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Title: **Investing in Volatility**

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Synopsis: Various products deliver exposure to volatility as an investment in its own right, including VIX futures, variance swaps and managed volatility funds. This report reviews the nature of these products, and how they might fit into a portfolio. Volatility exposure can be used to either enhance returns through capturing the 'volatility risk premium' or hedge via exploiting a negative correlation with equity markets. An investor's interest in volatility as an investment will inevitably depend on their circumstances.

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Investing in Volatility

By: Chris Inman and Geoff Warren

SECTION 1: INTRODUCTION

This report examines the case for investing in volatility. The aim is to provide an outline of available products and the nature of the payoffs they offer, sufficient for a reader to decide whether to pursue a more in-depth investigation on their own behalf. The key points are as follows:

1. ***The general character of long volatility exposure is that it generates negative returns on average, but hedges equity risk.*** The negative returns, also known as the 'volatility risk premium', go hand-in-hand with the fact that volatility exposure has a negative equity beta. Further, volatility exposure seems to provide an effective hedge against equity market sell-offs due to non-linear payoffs which tend to increase with large market declines. Indeed, the payoffs are very similar to buying puts or insurance over equity market weakness: it costs something on average, but it protects when markets turn sour.
2. ***Different volatility products offer different payoff structures.*** The volatility risk premium is closely associated with the tendency for realised volatility to be less than the implied volatility reflected in option markets. As one-month variance swaps provide the most direct exposure to this aspect, short positions in this product might be favored for investors seeking to capture the volatility risk premium. Alternatively, forward variance swaps might be used by investors seeking to hedge. Forward variance swaps seem to offer limited (if any) exposure to the volatility risk premium, but still retain the capacity to hedge equity market risk.
3. ***Whether long or short volatility positions might be considered depends on the circumstances.*** Factors that could influence whether an investor contemplates either long or short volatility exposure include their tolerance for both portfolio risk and peer risk, investment horizon, the level of volatility given its propensity to mean-revert, and capacity to implement positions. For those investors looking to use long volatility positions for hedging purposes, key issues include the potential adverse implications for returns over time and peer risk. For investors thinking about short volatility positions to capture the volatility risk premium, the main consideration is capacity to bear potentially substantial short-term performance risk.
4. ***Managed volatility products may be worth a look.*** A small but diverse pool of managed volatility products are available, usually offered by hedge fund managers. While most managers aim to generate positive returns in all market environments, they may do so through various combinations of directional volatility exposure (sometimes time-varying), and non-directional strategies aimed at exploiting mispricing of the volatility implicit in derivative products across securities or markets. Portfolio protection products also

exist. Most managers aim to structure their portfolios towards a primary exposure to volatility, while controlling exposure to other factors.

5. ***Volatility exposure will not be everybody's cup of tea.*** Some investors may want neither a potentially costly hedge nor the occasional anguish that comes with trying to capture the volatility premium. Volatility investing is also a very technical area. Not all investors will be willing or able to commit the time and resources needed to understand and manage an investment, be it either directly or via manager selection and monitoring.
6. ***An emerging investment area.*** As an emerging investment area, the range of products tends to be limited and market liquidity often unreliable. But there may be opportunities for early movers. Over time, the product suite should broaden beyond the current focus around US and European equity indices towards other markets, while markets should deepen. Amidst such developments, there is no guarantee that the observed return relationships will persist.

In addition to this introduction (Section 1) and a conclusion (Section 4), this report comprises two main sections plus appendices. Section 2 considers directional volatility strategies, focusing on products based around the S&P 500 such as VIX futures and variance swaps. Section 3 discusses volatility managers in broad terms. To limit the size and density of the body of the report, a substantial slice of the more in-depth and technical materials are relegated to appendices or footnotes.

SECTION 2: DIRECTIONAL VOLATILITY STRATEGIES

This section provides an overview of directional volatility strategies, which involve either long or short exposure to volatility. The section commences with the preliminaries of the nature of volatility exposures, and how a position might be achieved. It then discusses the payoffs from volatility exposure, and how they may relate to portfolio performance. The question of whether volatility exposure might be timed is also addressed. The section finishes by discussing the case for long or short positions given investor objectives.

2.1 NATURE OF VOLATILITY

The term 'volatility' can represent various things, and is often used loosely. In investment markets, volatility can be used in a general sense to refer to the variability of asset prices or returns. While all assets implicitly bring exposure to volatility in a sense, the focus here is a range of investment products whose payoffs are based around some measure of asset volatility. When 'volatility' is used in this specific context, it usually equates to *standard deviation*, typically expressed at an annual rate. Another closely related measure is *variance*, which is volatility squared.

Further, volatility (and variance) may be discussed in three different contexts:

1. ***Realised volatility*** – the historical volatility observed over a specific period
2. ***Implied volatility*** – typically used in reference to the volatility that is implied in option prices under some option pricing model such as the Black-Scholes option pricing formula.
3. ***Expected volatility*** – some expectation or forecast for future volatility.

The main available products are technically based around either implied volatility (VIX) or realised variance (variance swaps). Expected volatility plays a role by influencing how the market prices these products. That is, there exists a ‘volatility term structure’ which reflects market expectations for future volatility, in a similar fashion that the ‘interest rate term structure’ in bond markets reflects market expectations for future interest rates.

2.2 VOLATILITY EXPOSURES

Products that generate ‘pure’ volatility exposure are summarised here, and discussed in more detail within Appendix A. The major products are:

- ***VIX futures*** – The payoff on VIX futures depends on the value of the VIX, which measures the *implied volatility* for S&P 500 index options of one-month to expiry. The easiest way to think about VIX futures is as a bet that implied volatility at expiry will differ from the futures contract price. If the VIX at expiry is above the original futures price, the investor going long will gain.
- ***VIX options*** – VIX options also settle to implied volatility at expiration date.
- ***Variance swaps*** – The payoff on a variance swap depends on *realised variance*. A variance swap can be thought of as a bet that realised variance over the term of the swap will differ from the swap rate. If realised variance is more than the swap rate, the investor going long will gain. There is an active over-the-counter market encompassing most major equity markets.
- ***Forward variance swaps*** – The payoff on forward variance swaps reflects the difference between an agreed swap rate at which a variance swap may be purchased in the future, and the actual swap rate at the time of expiry. The payoff hence reflects changes in the variance swap rate.

To the extent that expected volatility is reflected in the pricing of these products, their payoffs will be a function of:

(a) any unexpected changes in volatility over the term of the contract, and
(b) any risk premiums impounded into the price.

Notwithstanding the common drivers for the various products, there are also some important differences. First, the fact that VIX futures are based around volatility while variance swaps are based around variance means that the shape and magnitude of the payoffs differ for equivalent moves. This reflects the non-linear transformation between volatility and variance, with variance-based payoffs being far more volatile. For example, between August and October 2008, volatility as measured by the VIX rose by about three times, from of 0.20 (20%) to 0.60 (60%). The equivalent in variance was a rise of nine times, from 0.20*0.20 = 0.04 to 0.60*0.60 = 0.36. Similarly, a 50% decline in volatility from 20% to 10% equates to a 75% decline in variance (from 0.04 to 0.01).

Second, the various products bring exposure to differing aspects of volatility. Variance swaps settle to what is a backward-looking estimate of volatility. They bring direct exposure to any tendency for realised volatility to be less than the volatility priced into the market. On the other hand, VIX futures settle to a quantity that reflects future expectations for volatility, i.e. volatility implied in option prices with another month to run. The same can be said of forward variance swaps, which settle to the price at which volatility exposure can be purchased at some future time.

2.3 IS VOLATILITY AN ASSET CLASS?

Quite frankly, it probably doesn’t matter. Exposure to volatility (or variance) will generate future payoffs with particular features. The issue is whether an investor will benefit from adding such exposure to their portfolio. Whether this exposure happens to be labeled as an ‘asset class’ is only of tangential relevance.

However, if pushed, we would come down on the side of saying volatility exposure is NOT an asset class in the true sense. Asset classes typically appear in positive net supply, i.e. they are associated with claims over future cash flows generated by assets in the economy. In contrast, all volatility exposure amounts to contracts between two investors that do not generate any net cash flow, i.e. a zero-sum game in which gains and losses are offset. Volatility products are akin to derivative contracts which exist in zero net supply.

