

# Profiting from the Credit Volatility Premium

## Selling credit volatility can be consistently profitable even after paying bid-ask

- **Volatility risk premium is almost always positive in credit markets** — We develop trading strategies that leverage the positive risk premium between implied volatility of a credit option and the realized volatility of the underlying index.
- **Back-testing shows value of short-dated delta-hedged straddles** — The main contributor to P&L is the net position gamma, and the position is profitable so long as realized volatility remains below the implied volatility of the underlying index.
- **OTM Strangles are less effective than ATMF straddles** — When selling volatility, at-the-money forward (ATMF) straddles are generally more profitable than out-of-the-money (OTM) strangles because the short straddles have significantly more negative convexity.
- **Round-lots and ATMF strikes are operationally efficient** — Delta hedging using round lots in index notional significantly reduces transaction costs with negligible impact on total P&L. Lower bid-ask spreads of ATMF options also favor ATMF straddle strategies over OTM strangles.
- **Positive volatility risk premium provides upside for investors and can also be used as efficient hedges** — The consistent profitability of selling short-dated ATMF straddles that are held to expiry and delta-hedged with the index indicates that selling receivers may be a more effective tail risk hedge than buying payers.

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## What is the Credit Volatility Risk Premium?

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Volatility trading has a long history, especially in equity markets where participants have traded index and single name options for decades. Credit is a recent entrant in the volatility market, where credit options (or credit default swaptions) began trading in the late 2000s. While single name credit options do exist, the most liquid market in this space is in credit index options – the right (but not the obligation) to buy (called “payers”, similar to an equity put) or sell (called “receivers”, similar to an equity call) credit index protection at a predetermined spread (or price) at a given point in the future. The credit option markets have experienced significant growth in recent years and currently stand at a total of \$306 Billion in outstanding gross notional, across all indices and option maturities (source: DTCC, data as of 8/31/2012). Most credit options trade with short expiry dates, ranging from 1 month to 6 months, with most of the volume being in the 1 month and 3 month maturities.

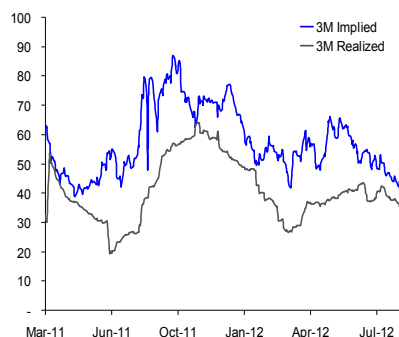
Credit options, like options in other markets, can be either traded “naked” or “delta hedged”. Trading a naked option implies an outright purchase or sale of a payer or a receiver whereas delta-hedging involves hedging the option position with an opposite position in the underlying index. The magnitude of the index position is determined by the “delta” of the option position, where delta denotes the change in value of the option for a unit move in the underlying index. While naked option positions are subject to both volatility and (directional moves in underlying) spread risk, a delta hedged option is mainly subject to volatility risk.

### Realized versus Implied Volatility

As in other option markets, credit option prices are determined by various factors, including the strike price, the option maturity and, most importantly, the (expected) volatility in the underlying index. The expected volatility (or, **implied volatility**, as it is called) can be backed out from the quoted option price using a modified version of Black’s formula and is one of the main parameters that determine the movement in option prices. An investor who is long a delta hedged option profits if implied volatility goes up and vice versa.

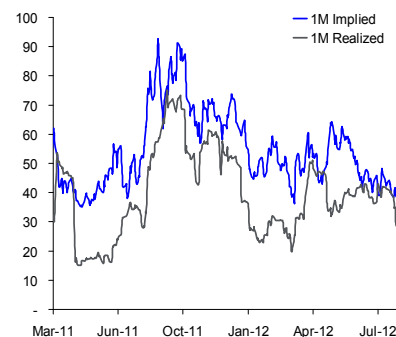
A related measure that is important in volatility markets is the **realized volatility**, which represents the actual volatility experienced by the underlying index over a given period of time. Figure 1 shows time series plots of the 3 month implied volatility of at-the-money CDX IG options as well as 3 month realized volatility of CDX IG index spreads. We observe that implied volatility is almost always higher than realized volatility and note that this phenomenon persists across option maturities (see Figure 2) and markets (see Figure 3 and Figure 4). In other words, credit option markets tend to price volatility at a **premium** to the volatility that is actually observed in practice, and this premium (or difference) is called the **volatility risk premium (or VRP)**. Many reasons have been postulated for the existence of a (almost always) positive volatility risk premium, including the “gappy” nature of credit spreads, jump risk of defaults, the somewhat illiquid nature of credit volatility markets and so on.

