2%, so we sell protection on €623,461 at -115c at a cost of €7,175 (the current spread of 276bp is lower than the index coupon of 290bp so we must pay an upfront amount of 115c).

2 Dec
Our delta has declined to 5.9%, so we must buy protection on €33,196 at -116c for a profit of €384, in order to remain delta neutral.

5 Dec
Our delta has increased to 8.3%, so we must sell protection on €235,982 at -110c for a loss of €-2,594, in order to remain delta neutral.

28 Dec
We close out our delta position of -0.2% by selling protection on €21,795 at 124c for a loss of €-270. We now have no index position.
Additionally, we close out our option position at 139c for an amount €139,248.

Our net position is a loss of €24,765 on the trade

Method 2: Mark-To-Market

1 Dec
We buy the 293-strike straddle on our notional of €10,000,000.
We sell protection on iTraxx at 276bp (We have an upfront cost of €7,175, but our MTM is 0).

2 Dec
Our option price has moved from 166.7c to 165.7c, so we have a negative MTM of -€972.
The index remains at 276bp, so the MTM on our position (€46) is the difference in the dirty price (upfront) of the index, multiplied by our position of €623,461. We can imagine that we completely exit our delta and then sell protection on our new delta of 5.9%.

5 Dec
Our option price has moved from 165.7c to 163.3c, so we have a negative MTM of €2.358.
The index spread has widened to 278bp, so the MTM on our position (-€348) is the difference in the dirty price (upfront) of the index, multiplied by our position of €590,265. We can imagine that we completely exit our delta and then sell protection on our new delta of 8.3%.

28 Dec
Our option price has moved 139.2c, so we have a positive cumulative MTM of -€27,413.
The index spread has widened to 279bp, so the cumulative MTM on our position is €2,648.

Our net position is a loss of €24,765 on the trade

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Table 6: Delta-Hedging in a Volatile Market

						Cost			MTM Daily		MTM Cumulative	
	Spread	Dirty Price	Delta	Option Price	Action	Delta-Hedge	Option	Net Position	Delta-Hedge	Option	Delta-Hedge	Option
12 May 2006	246	-246.2	5.2%	140.2	Sell Protection on €523,697 at -246c	-12,896	-140,246	Short Protection on €523,697 at -246c	0	0	0	0
15 May 2006	254	-215.4	19.7%	141.7	Sell Protection on €1,449,509 at -215c	-31,226		Short Protection on €1,973,206 at -215c	-1,614	1,450	-1,614	1,450
16 May 2006	257	-203.8	25.1%	143.6	Sell Protection on €533,720 at -204c	-10,877		Short Protection on €2,506,926 at -204c	-2,296	1,869	-3,910	3,319
17 May 2006	257	-204.5	24.8%	142.5	Buy Protection on €22,199 at -205c	454		Short Protection on €2,484,727 at -205c	189	-1,058	-3,720	2,261
18 May 2006	258	-201.2	26.5%	142.5	Sell Protection on €162,770 at -201c	-3,275		Short Protection on €2,647,497 at -201c	-838	41	-4,558	2,302
19 May 2006	275	-131.8	54.1%	171.4	Sell Protection on €2,760,991 at -132c	-36,390		Short Protection on €5,408,488 at -132c	-18,367	28,854	-22,925	31,155
22 May 2006	263	-183.6	34.8%	144.7	Buy Protection on €1,927,889 at -184c	35,394		Short Protection on €3,480,599 at -184c	28,012	-26,678	5,087	4,478
23 May 2006	271	-151.4	48.1%	157.9	Sell Protection on €1,327,068 at -151c	-20,090		Short Protection on €4,807,667 at -151c	-11,209	13,149	-6,122	17,626
24 May 2006	264	-181.0	36.3%	144.0	Buy Protection on €1,177,491 at -181c	21,312		Short Protection on €3,630,176 at -181c	14,235	-13,913	8,113	3,713
25 May 2006	254	-222.9	17.0%	131.3	Buy Protection on €1,932,226 at -223c	43,078		Short Protection on €1,697,949 at -223c	15,227	-12,662	23,340	-8,949
26 May 2006	262	-190.8	32.4%	138.7	Sell Protection on €1,538,615 at -191c	-29,350		Short Protection on €3,236,564 at -191c	-5,465	7,401	17,876	-1,548
30 May 2006	260	-202.0	27.8%	131.5	Buy Protection on €457,846 at -202c	9,250		Short Protection on €2,778,718 at -202c	3,648	-7,209	21,523	-8,757
31 May 2006	258	-211.0	23.5%	128.1	Buy Protection on €425,520 at -211c	8,979		Short Protection on €2,353,198 at -211c	2,496	-3,352	24,019	-12,109
01 June 2006	253	-232.3	12.7%	123.1	Buy Protection on €1,087,042 at -232c	25,254		Short Protection on €1,266,156 at -232c	5,014	-5,003	29,033	-17,112
02 June 2006	255	-224.8	16.7%	123.3	Sell Protection on €400,866 at -225c	-9,013		Short Protection on €1,667,022 at -225c	-945	149	28,087	-16,963
05 June 2006	265	-186.1	36.6%	131.2	Sell Protection on €1,995,788 at -186c	-37,133		Short Protection on €3,662,810 at -186c	-6,467	7,869	21,620	-9,094
06 June 2006	260	-207.3	26.3%	123.2	Buy Protection on €1,032,415 at -207c	21,406		Short Protection on €2,630,394 at -207c	7,796	-7,955	29,417	-17,050
07 June 2006	274	-150.7	52.8%	145.8	Sell Protection on €2,630,394 at -151c	39,629	145,841		-14,909	22,645	14,507	5,596
						20,103			20,103		20,103	