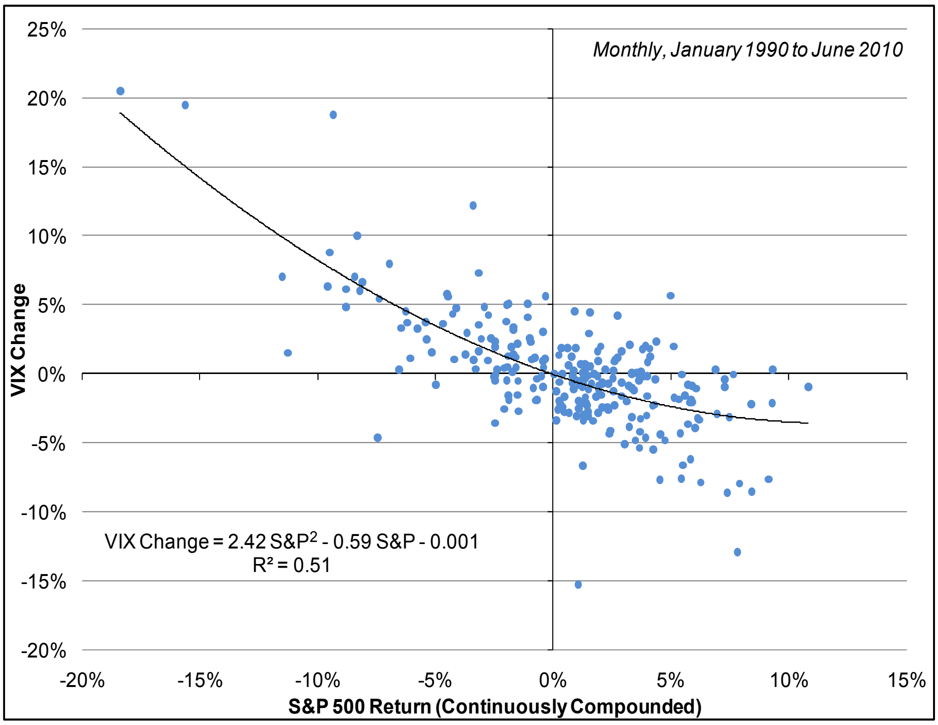
2.4 PAYOFFS FROM VOLATILITY EXPOSURE

The objective here is to sketch out the shape of the payoffs that might be expected from a directional volatility exposure. An overview of the stylistic facts about volatility exposure appears in Appendix B, including a brief summary of the findings from the academic literature. Appendix C plots the times series of payoffs for selected volatility products.

The vast bulk of academic literature in the area focuses on equity market volatility. The over-riding feature is that long volatility exposure has tended to generate negative returns on average, but has provided a quite effective hedge against equity market weakness. Indeed, volatility exposure seems to act like a put option on equity markets or an insurance contract over equity market declines. The buyer of volatility exposure pays a premium for downside protection; while the seller earns a premium for accepting the risk.

In addition, payoffs to volatility exposure are non-linear (convex). Gains from a long volatility exposure tend to be greater when the equity market is weaker, while losses are relatively modest when the equity market is rising. This pattern is reflected in Figure 1, which compares the monthly change in the VIX versus (continuously compounded) S&P 500 returns over the period January 1990 to June 2010. A quadratic line of best fit is shown for reference, but clearly the payoff structure is also not unlike a put option. The payoff distribution for all volatility products has a similar shape.

FIGURE 1: CHANGE IN VIX VERSUS S&P 500 RETURN



Source: CBOE, S&P, Russell

Figure 1 reflects the broad shape of the relationship between equity returns and changes in volatility. But it does not reveal the magnitude of returns to volatility exposure which also depends on how the exposure is priced. Given the central role of equity risk in many portfolios (see Leibowitz and Bova, 2007; Warren, 2008), any investment that hedges equity market risk might be expected to generate a negative risk premium. The more recent academic literature[1] focuses on variance swaps,[2] and has found the negative risk premium to be quite substantial. Further, the premium seems larger than can be explained by equity beta or indeed any of the usual risk factors, hinting at the possibility of excess returns from shorting volatility. The term 'volatility (or variance) premium' has become part of the vernacular in the academic literature, which is currently moving towards attempting to explain why such a large premium might exist.

It is also worth noting that volatility itself tends to be persistent in the short term, mean-reverting over the medium-long term, and subject to occasional 'jumps' (i.e. upwards spikes). These features are reflected in the payoffs from volatility products. The tendency for volatility to jump infuses these payoffs with high skewness, so that they are not well described by a normal distribution.

Before providing some data on the volatility premium, it is worth describing how the volatility premium manifests itself in the various products. The departure point is the observation that option-implied volatility has exceeded realised volatility by a significant margin on average. Variance swaps directly capture this feature, as they are priced by investment banks with reference to option markets. If an investor shorts a variance swap on (say) the S&P 500, any investment bank taking the other side of the trade will hedge the variance exposure through a portfolio of S&P 500 index options.[3] The investor then profits to the extent that realised variance turns out less than what is implied in S&P 500 option prices.

VIX futures and forward variance swaps do not give direct access to this aspect, given that they settle to forward-looking volatility measures. Nevertheless, their payoffs can still reflect a volatility risk premium to the extent that it is built into the forward curve, i.e. the volatility term structure. If a premium exists, the term structure should be upward-sloping on average. This appears to have been the case – see Appendix D for charts on the VIX term structure. However, the slope of the term structure is relatively gentle beyond two to three months. This hints that exposure to the volatility risk premium may be modest for products like forward variance swaps and longer-dated VIX futures that are rolled at regular intervals.

With this background, Table 1 provides a sense for the average magnitude and shape of the payoffs measured in volatility points over the period January 1990 to June 2010. Each month is assigned to a bucket based on the z-score[4] for the continuously compounded S&P 500 returns. The average for each bucket is reported, as well as the overall average at the bottom. A positive (negative) number represents a gain (loss) from a long position.

[1] It is difficult to talk about the 'returns' in the usual sense with respect to volatility exposure, as it typically involves a zero cost investment (apart from any margin deposits or transaction costs). The academic literature reports either the dollar value of payoffs for a certain exposure level, or the log of the payoff divided by the swap rate.

[2] The earlier literature focused on various option strategies, such as delta-hedge buy-writes, and found similar results.

[3] This hedge is not as effective for volatility swaps, hence the lack of such products.

[4] z-scores measure the number of standard deviations from the mean.

TABLE 1: PAYOFFS TO VOLATILITY EXPOSURE SORTED BY S&P 500 RETURNS

z-score	No. of Months	% of Periods	S&P 500 Return $ln(R_t / R_{t-1})$	Change in Spot VIX	Realized Volatility less VIX: Annualized 252-day	Realized Volatility less VIX: Annualized 365-day	Realized Volatility *less* 1-month Variance Swap Rate	Change in Swap Rate for 3-month Forward 3-month Variance Swap
< -1.50	21	9%	-9.00%	6.9	5.0	11.5	5.2	3.1
-1.0 to -1.5	11	4%	-4.81%	3.2	-2.5	1.1	-2.3	1.8
-0.5 to -1.0	35	14%	-2.47%	1.9	-2.9	0.3	-2.4	0.9
0.0 to -0.5	36	15%	-0.47%	0.1	-3.7	-0.8	-3.3	-0.1
0.0 to +0.5	68	28%	1.61%	-0.9	-5.2	-2.6	-4.7	-0.2
+0.5 to +1.0	40	16%	3.76%	-1.4	-5.8	-3.3	-5.3	-0.7
+1.0 to +1.5	22	9%	5.83%	-2.8	-8.5	-5.2	-8.1	-1.3
> +1.50	13	5%	8.33%	-4.3	-7.2	-2.6	-6.6	-2.2
Total	**246**	**100%**						
Average Jan'90-Jun'10			**0.61%**	**0.07**	**-4.17**	**-0.90**	**-3.71**	**0.06**
Average Jan'90-Mar'10			**0.67%**	**0.00**	**-4.23**	**-0.98**	**-3.76**	**0.01**
Standard Deviation			4.41%	4.14	6.20	7.55	6.15	2.29