Figure 1. CDX IG 3M Realized vs Implied, %



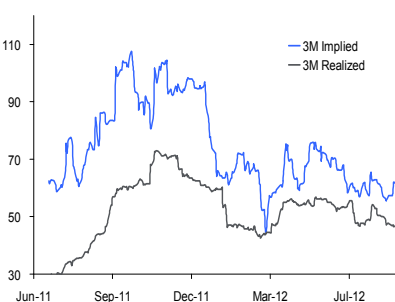
Source: Citi Research

Figure 2. CDX IG 1M Realized vs Implied, %



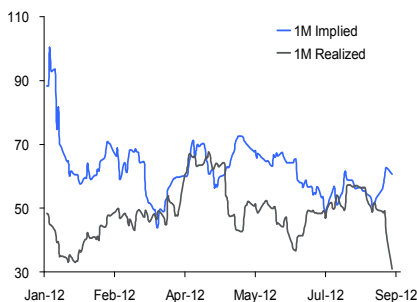
Source: Citi Research

Figure 3. iTraxx Main 3M Realized vs Implied, %



Source: Citi Research

Figure 4. iTraxx Main 1M Realized vs Implied, %



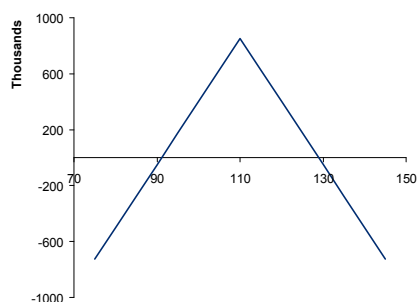
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In this article, we examine trading strategies that are constructed to take advantage of the persistent volatility risk premium that exists in credit markets. Based on a series of back tests, we try to understand the various factors that can influence the profitability of such a trading strategy, including the term of the option, how frequently the option position is rolled, and at what spread the option is struck. We then attempt to draw some conclusions about the most optimal way of trading the volatility risk premium. In the scenarios discussed below, past performance should not be viewed as an indicator of future results.

## Back Testing Volatility Risk Premium Trading Strategies

As we have discussed earlier, credit option markets exhibit a volatility risk premium that is (for the most part) persistently positive. In other words, investors have to pay a premium to go long credit volatility in the option markets, which implies that selling credit volatility using credit options should be mostly profitable. In this section, we describe the back testing framework that we have used to explore this idea further.

**Figure 5. P&L: Short 110 Strike Straddle, \$ Spread in bp, 100MM notional**



Source: Citi Research

In order to back test our idea of selling credit volatility, we first need to select a suitable instrument. The most commonly used instrument for this purpose is the **at-the-money forward (ATMF) straddle**. An investor who wants to sell volatility using an ATMF straddle will simultaneously sell a payer and a receiver with a strike that is equal to the forward spread (price) of the index at the time of option maturity. The P&L profile at option expiry for a (naked) short straddle position with a strike of 110bp is shown in Figure 5. There are two things that are worth noting here:

1. P&L is maximized if the underlying index spread equals the strike at maturity, i.e. there is no movement in the underlying. The larger the movement in the underlying spread, the lower the profit – in other words, if the realized volatility in the underlying spread is high, the ATMF straddle loses money.
2. The magnitude of the maximum possible P&L is determined by the level of implied volatility at the time of the trade. The higher the level of implied (or expected) volatility, the higher is the maximum realizable P&L.

Thus, an ATMF straddle is most profitable if expected volatility remains higher than realized volatility over the lifetime of the trade. In addition to the volatility component of the P&L, there is also a “delta” component of the P&L that is determined by the direction of the movement in the underlying. At any time, the delta depends on where the ATM forward spread is relative to strike – e.g., if the forward is higher than the strike, the net delta is positive (straddle will have positive P&L if spreads widen even if volatility remains at the same level). Since our strategy is to monetize volatility only (and be neutral to the direction of spread moves), we hedge the straddle position on a daily basis by its delta in index notional. The delta hedge neutralizes the “delta effect” on P&L and makes the position market neutral.