Source: JPMorgan

Method 1: Cost

12 May
We buy the 260 strike straddle and receive €140,246 on our notional of €10,000,000.
Additionally, our option has a delta of 5.2%, so we sell protection on -€523,697 at -246c at a cost of €12,896 (the current spread of 246bp is lower than the index coupon of 290bp so we must pay an upfront amount of 246c).

15 May
Our delta has increased to 19.7%, so we must sell protection on €1,449,509 at -215c for a loss of €31,226, in order to remain delta neutral.

16 May
Our delta has increased to 25.1%, so we must sell protection on €533,720 at -204c for a loss of €10,877, in order to remain delta neutral.

7 June
We close out our delta position of -0.2% by selling protection on €2,630,394 at -151c for a loss of €39,629. We now have no index position.
Additionally, we close out our option position at 145.8c for an amount €145,841.

Our net position is a gain of 20,103.

Method 2: Mark-To-Market

12 May
We sell the 260-strike straddle on our notional of €10,000,000.
We sell protection on iTraxx at 246bp (We have an upfront cost of €12,896, but our MTM is 0).

15 May
Our option price has moved from 140.2c to 141.7c, so we have a positive MTM of €1,450.
The index spread has widened to 254bp, so the MTM on our position (-€1,614) is the difference in the dirty price (upfront) of the index, multiplied by our position of €523,697. We can imagine that we completely exit our delta and then sell protection on our new delta of 19.7%.

16 May
Our option price has moved from 141.7c to 143.6c, so we have a positive MTM of €1,869.
The index spread has widened to 257bp, so the MTM on our position (-€2,296) is the difference in the dirty price (upfront) of the index, multiplied by our position of €1,973,206. We can imagine that we completely exit our delta and then sell protection on our new delta of 19.7%.

7 June
Our option price has moved 145.8c, so we have a positive cumulative MTM of €5,596.
The index spread has widened to 274bp, so the cumulative MTM on our position is €14,507.

Our net position is a gain of 20,103.