Based on monthly data, January 1990 to June 2010

Source: CBOE, S&P, various investment banks, Russell

The following observations can be drawn from Table 1:

- The ***change in the VIX*** is shown for reference (noting that the VIX itself cannot be traded – see Appendix A). The negative relation between S&P 500 returns and the VIX is clearly seen. The average change in the VIX was modestly positive over the full period, indicating that returns on long versus short positions may be influenced by a net rise in volatility. The analysis further below will hence be based on the period January 1990 to March 2010, during which the average VIX change was near zero.
- The *'**realised less VIX**'* columns compare realised daily volatility over the month with the opening VIX at the start of the period, i.e. realised less implied volatility. As there is no standardisation around whether realised daily volatility should be annualised based on business (252) days or calendar (365) days,[5] both are reported. Since 1990, realised volatility has averaged between -0.9% (calendar) and -4.17% (business day) below implied volatility. Further, realised volatility is meaningfully above implied volatility only for the bucket containing S&P returns with a z-score of less than -1.50, i.e. periods with the largest market declines. This amounts to just 9% of months.
- The difference between ***realised volatility and the one-month variance swap rate*** provides an indication of variance swap payoffs, bearing in mind that actual payoffs are based around variance and not volatility. The average returns are positive for only the 9% of periods when S&P returns z-score is less than -1.50, mirroring the findings for the VIX. The implication is that shorting one-month variance swaps tends to generate positive returns across most periods, except those which involve substantial equity market weakness. Note that the average difference is very large at -3.71 volatility points, which reflects the volatility risk premium.
- The ***change in the swap rate for forward variance swaps*** (of three months, starting in three months' time) has a negative relation with S&P 500 returns, confirming that such products provide an equity market hedge. The

[5] This point is made by Carr and Wu (2009) with respect to variance swaps. To the extent that volatility is a continuous process, it is unclear whether calendar or business day annualisation of discrete trading day observations provides the better proxy. Nevertheless, business day annualisation is emphasised here, as it is understood to accord with contract terms for the majority of variance swaps.

distribution of changes is somewhat even, in contrast to one-month variance swaps where payoffs are more skewed. Further, the average change is slightly positive, indicating small gains from a long position over the period.

Table 1 provides an initial hint that investors looking to capture the volatility premium through short positions might focus on one-month variance swaps, while those thinking about going long to hedge their equity exposure might favor forward variance swaps.[6]

2.5 PORTFOLIO ANALYSIS

The impact of volatility exposure on a portfolio is now investigated. First up, it is established that the relation between volatility exposure and equities can be generalised beyond the US. Table 2 reveals that the correlation and beta of the change in the VIX versus both world and Australian equities is similar to that with the S&P 500. In addition, the relation in European equity markets is similar to that observed in the US (see for example Hafner and Wallmeier, 2007). For all intents and purposes, an exposure to US-based volatility products is likely to provide an effective equity hedge in general.

TABLE 2: RELATIONSHIP BETWEEN CHANGE IN VIX AND SELECTED EQUITY INDICES

Monthly data, January 1990 to June 2010	**US** *S&P 500*	**World** *MSCI World, US$*	**Australia** *S&P/ASX 300, A$*
Correlation	-0.69	-0.64	-0.50
Beta vs index			
All months	-0.64	-0.59	-0.53
Positive return months	-0.37	-0.44	-0.26
Negative return months	-0.87	-0.84	-1.00

Source: CBOE, S&P, MSCI, Russell

The impact of adding volatility exposure is now examined through focusing on portfolios comprising the S&P 500 and the following investments:

- One-month variance swaps, held to expiry
- Three-month variance swaps, held to expiry
- Forward three-month variance swaps starting in three months' time, held to expiry
- VIX one-month futures, held to expiry
- VIX three-month futures, rolled monthly
- 5% of portfolio invested in the Barclay US Aggregate Bond Index, funded out of equities (i.e. an alternative risk reduction strategy)

The analysis proceeds by estimating returns over rolling three-month holding periods.[7] In scaling volatility exposure, the analysis maintains an approximately

[6] Seemingly contrary claims can be found across authors that the risk/return trade-off of a portfolio can be improved by respectively including short volatility (e.g. Grant et al, 2007; Egloff et al, forthcoming) or long volatility positions (e.g. Cheeseman, 2008; Jacob and Rasiel, 2008). On our reading, the key difference is that those suggesting short positions have based their analysis on variance swaps, while those recommending long positions base their analysis on forward volatility markets.

[7] Rolling three-month returns were adopted due to evidence of short-term dependencies in the joint returns for equity and volatility exposure, as documented by Bollerslev, Sizova and Tauchen [2009. It is likely that these dependencies would have run their course over three months.

equivalent and constant exposure to a point change in volatility in every period.[8] The approach involves taking one variance swap contract with a notional US$100,000 'vega' face value per US$100 million invested, or one VIX future contract per US$1 million invested. For the three-month variance swap products, one-third of a contract is adopted each month, and held over the three months to expiry. Thus the equivalent of one full contract is in place at all times.

Variance swap data is drawn from the period January 1990 to March 2010, during which the VIX was virtually unchanged.[9] Returns were estimated on a calendar month basis. Data was kindly provided by a number of investment banks.[10] The series mainly reflect hypothetical mid-point swap rates imputed from S&P 500 index options.

The VIX futures data was sourced from the CBOE website, with analysis drawing on the months May 2004 to March 2010.[11] Returns for the VIX futures were calculated based on settlement prices for periods spanning expiry dates (approximately, but not exactly, one month apart). A major issue is that the data period spans only five to six years, and is dominated by the spike in volatility and its subsequent reversion during the global financial crisis (GFC). The relative magnitude of payoffs during the GFC can be viewed in Appendix C. To address the fact that this extreme episode is 'over-weighted' in the data, and to place the variance swap and VIX futures analysis on a more comparable footing, a 'bootstrap' analysis was employed. The bootstrap analysis was implemented to effectively down-weight the GFC period in a manner that afforded such an event the probability of occurring once every 20 years. The bootstrap involved forming a hypothetical return series through random draws from the data, with a lower probability attached to drawing data from data points between September 2008 and June 2009.[12]

An overview of the key findings is provided here. The full results appear in Table 5 within Appendix E. A long volatility exposure generally reduces total portfolio risk, based on measures such as standard deviation, the lowest return decile and maximum loss. The opposite occurs for short volatility exposures. This is, as expected, given the negative correlation of volatility with equity markets. It is also generally the case that long volatility strategies generate negative returns. However, forward variance swaps are an exception over the period analysed, during which a long position generated positive returns. Given that the returns are modest and possibly due to idiosyncrasies of data, it seems reasonable to

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[8] This scaling approach is adopted on the basis that the underlying exposure is the change in volatility itself, rather than the notional face value of the contract. For VIX futures the face value varies with the level of volatility. Given multipliers of US$1,000 on the VIX futures, the notional face value equals US$10,000 for volatility of 10 and US$50,000 at volatility of 50. The variance swap is quoted in terms of US$100,000 of notional 'vega' value, and is hence designed so that a one-point change in volatility will give rise to a payoff of approximately ±US$100,000. Note that this relation breaks down for large moves in volatility, given that the payoff depends on variance which has a non-linear relation with volatility.

[9] The VIX moved from 17.39 in December 1989 to 17.59 in March 2010.

[10] A range of data for indicative variance swap strike rates was provided by Bank of America Merrill Lynch, Credit Suisse, Goldman Sachs and JP Morgan. Available data was averaged. Correlation between the series was in excess of 0.99 in all cases.