### Back Testing Methodology

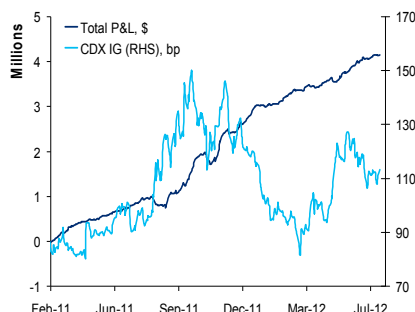
We back test our proposed strategy as follows. We use 1 month (1M) options on the on-the-run CDX IG index and sell an ATMF straddle each month on the day after the previous option expiry (which is usually on the 3<sup>rd</sup> Wednesday of every month). The net position is delta hedged daily and held till option expiry the following month, at which point, the cycle is repeated. In other words, the strategy systematically sells front month volatility and holds it to expiry. Note that in order to be realistic, we round the ATMF strikes to the nearest multiple of 5, since most dealers do not usually quote or trade intermediate strikes.

All pricing is done at mid prices (gross of bid-ask spread), based on a volatility surface that is updated daily. We use a notional of \$100 million on each leg of the straddle. Finally, if there is an index roll (i.e., the on-the-run index changes) during the holding period of an option, we continue to hold the existing option and hedge daily with the “now off-the-run” CDX IG index for the remainder of the holding period. The new on-the-run index is used after the current option expires. The historical period that we have used here is from February 22, 2011 through July 23, 2012, i.e. a period of 17 months that includes the market decline in late summer/fall

of 2011 and the rally in early 2012. This enables us to view the performance of the strategy over a variety of market regimes.

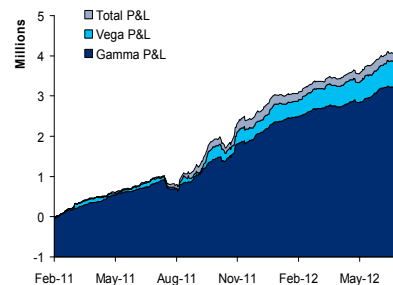
## Explaining the Back Testing Results

Figure 6. P&L: 1M Volatility Selling Strategy, \$



Source: Citi Research

Figure 7. P&L Decomposition, \$



Source: Citi Research

The performance of the strategy (cumulative P&L in USD) is shown in Figure 6 (the light blue line shows how the underlying index spread moved during this period). We observe that the P&L profile is extremely stable and the strategy continues to generate profits except for brief loss making periods in late Jul/early Aug 2011 and Oct 2011 during which there were significant spikes in realized volatility. We now describe the factors that influence the daily P&L of such a strategy. The readers may recall that the value of any option depends on three parameters – the level of the underlying (in this case, the credit index), the level of implied volatility, and the time to expiry. Therefore, the “greeks” that describe the risks associated with an option position are

1. **delta**, or change in option value as the underlying index level changes (the first derivative with respect to the underlying),
2. **gamma**, or the change in delta as the index level changes (i.e., the second derivative with respect to the underlying),
3. **theta**, or the change in value as the option gets closer to expiry by a day (also known as time decay), and
4. **vega**, or change in value as the implied volatility changes.

Since, we use delta hedged straddles, we assume the delta risk to be zero (or negligible)<sup>1</sup>. This leaves a position that has gamma, theta and vega risks. A short ATM/F straddle position is short gamma (profits if there are no large moves in the underlying), long theta (gains value as option gets closer to expiry), and short vega (short implied volatility). The daily P&L of such a position can be decomposed into:

$$\begin{aligned} \text{Daily P\&L} &= \text{Gamma P\&L} + \text{Theta P\&L} + \text{Vega P\&L} \\ &= \frac{1}{2} \Gamma (\Delta S)^2 + \theta (\Delta t) + \upsilon (\Delta \sigma) \end{aligned}$$

where  $\Gamma$  denotes position gamma,  $\theta$  denotes position theta, and  $\upsilon$  denotes position vega,  $S$  stands for the underlying index spread,  $t$  denotes time,  $\sigma$  denotes implied