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Appendix IV: Expected P&L from Delta-Hedging

The price of an option is intimately related to the cost of replicating the option through delta-hedging the underlying asset. In fact, if we knew a priori the realised volatility of an option over the term of the options, the price of the option should be equal to the cost of hedging the option given the volatility.

For an ATM option (call or put), with a forward spread, *S*, and an option term, *T*, the price of the option can be estimated by:

$$Price \approx \sigma_{Implied} \times \sqrt{\frac{T}{2\Pi}} \times S \times Annuity$$

So if we knew the option volatility over the coming option term would be σ_{Realised}, then the price of the option should be:

$$Price \approx \sigma_{Relised} \times \sqrt{\frac{T}{2\Pi}} \times S \times Annuity$$

Therefore, since we don't know the realised volatility over the coming term of an option, but guess it to be σ_{Realised}, then to a first order approximation, the expected P&L from a delta-hedged ATM option is:

$$P\&L \approx \sqrt{\frac{T}{2\Pi}} \times S \times Annuity \times \left(\sigma_{Realised} - \sigma_{Implied}\right) = Vega \times Annuity \times \left(\sigma_{Realised} - \sigma_{Implied}\right)$$

In order to test the validity of this formula, we have performed a Monte-Carlo Simulation on the iTraxx Crossover index. Given the assumptions in Table 7 we simulated the path of the iTraxx Crossover index 1000 times and found that the average return was indeed close to our predicted value.

Table 7: Pricing Assumptions

Index	iTraxx Crossover
Implied Volatility	20%
Realised Volatility	40%
Spread (bp)	280
Forward (bp)	300
Forward Duration	3.60
Today	14/06/2006
Maturity	20/09/2006
Term (days)	98

Source: JPMorgan

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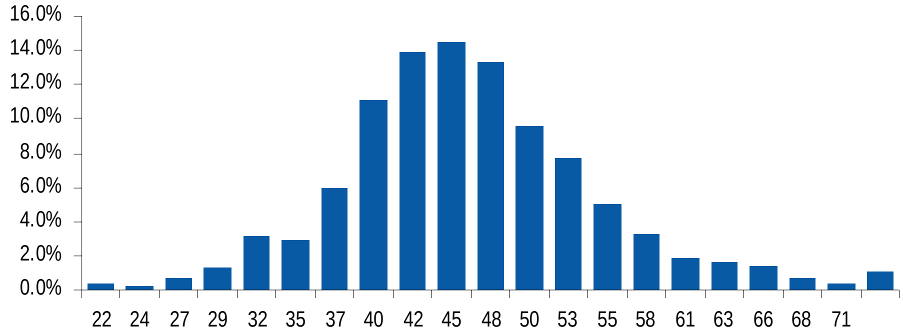
Figure 25: Distribution of Payoffs from Delta-Hedged Option



Source: JPMorgan

Table 8: Payoff Analysis

Expected P&L	44.8c
Average P&L	44.9c
Standard Dev of P&L	8.7c

Source: JPMorgan

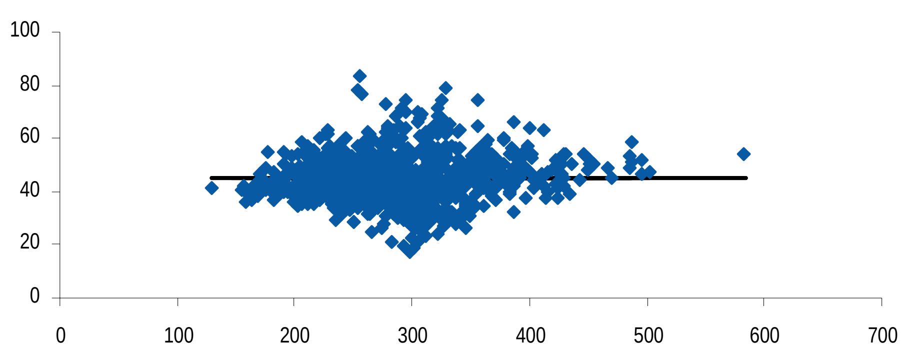
Figure 25 shows our distribution of P&L, which is has an expected value of 45c. As we note in the section on the drivers of our P&L, this distribution is dependent on the frequency of our delta-hedging.