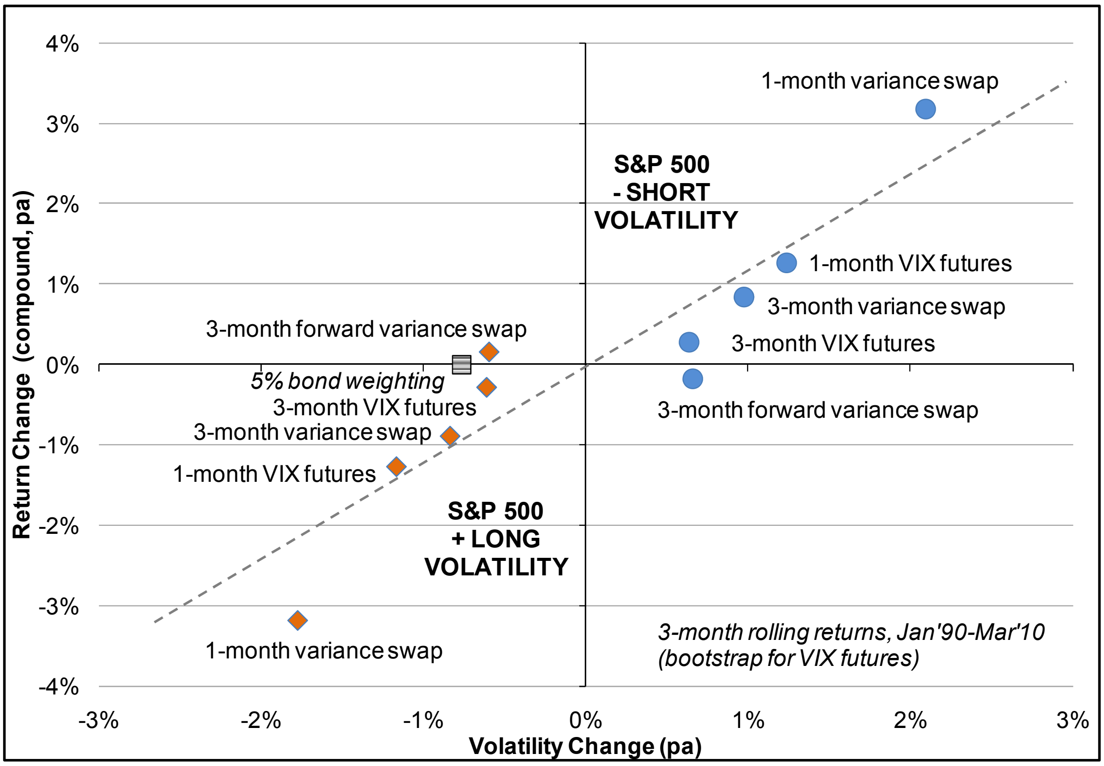
[11] When three-month VIX futures prices were unavailable, estimates were formed by linearly interpolating from other contracts. When the one-month VIX futures were unavailable, the change in the two-month VIX futures was used.

[12] The bootstrap was based on 5000 random draws, with probability attached to drawing data from the GFC period at 1/(12*20) or 0.4167% per month. As the analysis is based around three-month averages, the GFC data points effectively span the period July 2008 to June 2009 which includes the spike in volatility and its subsequent reversion back towards more "normal" levels. With the GFC period spanning nine months it is given a 3.75% probability mass, with the residual apportioned equally across the remaining data.

take the results as an indication that forward variance swaps reduce risk without any meaningful impact on returns.

Figure 2 summarises the findings by plotting the change in portfolio return versus the change in portfolio standard deviation across strategies. An average return-to-risk trade-off is revealed that sits close to a 1.2-to-1 ratio, as represented by the dashed trend line. That is, volatility strategies that add (subtract) 1.2% pa to portfolio return also add (subtract) about 1% pa to portfolio volatility. Strategies higher on Figure 2 offer a better trade-off in terms of return change per unit of volatility change. The magnitude of the impact of strategies appearing in Figure 2 varies because of differences in payoff volatility. While this can be partly addressed by scaling the position size, it can be dangerous to extrapolate when non-linear payoffs are involved. Table 6 in Appendix E reports some results at differing levels of position size.

FIGURE 2: IMPACT ON PORTFOLIO OF ADDING VOLATILITY STRATEGIES

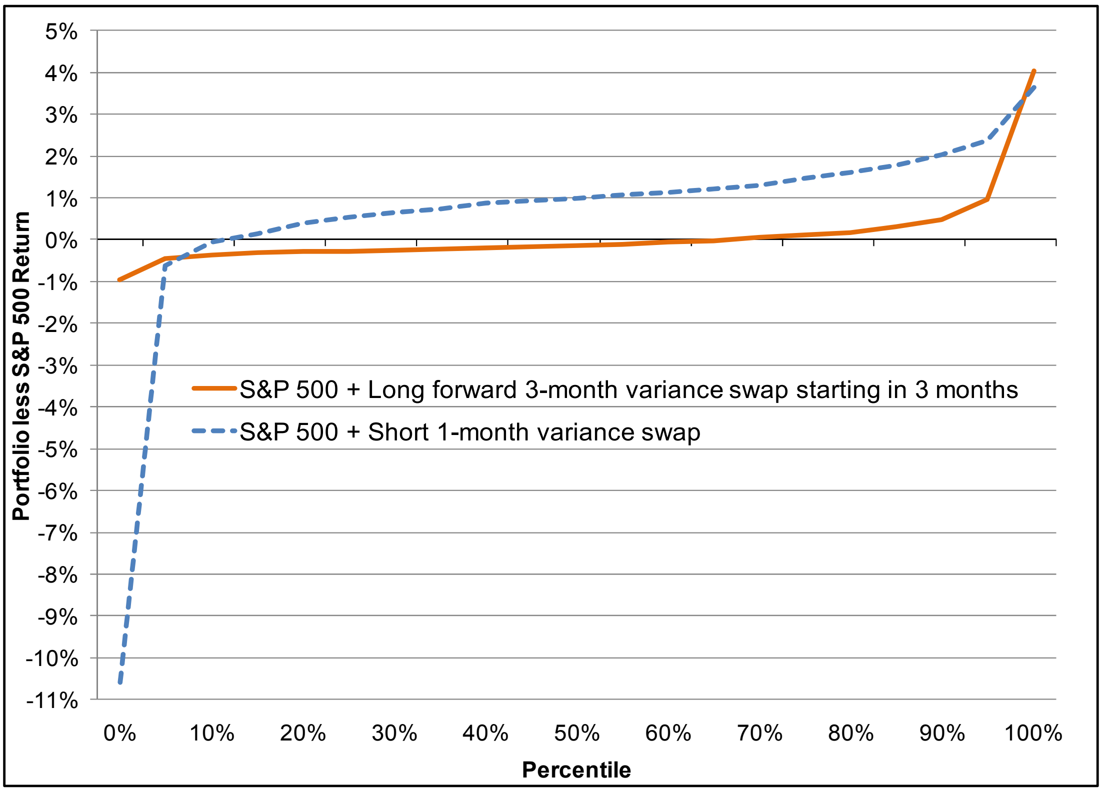


Source: Barclays, CBOE, S&P, various investment banks, Russell

While one has to be wary about forming opinions based on historical data, some general messages can nevertheless be gleaned from Figure 2. For long volatility strategies, the three-month strategies have provided better long-side results than the one-month strategies. This is consistent with the idea that volatility risk premium applies more strongly with respect to short investment horizons. Of the strategies examined, forward three-month variance swaps appear to offer the best trade-off. On the short side, the best trade-off seems to arise from one-month variance swaps which directly capture the large difference between implied and realised volatility over one-month periods.

Figure 3 provides another view of the impact of volatility exposure, by plotting the percentile distribution of relative returns versus the S&P 500 for both long positions in forward three-month variance swaps and short positions in one-month variance swaps. Shorting one-month variance swaps generates *out*performance over a large majority (88%) of periods, but delivers very substantial underperformance in the lower tail. The distribution for forward three-month variance swaps is somewhat more even, although *under*performance is generated during a majority (66%) of periods. However, this strategy delivers a meaningful return improvement in the upper tail of the distribution. In both cases, the tails being discussed are associated with equity market sell-offs.

FIGURE 3: DISTRIBUTION OF PORTFOLIO RETURNS RELATIVE TO S&P 500



Source: S&P, various investment banks, Russell

In summary, the analysis confirms that long volatility exposure has tended to reduce both portfolio return and risk. Short volatility positions do the opposite. However, the shape of payoffs differs in meaningful ways across the various products, and some of the most relevant action occurs in the tails of the distribution. Long volatility positions seem better taken via products with longer terms. Forward variance swaps were the most attractive over the period analysed, although they delivered underperformance in a majority of periods. Short volatility positions appear best taken via one-month variance swaps, which capture the volatility risk premium over the large majority of periods. However, they can greatly exacerbate the downside during equity markets sell-offs. How investors might respond to these opportunities will be discussed in section 2.9.