<sup>1</sup> In theory, a delta hedged position should have zero delta risk if hedged continuously in time. The small delta risk comes from the fact that we hedge the position daily, i.e., in discrete time intervals.

volatility, and the  $\Delta$  in front of each quantity denotes the daily change in those quantities. It can be shown (using option math) that the combined gamma and theta P&L can be expressed in terms of gamma only, and the daily P&L can be approximated as:

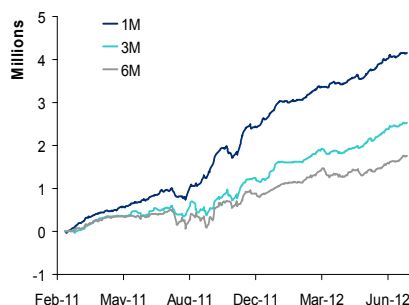
$$\text{Daily P\&L} = \frac{1}{2} \Gamma S^2 [(\Delta S/S)^2 - \sigma^2 t] + \nu (\Delta \sigma)$$

The first term on the right consists of two parts:  $(\Delta S/S)^2 - \sigma^2 t$  can be interpreted as the difference between the realized and the implied one-day variance (which is the square of one-day volatility), which is then multiplied by the half the position gamma times index spread squared. This P&L is purely due to the volatility risk premium and is positive only when the volatility risk premium (or spread between implied and realized volatility) is positive, since position gamma is negative for a short straddle position. The second term, which is  $\nu (\Delta \sigma)$  is the vega P&L due to a change in implied volatility, which is positive if the level of implied volatility falls.

Using these formulas, we estimate the contribution of vega and gamma to the total P&L of the strategy (see Figure 7). We observe that the majority of the contribution comes from gamma, and to a lesser extent, vega. The residual P&L is due to inexact hedging (delta P&L) and other factors such as change in interest rates and so on. On a percentage basis, gamma accounts for roughly 74% of the P&L and vega for roughly 15% of the P&L. We can therefore conclude that the main factor driving P&L in such a volatility selling strategy is the overall gamma of the position and the behavior of realized volatility vis-à-vis implied volatility on a daily basis. Note that the dependence on daily gamma and vega makes the P&L path-dependent. For example, it is possible to see negative P&L for such a strategy even if the realized volatility over the holding period is lower than the implied volatility if there is a sudden spike in realized volatility towards the end of the holding period, when the (negative) gamma is at its highest.

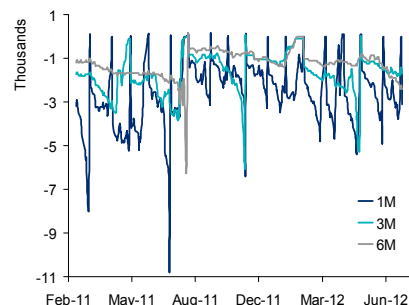
## Using Longer Dated Options

Figure 8. P&L: Different Option Maturities, \$



Source: Citi Research

Figure 9. Position Gamma, \$/(bp)<sup>2</sup>



Source: Citi Research

Thus far, we have focused on analyzing the results of back testing a strategy that uses 1 month options. We now look at the results for running the same strategy using ATM straddles composed of longer dated options – in particular, 3 month and 6 month options that are held till expiry. The P&L for each of these strategies is shown in Figure 8. We find that the strategy using 1 month ATM straddles performs the best. This is because the P&L of a short straddle position is mainly driven by the net gamma of the position. We know that the net gamma for a short option position (or straddle) becomes more negative as it gets closer to expiry. Thus, at the time of putting on a straddle, the net gamma for shorter maturities (e.g.

1M) is more negative than the longer maturities (e.g. 6M). As the straddle gets closer to maturity, the net negative gamma of the position may

1. become more negative if the straddle remains close to at-the-money (small moves in underlying) or,
2. become less negative if the straddle becomes in-the-money or out-of-the-money (large moves in the underlying).