In Figure 26 we show our P&L against the final spread of the index, with the black line showing the average. This shows us that options that move away from their ATM point are more likely to only return their expected P&L. This is because as we move away from the ATM point, our gamma declines as does our theta. A smaller gamma means that we are more likely to replicate the P&L of the option through delta-hedging and are therefore more likely to make the difference between the initial volatility priced into the option and volatility over the life of the option.

Spreads that remain ATM, however offer a greater chance of outperforming our expected return and investors who believe they are able to do better than a simple daily delta-hedging strategy may be able to outperform.

Figure 26: P&L with Final Level of Spreads

x-axis shows the final spread level in bp, y-axis shows the P&L in cents



Source: JPMorgan

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Appendix V: Transaction Costs

In order to calculate the transaction cost involved in adjusting our delta for a delta-hedged CDS option, we turn to a result by Wilmott (Derivatives – The Theory and Practice of Financial Engineering). The reader is referred there for further details on this result, which we have adapted for CDS index options.

Wilmott considers an asset whose hedging cost at each point is equal to ν×S×k, where S is the asset level, k is the cost as a percent of the asset and ν is the notional units traded. Each time an investor trades, he does so in order to adjust his delta and remain delta neutral. Therefore, the amount we trade, ν, is equal to the change in our delta. Since the cost of trading in credit is not dependent on the asset level, S, we ignore this term. The number of assets traded is therefore equal to:

$\nu = \Delta(S + \delta S, t + \delta t) - \Delta(S, t)$, where $\Delta(S, t) =$ delta at time t and spread S.

Wilmott shows that the usual Black formula can be adjusted to include bid/offer costs to yield:

$$\Theta + \frac{1}{2}\sigma^2 S^2 \Gamma - k\sigma S\sqrt{\frac{2}{\Pi \delta t}}|\Gamma| = 0$$

Comparing this to the regular Black formula, we find that the bid/offer costs are equal to:

Equation 12

$$Cost = k\sigma S\sqrt{\frac{2}{\Pi \delta t}}|\Gamma|$$

This shows that the cost of hedging is proportional to $\delta t^{-\frac{1}{2}}$. Meaning that if we quadruple the time between hedges, we halve the cost of hedging.

For an ATM option, we know that:

$$\Gamma = Vega \times \frac{1}{S^2\sigma T} = S\sqrt{\frac{T}{2\Pi}} \times \frac{1}{S^2\sigma T} = S\sqrt{\frac{T}{2\Pi}} \times \frac{1}{S^2\sigma T} = \frac{1}{S\sigma}\sqrt{\frac{1}{2\Pi T}}$$

Therefore, Equation 12 becomes:

$$Cost = k\sigma S\sqrt{\frac{2}{\Pi \delta t}}|\Gamma| = Cost = k\sigma S\sqrt{\frac{2}{\Pi \delta t}} \times \left|\frac{1}{S\sigma} \times \sqrt{\frac{1}{2\Pi T}}\right|$$

$$= k\frac{1}{\Pi} \times \sqrt{\frac{1}{\delta t}} \times \sqrt{\frac{1}{T}}$$

Now if we say that δt is equal to $\frac{1}{Tn}$ then we can solver for the cost of delta-hedging

Equation 13

$$Cost = k\frac{1}{\Pi} \times \sqrt{Tn} \times \sqrt{\frac{1}{T}} \quad \text{or} \quad Cost = k\frac{\sqrt{n}}{\Pi},$$

which show that for an ATM option, the expected cost of hedging is equal to the cost of each hedge, *k*, multiplied by the square root of the number of times we hedge, *n*, divided by pi.