2.6 WILL THE PAYOFFS PERSIST?

There is a strong case to expect that long volatility exposures will continue to generate negative risk premiums on average going forward. This case stems directly from the nature of volatility as an equity market hedge, which in turn justifies a negative risk premium as a matter of market equilibrium. Hafner and Wallmeier (2007, pp 534-5) outline the reasons to expect higher volatility to be associated with lower equity prices. There are two hypotheses. The first is the 'leverage effect', which argues that lower stock prices lead to increased corporate leverage, which in turn leads to increased future volatility. The second is the ‘volatility feedback hypothesis’, where higher volatility is associated with higher risk premia, which in turn leads to lower equity prices. Both explanations imply that lower equity prices and higher volatility go hand-in-hand, so that a long volatility exposure should provide an equity market hedge as observed. The non-linear nature of this payoff only serves to reinforce the rationale for long volatility to generate a negative risk premium in equilibrium.

The more difficult question is whether the volatility premium captured by one-month variance swaps amounts to excess returns after risk adjustment, and if so, whether any excess returns will continue. The consensus in the academic literature is that excess returns have indeed been available. Appendix B discusses some explanations. One notable reason relates to a mismatch between demand for options and the capacity of market-makers to supply this demand. This particularly applies to puts in the case of equity index options. If this explanation is valid, then persistence of *excess* returns may depend on whether substantial fresh funds are attracted to take advantage of the opportunity. The capacity of volatility strategies may be relevant in this respect. Investors considering shorting volatility to capture the premium might hence want to monitor the popularity of their chosen strategy relative to capacity.

Another key issue is whether forward variance swaps can be expected to deliver hedging benefits at minimal return cost going forward. It seems sensible to assume that the positive returns experienced historically will not be available going forward. In all likelihood, this result probably reflects either distortions within what is hypothetical pricing data, or a combination of market immaturity and barriers to arbitrage. It seems reasonable to expect that a zero-dollar investment which is negatively correlated with equity markets will generate negative payoffs. Nevertheless, it remains entirely possible that forward variance swaps might continue to deliver hedging benefits at more than a reasonable cost.

2.7 TIMING EXPOSURE

The analysis so far has assumed constant exposure to volatility. A number of aspects suggest the possibility that exposure might be timed. Both volatility itself and payoffs from volatility exposure are known to be persistent in the shorter-term, subject to jumps, and mean reverting over the medium-long term. (The VIX has averaged 20.3 since 1990, with a range of 9.3 to 80.9). Further, the volatility risk premium seems to be time-varying, with some evidence that it is higher after volatility spikes. Together these aspects suggest that the worst time to hold long positions may be after volatility has increased, as at this point both the (negative) volatility risk premium and the potential for downward mean-reversion are greatest. The opposite should hold for short positions. Conversely, low levels of volatility may indicate potential for higher volatility in future, perhaps making long positions more attractive and placing short positions at greater risk of loss.

Table 3 provides an indication of the potential to time volatility exposure by testing a simple strategy that is mindful of mean reversion. The strategy is applied via long positions in forward three-month variance swaps (starting in three months) and short positions in one-month variance swaps. The trading rules are:

***Rule for long volatility exposure**: Take a one-third of one contract per US$100 million invested in three-month forward variance swaps during months when the VIX is less than some upper threshold, and hold position to expiry.*

***Rule for short volatility exposure**: Take a short position of one contract per US$100 million invested in one-month variance swaps during months* *when the VIX is greater than some lower threshold, and hold position to expiry*.

This strategy aims to take long positions only when implied volatility is deemed to be sufficiently 'low' in the sense that it sits *below* some threshold. Similarly, short positions are taken only when implied volatility is deemed to be sufficiently 'high' in the sense that it sits *above* some threshold. Analysis draws on data from the period January 1990 to June 2010. The strategy is evaluated across a wide spectrum of thresholds. Table 3 reports the results. A heavy border is placed around the optimum outcome on each metric.

TABLE 3: TIMING OF VOLATILITY EXPOSURE

Analysis Period: Jan'90 to Jun'10	Trades		Total $ Profit (Loss)	Success Ratio	Portfolio Attributes		Relative versus S&P			Information Ratio
	No.	% of Periods			Compound Return	Standard Deviation	Compound Return	Standard Deviation	Tracking Error	
S&P 500	244	100%			7.64%	15.84%				
+3-Mth Fwd Var Swap										
Taken at VIX below:										
11	3	1%	358,175	100%	7.64%	15.11%	0.00%	-0.15%	0.03%	0.15
12	23	9%	-940,105	43%	7.62%	15.10%	-0.01%	-0.16%	0.08%	-0.17
13	40	16%	-3,406,990	38%	7.59%	15.10%	-0.05%	-0.16%	0.13%	-0.35
14	62	25%	-4,567,659	29%	7.54%	15.10%	-0.10%	-0.17%	0.19%	-0.52
15	74	30%	-4,643,023	27%	7.52%	15.09%	-0.12%	-0.17%	0.23%	-0.50
16	88	36%	-7,686,116	25%	7.48%	15.08%	-0.15%	-0.19%	0.27%	-0.56
17	102	42%	-7,662,094	26%	7.47%	15.07%	-0.16%	-0.19%	0.31%	-0.53
18	112	46%	-3,755,492	30%	7.54%	15.05%	-0.10%	-0.22%	0.34%	-0.28
19	120	49%	-2,705,766	33%	7.55%	15.04%	-0.09%	-0.22%	0.35%	-0.26
20	135	55%	5,094,877	36%	7.65%	15.04%	0.01%	-0.23%	0.44%	0.03
21	144	59%	14,804,191	37%	7.77%	14.99%	0.14%	-0.27%	0.60%	0.23
22	160	66%	21,311,896	38%	7.89%	14.94%	0.25%	-0.33%	0.71%	0.35
23	170	70%	29,922,595	39%	7.99%	14.84%	0.35%	-0.43%	0.90%	0.39
24	180	74%	28,628,874	39%	7.98%	14.82%	0.34%	-0.44%	0.93%	0.36
25	193	79%	25,626,118	39%	7.95%	14.82%	0.31%	-0.44%	0.96%	0.33
26	202	83%	25,265,903	38%	7.97%	14.79%	0.33%	-0.47%	1.00%	0.33
27	211	86%	20,994,832	37%	7.92%	14.78%	0.28%	-0.48%	1.01%	0.28
28	214	88%	20,545,633	37%	7.92%	14.78%	0.28%	-0.48%	1.01%	0.27
29	219	90%	19,036,013	36%	7.90%	14.78%	0.26%	-0.48%	1.01%	0.26
30	224	92%	18,249,105	36%	7.90%	14.78%	0.26%	-0.48%	1.02%	0.25
35	232	95%	17,765,067	36%	7.89%	14.78%	0.25%	-0.48%	1.04%	0.24
40	236	97%	19,194,195	36%	7.91%	14.78%	0.27%	-0.49%	1.10%	0.25
45	241	99%	15,530,466	36%	7.86%	14.77%	0.23%	-0.50%	1.11%	0.20
50	242	99%	14,340,695	36%	7.85%	14.76%	0.21%	-0.50%	1.12%	0.19
–1-Month Var Swap										
Taken at VIX above:										
50	2	1%	-2,715,131	50%	7.60%	15.14%	-0.04%	-0.12%	0.17%	-0.23
45	3	1%	-3,739,919	33%	7.58%	15.14%	-0.05%	-0.13%	0.18%	-0.30
40	7	3%	10,715,172	71%	7.79%	15.20%	0.15%	-0.07%	0.59%	0.26
35	12	5%	-14,424,404	67%	7.48%	15.65%	-0.16%	0.39%	1.55%	-0.10
30	21	9%	8,806,325	76%	7.82%	15.71%	0.19%	0.45%	1.67%	0.11
29	26	11%	14,974,485	81%	7.97%	15.72%	0.33%	0.45%	1.74%	0.19
28	31	13%	21,036,389	77%	8.05%	15.73%	0.41%	0.46%	1.83%	0.23
27	34	14%	30,696,504	79%	8.17%	15.72%	0.54%	0.46%	1.89%	0.28
26	43	17%	44,418,556	81%	8.34%	15.75%	0.70%	0.49%	1.96%	0.36
25	52	21%	54,598,412	83%	8.43%	15.84%	0.80%	0.58%	2.07%	0.38
24	65	26%	77,194,396	83%	8.63%	15.96%	1.00%	0.69%	2.16%	0.46
23	75	30%	79,019,366	80%	8.65%	15.97%	1.01%	0.70%	2.20%	0.46
22	86	35%	85,304,510	79%	8.72%	16.03%	1.09%	0.77%	2.24%	0.48
21	102	41%	115,771,345	80%	9.07%	16.06%	1.43%	0.80%	2.32%	0.62
20	111	45%	81,051,127	80%	8.83%	16.37%	1.19%	1.10%	2.98%	0.40
19	126	51%	103,751,239	81%	9.15%	16.41%	1.51%	1.14%	3.02%	0.50
18	133	54%	108,055,209	81%	9.25%	16.45%	1.61%	1.19%	3.04%	0.53
17	144	59%	119,371,634	81%	9.39%	16.47%	1.75%	1.20%	3.05%	0.57
16	158	64%	142,413,133	82%	9.65%	16.48%	2.02%	1.21%	3.07%	0.66
15	172	70%	162,840,590	83%	9.87%	16.49%	2.23%	1.22%	3.06%	0.73
14	184	75%	183,287,541	83%	10.07%	16.49%	2.43%	1.22%	3.06%	0.80
13	206	84%	207,501,919	83%	10.39%	16.50%	2.75%	1.24%	3.03%	0.91
12	223	91%	229,790,109	83%	10.56%	16.51%	2.92%	1.24%	3.01%	0.97
11	243	99%	249,957,827	84%	10.76%	16.53%	3.12%	1.26%	3.01%	1.04