We can therefore conclude that on an average, the net position gamma of a strategy using a shorter dated straddle (e.g., 1M) is more negative than that for a strategy using a longer dated straddle (e.g. 6M). This is because over the entire back test period (on average)

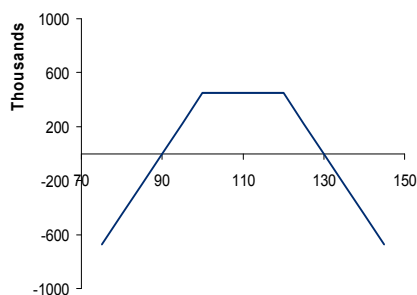
1. a strategy using a shorter dated straddle is closer to option maturity than one using a longer dated straddle, and
2. a strategy using a longer dated straddle is more likely to see larger moves (away from ATM) in the underlying during the life time of a trade than one using a shorter dated straddle – this implies that for a longer dated straddle, the chances of the position gamma becoming less negative are higher.

Indeed, that is what we observe in Figure 9 that shows the position gamma over time. The spikes in the figure show how the gamma drops faster (becomes more negative) as we get closer to maturity and then gets reset to a much less negative value when a new position is initiated after option expiry.

The results in this section also imply that using longer dated options and rolling the positions more frequently would be even less optimal. In order to understand this, we refer to Figure 9 which shows that the net position gamma at (close to) option inception is much less negative than at (close to) option expiry. Thus a long dated straddle that is rolled frequently (e.g., every month) is restricted to the “less negative gamma” portion of its life cycle. This implies that a frequently rolled straddle position will see much lower P&L from its gamma compared to a straddle held to maturity. A table showing the performance of all the strategies we examine in this report is shown in the Appendix (see Figure 21).

## Straddles versus Strangles

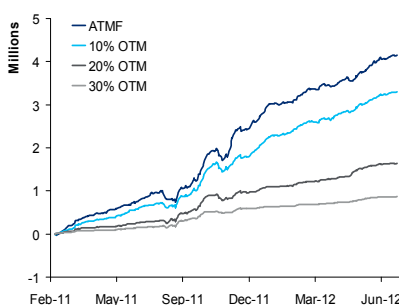
Figure 10. P&L: Short 100-120 Strangle, \$



Source: Citi Research

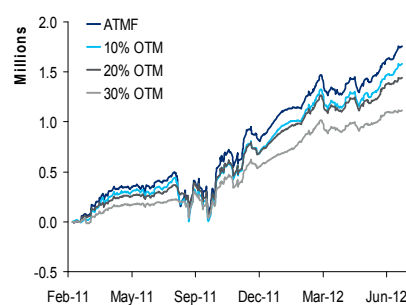
We now explore if our volatility selling strategy can be optimized if we use strikes that are different from the at-the-money forward spread. To understand this issue further, we examine the performance of volatility selling using **out-of-the-money (OTM) strangles**. A strangle is similar to a straddle except that the receiver and the payer options that are sold are both out-of-the-money, and therefore have different strikes. For example, the P&L profile at maturity of a strangle with a receiver strike of 100bp and a payer strike of 120bp (where the ATM forward is 110bp), is shown in Figure 10. We see that the maximum P&L occurs over a wider range of spreads than an ATMF straddle (see Figure 5), but the maximum P&L is lower than the maximum P&L for a straddle. We characterize a strangle by the “moneyness” of the receiver/payer strikes – for example, a 10% OTM strangle is a strangle with a payer strike that is 10% more than the ATMF strike, and a receiver strike that is 10% less. A straddle is a special case of a strangle, with 0% moneyness. A short strangle position that is more out-of-the-money has a lower maximum upside but a higher chance of realizing that upside at maturity.