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In Table 9 we show the average bid/offer of each traded index along with the cost of hedging a unit of the underlying. The cost is half the bid/offer times the duration.

Table 9: Transaction Costs

Using the bid/offer given, k is the cost of delta-hedging one unit of the underling

	Bid/Offer (c)	Duration	k (c)
Main	0.5	4.5	1.125
HiVol	1.0	4.3	2.125
Crossover	2.0	4.0	4.000

Source: JPMorgan

By combining Table 9 with Table 10, which gives the units of notional we need to trade over each period for a given trading frequency, we can calculate the cost of delta-hedging. For example, to delta-hedge a Crossover option weekly over a six-moth period would cost 6.4 (=4×1.6).

Table 10: Number of Units Traded

Notional units traded over a given period and a frequency of trading

	3 Months	6 Months	9 Months	12 Months
Daily	2.6	3.6	4.5	5.2
Weekly	1.2	1.6	2.0	2.3
Fortnightly	0.8	1.2	1.4	1.6

Source: JPMorgan

Simulating the Costs

In order to test the above result, that the average cost is equal to $k\frac{\sqrt{n}}{\Pi}$, we perform a Monte Carlo simulation and sum up the amount of delta we need to trade over the option life. Since we must trade an amount equal to our change in delta each time we adjust our delta-hedge, the sum of these changes over the option term will equal the amount of notional we need to trade. We simulate the Crossover index, but the results would be equally valid for the Main or HiVol index. The results are shown in Table 11, where we consider daily hedging over the given periods. We see that these results closely mimic those shown in the first row of Table 10.

Table 11: Sum of Delta for Differing Trade Terms

in notional units

	1 Month	3 Months	6 Months	9 Months	1 Year
Sum of Delta	1.5	2.6	3.6	4.4	5.1
Standard Deviation	0.5	1.0	1.3	1.6	1.9

Source: JPMorgan

Additionally, we look at delta-hedging a three-month option with the frequencies shown in Table 12. Here again the results follow those in the first column of Table 10.

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Table 12: Sum of Change in Delta for three-month trade

in notional units

	Daily	Weekly	Monthly
Cost	2.6	1.1	0.7
Stdev	1.0	0.4	0.2

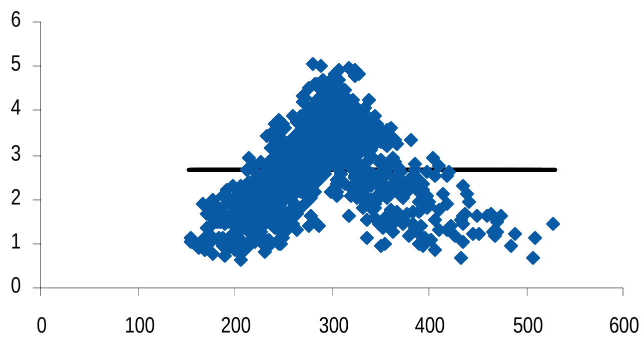
Source: JPMorgan

The results of our Monte-Carlo simulation is shown in Figure 27 and Figure 28 where we have plotted the sum of our daily delta hedges over the option term against the final spread level, which we use as a proxy for the spread path over the option term. We can see that when we stay ATM, our delta-hedging costs are highest, since our gamma is greatest. Also, as we move from daily to weekly hedging, our expected cost as well as our maximum cost declines.