Source: CBOE, S&P, various investment banks, Russell

The three-month forward variance swap produces optimal results if long positions are only held when the VIX is below about 23-24 as measured by total dollar profits, success rate, portfolio returns and information ratio. Portfolio standard deviation continues to reduce if positions are held at a VIX above this threshold. It may be tempting to conclude that long positions should be closed out at a VIX above 23-24 to improve returns. However, the risk of closing the hedge at the wrong time should be considered. For example, during the GFC the VIX rose from 20.7 at end-August 2008 to 39.4 at end-September and 59.9 at end-October. The latter was the month of largest S&P 500 decline (-16.8%). A rule of closing a long position when the VIX exceeded 24 would have resulted in no hedge being in place during October 2008 when it counted most.

With respect to shorting one-month variance swaps, the optimum outcome for both returns and the information ratio emerges at the minimum VIX threshold examined of 11. The implication is that holding constant short exposure regardless of the VIX level appears superior to applying the simple rule examined here. The reason is that realised volatility averages less than implied volatility even when implied volatility itself is very low. Accordingly, closing a short position because implied volatility seems low can miss out on the gathering of some risk premium, notwithstanding the risk of eventual upward reversion in volatility towards the mean.

Table 3 tests just one simple rule based around the concept that volatility mean reverts. Brière et al (2010) investigate an alternative strategy where exposure to long VIX futures is varied as an inverse function of the VIX, so that the position size declines as the VIX increases. Their strategy produces some impressive results. An attempt was made to apply an equivalent rule to long 3-month forward variance swap and short 1-month variance swap positions. No meaningful improvement in the risk/return trade-off was forthcoming. It remains a moot point whether the contrasting results relate to differences in products examined, data period or methods used. [13]

More intricate strategies might take into account short-term persistence and the forward volatility curve. However, given that (short) volatility exposure tends to generate high payoffs, except during periods when the equity market declines and volatility spikes, any effective trading rule probably needs to preempt such episodes. This seems an inherently difficult task. Alternatively, a trading rule might be built on any capacity to forecast volatility movements (above those that are already priced into the volatility term structure). This also seems difficult. For instance, Konstantinidi et al (2008) test various models for predicting implied volatility across seven US and European indices, including some based on economic variables and others based on the time series properties (VAR, ARIMA). None of the models tested were found to support a successful trading strategy. Arguably timing strategies based on volatility forecasting may be better left to specialists such as managers with the requisite skills.

In conclusion, it is remains possible that returns to directional volatility strategies could be enhanced through timing. For instance, it makes sense that investors should be mindful of the potential for volatility to mean-revert when taking long positions. Nevertheless, the exact form of any timing strategy requires deeper work than presented here.

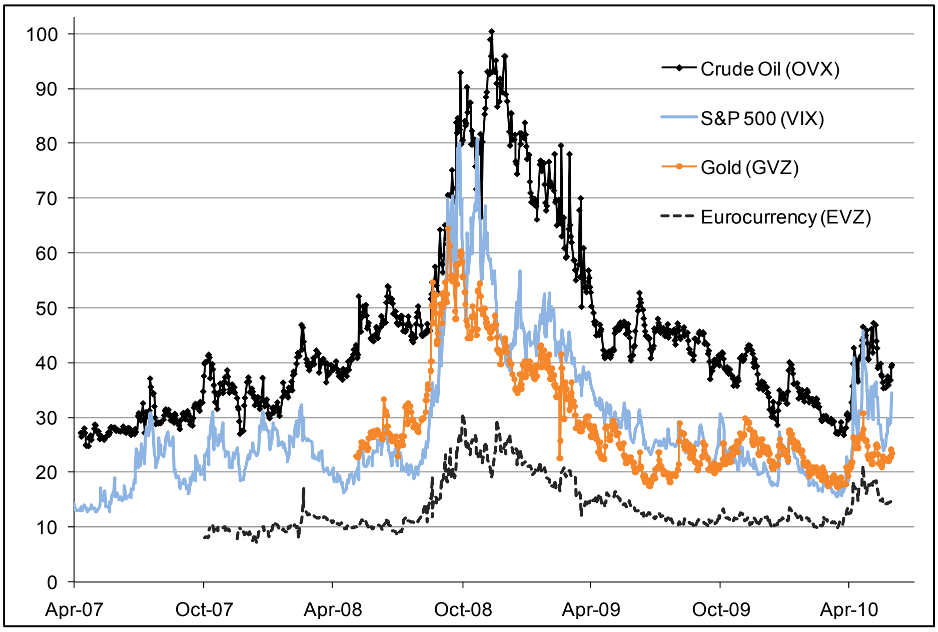
2.8 VOLATILITY AS A BROADER INVESTMENT

The analysis and discussion in this report focuses on equity index volatility. This is justified by the importance of equity market risk in most portfolios, plus the

[13] Brière et al (2010) use a hypothetical VIX futures series in their analysis, constructed from a model of the relation between VIX futures and the VIX over the period March 2004 to August 2008. Notional trades are conducted over February 1990 to August 2008, i.e. a period that excludes the GFC.

notion that the majority of available products and data are based around equity markets and the S&P 500 in particular. Nevertheless, it makes sense to view volatility exposure in a broader sense. Volatility is entwined with the return process of all assets. And there are pointers to an expanding market for volatility products. For instance, implied volatility indices are calculated for a range of US and European equity indices; while the CBOE has been generating implied volatility indices for crude oil, gold and Eurocurrency since 2007-2008. Figure 4 plots the VIX futures against the three other volatility indices currently calculated by the CBOE. Although the time period is short, the notion of common exposure to volatility across markets appears to be borne out. The correlation between the four series plotted ranges between 0.79 and 0.87. These indices could potentially support products similar to VIX futures and options. It is probable that any new products will have their own unique characteristics and return premia.

FIGURE 4: CBOE IMPLIED VOLATILITY INDICES



Source: CBOE, Russell

2.9 SUMMING UP: SOME ADVICE

Directional volatility exposure essentially offers three possibilities to an investor:

1. Going long to hedge portfolio risk, most notably with respect to equities
2. Going short to capture the volatility risk premium
3. Trading volatility

Here the third possibility is put aside, with the discussion focusing on how investors might respond to the first two given their circumstances.