Figure 11. P&L: Various OTM 1M Strangles, \$



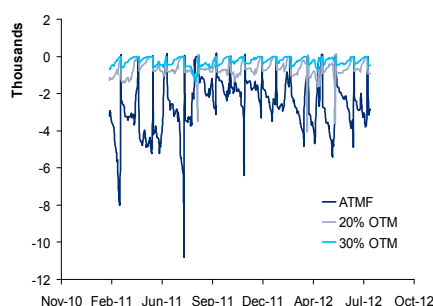
Source: Citi Research

Figure 12. P&L: Various OTM 6M Strangles, \$



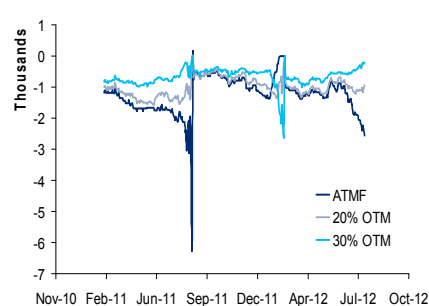
Source: Citi Research

Figure 13. Gamma: OTM 1M Strangles, \$/(bp)<sup>2</sup>



Source: Citi Research

Figure 14. Gamma: OTM 6M Strangles, \$/(bp)<sup>2</sup>

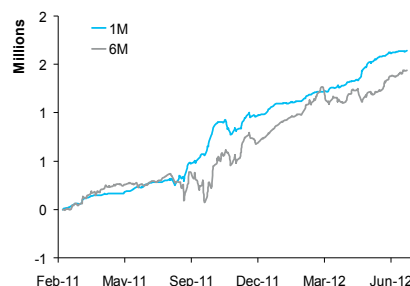


Source: Citi Research

The performance of volatility selling strategies using OTM strangles for 1M and 6M (3M is similar) is shown in Figure 11 and Figure 12. We note that the more out-of-the-money a strangle is, the worse it performs. Once again, the change in performance can be explained using the position gammas. Recall that the position gamma of a short option depends on the strike of the option and is the most negative when the option is at-the-money (or close to it). As the option strike moves away from the ATM strike (becomes out-of-the-money), the position gamma becomes less negative – this is illustrated in Figure 13 and Figure 14. Therefore, the more out-of-the-money a strangle is, the lower is the (mainly gamma dependent) P&L for our volatility selling strategy.

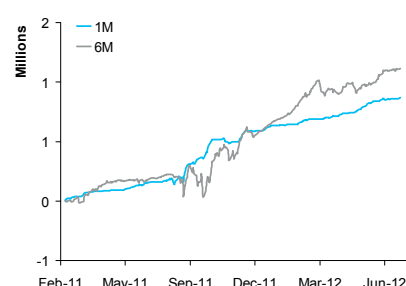


Figure 15. P&L: 20% OTM Strangles, \$



Source: Citi Research

Figure 16. P&L: 30% OTM Strangles, \$



Source: Citi Research

Another interesting point to note is the relative deterioration in performance for OTM strangles as we move across different option maturities (see Figure 15 and Figure 16 and compare with Figure 8). It is clear that the deterioration is most pronounced for the shorter dated options (1M). We observe that the 1M ATM straddle outperforms the longer maturity ATM straddles but the 1M strangles underperform the longer maturity strangles especially as the strangles become more out-of-the-money (e.g., Figure 16).

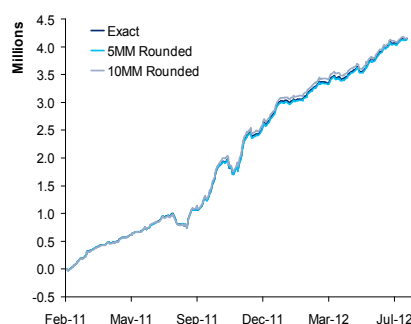
This can be explained by the correlation between option deltas and option gammas. Since OTM options (low delta) have lower gamma than ATM options (high delta), there exists a positive correlation between the delta of an option and its gamma. For a 1M option, as we get more OTM in terms of moneyness, its delta decays faster than that of a 6M option. This is because a 10% OTM 1M option has a much lower chance of being at- or in-the-money at option expiry, compared to a 10% OTM 6M option, given that both have to see the same absolute spread move (10% of ATM strike) but over different time horizons. Thus, relatively speaking, the gamma of a 1M option (that is positively correlated with the delta) becomes much less negative as it moves more and more out of the money, compared to a 6M option. This explains why we see the relatively rapid performance deterioration for shorter dated options.