Figure 27: Distribution of Hedging Costs for Daily Hedging versus Final Index Level

Three Month Option on iTraxx Crossover

x-axis shows final spread level, y-axis shows sum of delta changes over the period in notional units, Straight line shows the average sum

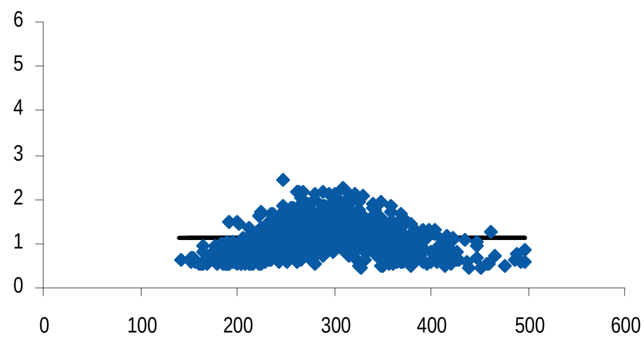


Source: JPMorgan

Figure 28: Distribution of Hedging Costs for Weekly Hedging versus Final Index Level

Three Month Option on iTraxx Crossover

x-axis shows final spread level, y-axis shows sum of delta changes over the period in notional units, Straight line shows the average sum



Source: JPMorgan

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Appendix VI: Option Glossary

Call – A call gives the holder the right, but not the obligation to enter into a long risk CDS index contract at a given spread, the strike. This is also called a receiver option.

Put – A put gives the holder the right, but not the obligation to enter into a short risk CDS index contract at a given spread, the strike. This is also called a payer option.

Straddle – A straddle is an option strategy where an investor purchases a call and a put option with the same strike. ATM straddles have a delta close to zero and are therefore often used to trade volatility.

Strangle – A strangle is an options strategy similar to the straddle, but with different strike levels for the call and put. Strangles are frequently sold by investors who believe the index will remain in a particular range.

Strike – The strike is the agreed spread at which CDS index contract will be struck at maturity of the option.

Maturity – There are two maturities in a CDS option contract. The maturity of the option and the maturity of the underlying CDS index contract. As traded indices have fixed maturities, the term of the index decreases as time passes.

Adjusted Forward – The forward is the fair spread, agreed today, at which we would enter into an index contract at a given date in the future. We use the forward at the option maturity to price the option. Since index options do not knock out if a name in the underlying index defaults, the forward spread is adjusted to account for the additional protection this affords. If a name in the index defaults before the maturity of the option, we will still be entered into an index, at the options maturity, that can be immediately triggered to collect on the defaulted name.

At-The-Money (ATM) - An option is ATM if its strike is equal to the forward spread on the underlying.

In-The-Money (ITM) - An option is ITM if its strike is above the forward spread for a call and vice versa for a put.

Out-Of-The-Money (OTM) - An option is OTM if its strike is below the forward spread for a call and vice versa for a put.

Realized Volatility (also known as Historic or Delivered volatility) – This is the standard deviation of the daily log returns of the index. This is annualized by multiplying by sqrt(252). Realized Volatility is a backward-looking measure and tells us how volatile the index has been over a given period.

Implied Volatility – This is the volatility implied from an option price, using the Black Equation. This is the equation used to price options and is detailed in "Option Pricing Model - March 2004, JPMorgan". Implied volatility is a forward-looking measure and reflects the expected volatility of the index to the maturity of the option.

Volatility Skew – This describes the different levels of implied volatility for different strikes.

Breakeven – This is the spread level at which the profit from exercising the option equals the cost of the option. For example if we own a call and the spread ends up below the breakeven spread we will make money. If the spread ends up at any level above this we will lose part or all of our premium. The reverse holds for a put.

Forward Duration – This is the duration of the forward. It is the duration of the contract we can enter into at maturity of the option. We can convert option prices to breakevens by multiplying by the forward duration.

The Greeks – These are the sensitivities of the option price.

Delta – This describes how the option price changes with respect to the underlying index price. We calculate delta as the ratio of the change in option price to change in index upfront for a 1bp widening in index spread. An ATM option has a delta of around 50% meaning that for a 1bp spread widening the option price will change by around 50% of the upfront price change on the index. The delta tells us how much of the underlying we need to purchase or sell in order to hedge or replicate the option payoff.

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Gamma – This describes how the delta changes for a 1bp shift in underlying index spread. Owning options results in a positive gamma position. This means that as the spread on the underlying moves our way, the option delta increases and the option becomes more likely to end up ITM. Effectively we get "longer in a rally and shorter in a sell-off."