HEDGING POSSIBILITIES

Analysis presented above suggests that long positions in forward variance swaps may be considered by investors who are looking to hedge their equity risk, and are willing to accept there could be some return reduction to do so. However, before embracing such a strategy, there are some further issues to contemplate:

- *Taking long volatility exposure may not be the most effective way of limiting equity risk.* Volatility exposure is an indirect way of hedging equity risk, notwithstanding its high negative correlation and beta. A simpler and more direct possibility includes reduction in equity weightings. Figure 2 and Table 5 found that adding a 5% bond weighting to an equity portfolio can generate a similar degree of risk reduction (except during equity market collapses, when gains on bonds have been more modest than those available from volatility exposure). De-risking via tweaking asset weightings is also much easier to understand and implement. Another possibility is purchasing equity put options, which provides a direct equity hedge. However it could be more costly as it effectively incurs the negative volatility premium that forward variance swaps appear to avoid. Sahlin and Maidel (2010) discuss various strategies for implementing protection against downside equity market risk.

- *Hedging via long volatility exposure may not gel with the long-term objectives of most institutional investors.* The logic of (possibly) paying a premium for protection against short-term fluctuations is questionable for institutional investors who are concerned with longer-term risk and return, and have the latitude to ride out any storm. Over longer horizons, the bumps will tend to get smoothed, particularly if markets ultimately mean-revert after any crash. Paying a premium to hedge seems more appropriate for shorter-term investors who are particularly vulnerable to large equity market sell-offs. This might include some market-makers, traders or certain hedge funds that would be adversely affected by a crash.
- *Peer risk implications may need to be considered*. Long volatility positions can generate underperformance over a majority of periods, speckled with periods of significant outperformance in weak equity markets (see Figure 3). In addition, Tables 5 and 6 in Appendix E provide some estimates of tracking error versus the equity market. An investor that goes long via one three-month forward variance swap will generate tracking error of 1.1% pa for a -0.6% reduction in portfolio standard deviation.
- *Level of volatility*. The results of Table 3 suggest that long positions might be reviewed when the VIX moves above (say) 23-24.
- *Not all institutions will have the capacity to implement.* Not only does it require the ability to understand and trade the targeted instruments, but there may be other hurdles such as explaining the strategy to the trustee board or investors.

The upshot is that before going long volatility to secure an equity hedge, investors should ask how such a position fits with their objectives and circumstances. They might also ask if another approach may be more effective.

RISK PREMIUM CAPTURE

Shorting one-month variance swaps to capture the volatility risk premium will be appropriate for only certain types of investors. Such investors are likely to have a longer-term investment horizon, a secure fund base and the capability to implement and manage positions. Short volatility positions require fortitude to see out occasional large losses, and maintain the position to take advantage of any higher premium on offer thereafter. Such fortitude is more likely from those that can afford a long view, because they will not be called into account over short-term losses. Such strategies will sit more comfortably where funds are sticky, and not likely to be withdrawn due to performance fluctuations. Not all investors will feel comfortable taking on such risks in pursuit of higher returns.

A short volatility strategy will also increase peer risk. Tables 5 and 6 in Appendix E reveal that one-month variance swaps can generate substantial tracking error.[14] However, a closer look finds that the benchmark-relative risk associated with short one-month variance swaps is concentrated in the tails of the

[14] Shorting one one-month variance swap gives rise to tracking error of 3.0% pa (as well as +2.1% pa to standard deviation and +3.2% pa to returns).

distribution, while producing outperformance during 88% of three-month rolling periods (see Figure 3). Hence the peer risk implications should be viewed in terms of sensitivity to underperformance during market sell-offs, when the focus on performance could well be heightened.

Regarding the issue of whether short positions might be reviewed when volatility is low, recall that Table 3 revealed gains to still be available at low volatility levels. An alternative approach for those concerned about a spike in volatility from low levels might be to offset short one-month variance swap positions with long forward variance swaps or perhaps long-dated VIX futures. Brière et al (2010) find a similar spread strategy to be effective in back-tests.

Implementation issues also need to be considered. In addition to having the required technical expertise, costs should be taken onto account. To gauge the impact of costs, a (generous) allowance was made for a pricing spread by re-estimating the short one-month variance swap strategy under the assumption that the swap rate was 0.5 and 1 volatility points below the mid-rate quotes provided by the investment banks. Returns were lowered by approximately 0.5% pa and 1.1% pa respectively, which compares to the gross return increment of 3.2% pa.

SECTION 3: MANAGED VOLATILITY PRODUCTS

This section provides a broad overview of the managed volatility products currently available. The various strategies employed by volatility managers are described,[15] followed by a brief discussion of the risk management of portfolios. Quantitative measures of the relation between manager returns and selected indices are then presented. The section finishes by discussing the role that these products may play in an investor's portfolio.

3.1 VOLATILITY STRATEGIES

Section 2 discussed VIX futures and variance swaps as means of attaining 'pure' exposure to volatility. As these markets are smaller in breadth and tend to be less liquid than options listed on the major exchanges, the bulk of volatility managers utilise option-based strategies to gain volatility exposure.[16] When structuring their option holdings to maximise exposure to changes in volatility, managers need to control exposure to other factors that affect the pricing of options. This includes time to maturity (theta), movements in the price of the underlying (delta), and interest rate fluctuations (rho). Managers typically gain volatility exposure through derivatives over the large equity indices in the US, Europe and Asia.

The investment strategies of managers may involve combinations of directional exposures to volatility (and perhaps other factors) and non-directional strategies aimed at exploiting volatility mispricing within or across markets. The latter is called '*volatility spreading*', and involves selling options (or other derivatives)

[15] Descriptions will be necessarily simplified due to the underlying complexity of strategies and the intended nature of this paper.

[16] Variance swaps tend not to be used as often as options and futures by volatility managers. A key reason is their lack of liquidity. Variance swaps are an over-the-counter product where an investment bank is usually the counterparty. As such, they are not as easily bought and sold as options listed on fluid exchanges. This also makes them quite expensive, as the market maker claims a premium for providing the liquidity. In contrast, the deep liquidity of listed instruments allows managers to more easily rebalance their portfolios. Further, there exists reduced counterparty risk as compared to swaps since they are listed on exchanges such as EUREX and CBOE. Another factor is the high volatility of variance swaps. That said, there may be opportunities to profit from variance swaps through providing liquidity in the over-the-counter market.

where volatility is over-priced while buying options where volatility is under-priced. This type of strategy relies on the manager's ability to identify pricing anomalies, and skill in executing trades. Positions are taken under the umbrella of the manager's overall strategy, e.g. if they want to be long volatility, then volatility spreading is used to build positions with a net long volatility exposure. Whilst implementing, the manager will be cognisant of structuring their holdings towards the desired exposure to delta, theta and rho. As being completely neutral to the aforementioned factors is near impossible (and rather costly), a decision must be taken on how much non-volatility exposure to accept.

As a simplistic example, using options to go long volatility while remaining delta neutral requires buying an option while selling the underlying asset. For this strategy to be profitable, the realised volatility of the underlying asset must be greater than the implied volatility on the option. It is not possible, however, to be constantly delta neutral as it requires continuously altering the hedge as movements in the underlying asset occurs. As such, a manager must make a strategic decision in terms of the effective exposures, and then monitor and rebalance the portfolio as required.

'*Portfolio protection*' is another type of managed volatility strategy made available by some managers. This involves a tailored mandate to hedge a client's exposure to equities, foreign exchange, interest rates, etc. The basic premise behind (and comparative advantage of) such strategies is to provide protection at a much cheaper price than relying solely on listed derivatives available in the local market. This is achieved through knowing the drivers of returns in a given market, and trading options in more liquid, global markets to attain protection at a reduced price. While not strictly a volatility arbitrage product, an element of arbitrage trading is undertaken when structuring the holdings. These products claim to have the ability to make profits even when markets are flat or rising (i.e. when volatility is falling or remaining flat). In essence, they attempt to cap the downside risk of an asset class or diversified portfolio by providing high returns in falling markets, while not taking away much of the upside.