## Operational Efficiencies

### Exact Delta Hedging versus Hedging in Round Lots

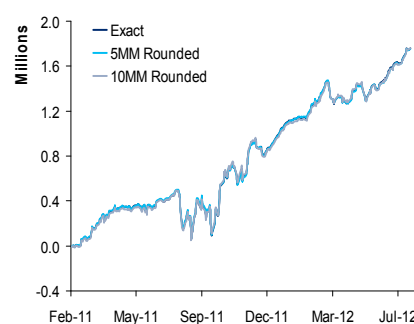
Thus far, our volatility selling strategies have used a delta hedging mechanism where the amount of index hedge is exactly equal to the net delta of the option position. In practice, dealers prefer to trade indices in round lots (typically, multiples of 5MM) and may charge higher transaction costs to trade the “odd lots” that are required for exact delta hedging. In this section, we take a closer look at the P&L impact that a round lot delta hedging strategy may have. For this purpose, we assume that instead of hedging daily with exact deltas, we round off the hedge notional to the nearest multiple of 5MM (or 10MM).

Figure 17. P&L: 1M ATM Straddle, Round lots, \$



Source: Citi Research

Figure 18. P&L: 6M ATM Straddle, Round lots, \$

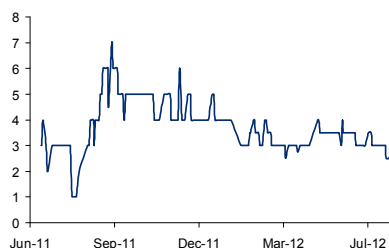


Source: Citi Research

The results are shown in Figure 17 (1M straddles) and Figure 18 (6M straddles). The results for the 3M maturity are similar. We see that the performance penalty for hedging in round lots is almost negligible. For all combinations of maturities and round lots sizes shown here, the difference in P&L is less than 0.5% in each case. In general, hedging in round lots may even increase the P&L net of transaction costs because of the lower transaction costs involved in doing a hedge in round lots – we discuss this further in the next section.

### Effect of Transaction Costs

Figure 19. 1M ATMF bid-ask spread, bp



Source: Citi Research

We finally come to the issue of transaction costs. There are two components of transaction costs involved in this strategy: the cost of executing the option trade itself, and the cost of daily hedging using the index, each of which can be quantified by the bid-ask spread of the respective security. For the option itself, the bid-ask spreads are typically high – we show the bid-ask spreads for 1M ATMF options in Figure 19. The range is 1-7bp, but it is mostly in the 3-6bp range, with an average of 3.6bp. The spread is higher for the OTM options. The index bid-ask spreads are lower, typically, in the 0.5-1bp range. For our calculations, we use a 4bp bid-ask for ATMF options, 6bp bid-ask for OTM options, 0.75bp bid-ask for odd-lots (exact) hedging, and 0.5bp bid-ask for round lots hedging.

Figure 20. Impact of Transaction Costs, \$

Expiry	Moneyness	Hedge Type	P&L	Option, bp	Transaction Cost		Total	P&L %
					Option, \$	Hedge, \$		
1M	ATMF	Exact	4,149,732	4.0	720,000	0.75	936,510	40%
3M	ATMF	Exact	2,524,026	4.0	240,000	0.75	490,440	29%
6M	ATMF	Exact	1,758,394	4.0	120,000	0.75	363,096	27%
1M	30% OTM	Exact	868,222	6.0	1,080,000	0.75	135,138	140%
3M	30% OTM	Exact	1,242,226	6.0	360,000	0.75	210,093	46%
6M	30% OTM	Exact	1,114,064	6.0	180,000	0.75	172,180	32%
1M	ATMF	5MM Round Lot	4,131,740	4.0	720,000	0.50	624,980	33%
3M	ATMF	5MM Round Lot	2,516,888	4.0	240,000	0.50	319,710	22%
6M	ATMF	5MM Round Lot	1,755,142	4.0	120,000	0.50	243,443	21%
1M	ATMF	10MM Round Lot	4,163,121	4.0	720,000	0.50	630,509	32%
3M	ATMF	10MM Round Lot	2,538,958	4.0	240,000	0.50	339,084	23%
6M	ATMF	10MM Round Lot	1,758,385	4.0	120,000	0.50	247,549	21%

Source: Citi Research

In Figure 20, we show the cost of hedging for some of the volatility selling strategies that we have described as a percentage of the total gross P&L. The transaction costs using round lots hedging are mostly in the 20-33% range of the total P&L, whereas if we hedge using odd-lots (exact notional), the costs can be as high as 40 – 45%. Since the gross P&L hit from round lot hedging is less than 0.5% (see previous section), the 7-10% improvement in transaction costs due to round lots hedging makes it the most optimal way to execute the hedges. As credit option markets become larger and more liquid, we expect the total transaction costs to decline further. Finally, we point out that the one case that stands out in this analysis is the 1M 30% OTM strangle where a combination of high bid-ask for OTM strangles as well as odd lots hedges make the transaction costs higher than the gross P&L (i.e. negative P&L net of transaction costs).