Vega – This is the sensitivity of the option price to changes in implied volatility. Vega tells us how much the option price changes, in cents, for a 1% increase in implied volatility. Owning options (puts or calls) results in a positive vega position as the holder benefits from increasing implied volatility. Longer dated options have higher vega and therefore are more sensitive to changes in implied volatility.

Theta – Theta describes the time decay of the option. This is the change in the option price due to a 1 day passage of time assuming all else remains unchanged (index spread, implied volatility etc.). Owning options usually has a negative theta position as options become less valuable as time passes. Theta is often thought of as the "rent" paid for having a positive gamma position.

Intrinsic Value – This tells us how much the option is ITM. For a call, if the strike on the option is higher than the current adjusted forward, then the option is already ITM. If we were to take out a forward at the strike, we could effectively lock in this value. The premium paid for the option will therefore include an amount that is paid for being ITM. For ITM options we look at the difference between the forward and the strike and convert this to an upfront price by multiplying by the forward duration. OTM options have no intrinsic value.

Time Value – If an option is OTM, its value lies in time. It has no intrinsic value and the value it has is due to the fact that as time passes, we may end up ITM. We define the time value as the difference between the option price and its intrinsic value.

Delta Exchange - When trading an option, the convention is to hedge the delta of the option by buying or selling a delta amount of the underlying index. All prices in this report include the cost of the delta hedge. To take an outright option position, investors need to buy or sell their delta hedge back to the market.

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Put/Payer Sale. Investors who sell put/payer options are exposed to the CDS spread of the underlying rising above the strike of the option. Therefore, at maturity of the option, if the spread on the underlying is above the strike, an investor will have to source a short risk position which he must hand over to the buyer of the option in return for the strike of the option. Additionally, if the CDS spread is below the strike at maturity, the option seller will not participate in this spread tightening.

Call/Receiver Sale. Investors who sell call/receiver options are exposed to the CDS spread of the underlying falling below the strike of the option. Therefore, at maturity of the option, if the spread on the underlying is below the strike, an investor will have to source a long risk position which he must hand over to the buyer of the option in return for the strike of the option. Additionally, if the CDS spread is above the strike at maturity, the option seller will not participate in this spread widening.

Call Overwrite. Investors who sell call options against a long risk position in the underlying give up any tightening in the CDS spread below the strike price of the call option. Additionally, they remain exposed to the widening in the underlying CDS spread in return for the receipt of the option premium.

Put Overwrite. Investors who sell put options against a short risk position in the underlying give up any widening in the CDS spread above the strike price of the call option. Additionally, they remain exposed to the tightening in the underlying CDS spread in return for the receipt of the option premium.

Call Purchase. Options are a decaying asset, and investors risk losing 100% of the premium paid if the underlying CDS spread is above the strike of the call option at maturity.

Put Purchase. Options are a decaying asset, and investors risk losing 100% of the premium paid if the underlying CDS spread is below the strike of the put option at maturity.

Straddle or Strangle. The seller of a straddle or strangle is exposed to underlying CDS spread ending up below the call strike or above the put strike at maturity of the option. If an investor has a short risk in the underlying CDS and overlays this with selling a straddle or strangle, they will define their exit point if the underlying spread widens above the put strike. Additionally, they will lose twice as much as an outright short risk position if the underlying spread is below the call strike. Conversely if an investor is long risk and overlays this with selling a strangle, they will define their lower exit point by the call strike and lose twice as much above the put strike.

Knockout on Default. Unless explicitly stated, single name CDS options will knock out if the underlying name defaults. Therefore if an investor has bought a put or call option and the underlying defaults before the maturity of the option, he will lose his premium. Index options do not knockout on default, unless explicitly stated otherwise. Therefore, if an option ends up in the money at maturity, an investor will be entered into an index contract which contains a defaulted name.

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