## Conclusions

Our analysis of credit volatility selling strategies shows that the persistent volatility risk premium in credit markets is significant and it is possible to monetize this premium easily, even after paying transaction costs. The most optimal way is to sell volatility using short dated ATMF straddles that are held to maturity and delta hedge using round lots to reduce transaction costs. While our current strategies are based on repeating the option selling process over time (i.e. enter into a new short straddle position after the previous one expires), we envisage that it may be possible to optimize the P&L by intelligently determining when to enter into a new short position. For example, under certain market regimes (especially when markets are declining rapidly), realized volatility can spike higher than implied volatility, causing losses in a short volatility strategy. A decision process based on an analysis of the relationship between the volatility risk premium and other market factors can help to avoid such scenarios and could be the subject of further work in this area.

Further, given the consistent profitability of selling volatility, we cannot help but wonder whether selling receiver options would be more effective as a tail hedge for investors who are long cash credit. This is the credit equivalent of writing a covered equity call option. Such a strategy would mitigate losses in the long portfolio through accumulating option premiums when markets decline and can even add to profits in rallying markets given the significant mispricing (difference between implied and realized volatility) of volatility in credit markets. We therefore believe that a carefully managed strategy that sells ATMF (or appropriately chosen OTM) receivers can be a better hedge than one that buys ATMF or OTM payers.

## Appendix

Figure 21. Performance Statistics for Different Strategies

Expiry	Moneyness	Hedge Type	P&L, \$		Daily		% Positive P&L Days	Annual Sharpe
			Gross	Net	Mean P&L	Std Dev		
1M	ATMF	Exact	4,149,732	2,493,223	6,984	32,998	64%	3.4
3M	ATMF	Exact	2,524,026	1,793,587	5,024	30,060	65%	2.7
6M	ATMF	Exact	1,758,394	1,275,298	3,572	34,005	65%	1.7
1M	10% OTM	Exact	3,296,279	1,615,573	4,525	27,140	71%	2.6
3M	10% OTM	Exact	2,341,625	1,544,365	4,326	26,164	65%	2.6
6M	10% OTM	Exact	1,580,652	1,066,067	2,986	31,233	64%	1.5
1M	20% OTM	Exact	1,642,050	299,060	838	19,866	70%	0.7
3M	20% OTM	Exact	1,808,765	1,134,363	3,177	20,648	64%	2.4
6M	20% OTM	Exact	1,441,499	993,823	2,784	26,672	65%	1.7
1M	30% OTM	Exact	868,222	(346,916)	(972)	16,039	68%	-1.0
3M	30% OTM	Exact	1,242,226	672,133	1,883	15,799	69%	1.9
6M	30% OTM	Exact	1,114,064	761,883	2,134	21,464	64%	1.6
1M	ATMF	5MM Round	4,131,740	2,786,761	7,806	32,826	64%	3.8
3M	ATMF	5MM Round	2,516,888	1,957,178	5,482	30,052	66%	2.9
6M	ATMF	5MM Round	1,755,142	1,391,699	3,898	34,211	66%	1.8
1M	ATMF	10MM Round	4,163,121	2,812,612	7,878	33,022	64%	3.8
3M	ATMF	10MM Round	2,538,958	1,959,874	5,490	29,974	64%	2.9
6M	ATMF	10MM Round	1,758,385	1,390,837	3,896	34,321	64%	1.8

All statistics computed on Net P&L (P&L net of transaction costs).

Sharpe defined as Mean Daily P&L / Std Dev of Daily P&L which is then annualized (multiplied by sqrt (252)).

Shaded rows show the most optimal strategies.

Source: Citi Research

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## Appendix A-1

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