ALPHA DRIVERS

Many of the opportunities for volatility managers arise from other investors entering the volatility space with a view to hedging their underlying holdings. Volatility managers can profit through providing liquidity, harvesting any risk premium by accepting volatility risk, and/or arbitrage across partially segmented markets where mispricing has arisen due to (say) demand pressures. Most managers exploit opportunities through using their trading skills and capacity to manage any incidental exposures within a portfolio context. Historically there have been relatively few managers attempting to exploit opportunities due to the lack of available institutional capital, as well as the fact that this type of investing is inherently risky and requires considerable skill. Providing that the supply of both capital and skilled managers remain restricted relative to the size of the market, managers with actual skill should be able to continue to create alpha.

EXAMPLES OF STRATEGIES

It is worthwhile sketching a couple of volatility strategies. This first is somewhat simple in its design, but complex in its implementation. It entails having a volatility exposure target for the overall portfolio (either long or short), given the prevailing implied volatility in the market (usually measured by the VIX). This simple directional strategy is long volatility when deemed undervalued and short volatility if deemed overvalued.[17] The target is expressed in terms of exposure

[17] This is similar to the strategy put forth in Section 2.7 of this paper.

to volatility movements, or ‘vega’. The dominant return driver under this strategy is based on the mean reverting nature of volatility. The further implied volatility moves away from its long term mean, the higher (or lower) the target vega exposure. Once a vega target has been set, exposure is gained through markets and options that have the most desirable trading opportunities. Arbitrage across partially segmented markets thus becomes another return driver. Although the design is simple, it is a difficult proposition to extract the volatility component while exploiting mispricings between implied and realised volatility within a portfolio that is structured to be hedged against movements in the underlying asset (delta neutral), interest rates, etc. The advantage of this strategy is the ease by which it can be explained and understood, and its discipline with scope for strict exposure limits that can be monitored and performance measured against agreed deliverables.

A second strategy involves taking away the hard exposure limits, and letting a computer program dictate the majority of trades based on perceived pricing disparities across various asset and index options. Under this strategy, the impact of any subjective overlay is minimal, and so it might be argued that the process becomes more disciplined. However, it is slightly more complex and difficult to monitor. It requires a lot of computing power and a great deal of trust in the program being used to identify opportunities. It also relies on the ability to innovate and change the program to identify pertinent factors affecting option pricing as and when they occur. Such factors might range from political and economic events to the psychological characteristics of the marketplace.

There are other volatility strategies, and managers are by no means the same. However, all managed volatility products come back to the premise of identifying and exploiting volatility mispricing. This general goal may be pursued using options, futures, swaps or other derivative instruments. It may involve a wide range of assets including individual securities, equity indices, commodities, convertible bonds, debt markets, and so on. Managers also generally aim to provide an absolute return stream that is uncorrelated with listed markets.

3.2 RISK MANAGEMENT

Listed below are seven main risks that volatility managers need to manage. Volatility managers utilise derivative risk models to monitor and measure these risks, usually in the form of a risk management software package.

1. *Asset Market Risk (Delta, Gamma)* – Delta hedging and monitoring of portfolio gamma involves following market prices of underlying assets and rebalancing the portfolio as required.
2. *Volatility Risk (Vega)* – Managers will manage towards a desired exposure to vega, possibly under a value-at-risk framework.
3. *Interest Rate Risk (Rho)* – Exposure to Rho may be hedged away by taking the appropriate positions in bond options or futures.
4. *Foreign Exchange Risk* – Exposure to foreign currency can arise from international positions, and may require managing via currency hedging.
5. *Credit Risk* – This can arise from any fixed-income-related positions. Restrictions on credit quality may be required.
6. *Counterparty Risk* – This relates to the quality of the counterparty on the contra side of the fund’s positions. It might be managed by referencing credit rating agency opinions and limiting exposure to lower rated counterparties. When trading derivatives on listed exchanges, the counterparty will be the clearing house of the exchange, and the counterparty risk will be minimal.
7. *Liquidity Risk* – Trading listed, liquid derivatives negates this risk to a degree. Nevertheless it must be continuously monitored, as market liquidity can be

time-varying and subject to the capacity of market makers and the depth of participation by other investors.

3.3 QUANTITATIVE ANALYSIS

Volatility manager returns are examined below based on managers with a history of at least one year. Given the very limited sample, the results are merely suggestive. Table 4 reports summary statistics for manager net excess returns (i.e. after fees) as well as the correlation and betas with selected equity indices and changes in the VIX. Managers have so far generated a reasonable premium over LIBOR, although they lagged the equity market during its rebound in 2009. The majority of managers had a negative correlation with equity markets, and a positive correlation to the VIX over the periods analysed. This is consistent with a bias towards a long volatility exposure, which would provide portfolio protection when equity markets decline. However, the low average absolute beta values suggest that the hedge is only modest

TABLE 4: ANALYSIS OF VOLATILITY MANAGER RETURNS

Monthly data to March 2010

Net Excess Return, pa	vs LIBOR	vs MSCI World US$	No. of Managers
Average for available months:	8.2%	7.4%	8
2009 only:	2.7%	-20.9%	8

	vs S&P 500	vs S&P/ASX 300 A$	vs MSCI World US$	vs Change in VIX
Correlation				
Average	-14%	-13%	-12%	7%
Min	-89%	-89%	-90%	-81%
Max	80%	80%	87%	90%
Beta				
Average	-0.01	-0.03	0.01	-0.03
Min	-1.03	-1.76	-0.92	-0.39
Max	0.76	0.77	0.84	0.09

Source: CBOE, MSCI, S&P, Russell

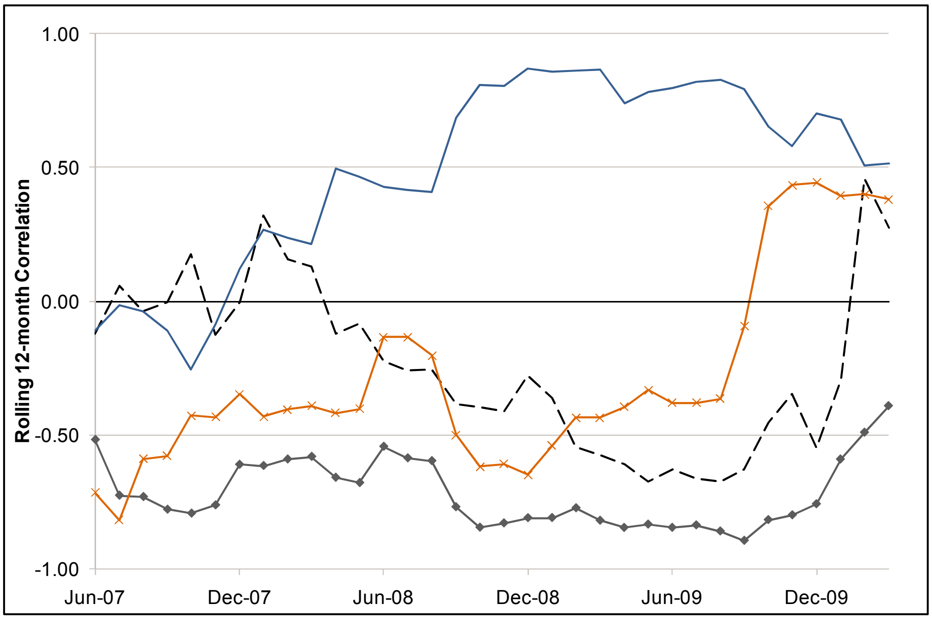
In any event, given that mangers may alter their volatility exposure over time, average correlations need not be representative. To gauge this possibility, Figures 5 and 6 present the rolling 12-month correlation of four managers with the MSCI World and the change in VIX. Even for this limited data set, it is clear that managers may generate various relations with equity markets:

- The unbroken line manager tends towards a consistently short volatility exposure, perhaps due to an attempt to harvest the volatility premium. From 2008, they have maintained a positive correlation with the presented equity indices whilst having a significant negative correlation to the VIX.
- The line with diamond markers has correlations consistent with a manager maintaining a portfolio protection or hedging strategy, as revealed strong negative correlations to equity markets and positive correlation with the VIX.
- The managers represented by the remaining two lines (dashed and cross markers) fluctuate significantly between positive and negative values, consistent with either an actively managed directional volatility strategy or residual exposure arising from implementing volatility arbitrage strategies.

Investors who are aiming to hire a volatility manager to provide an alpha return stream that is uncorrelated with equity markets should thus take a closer look.

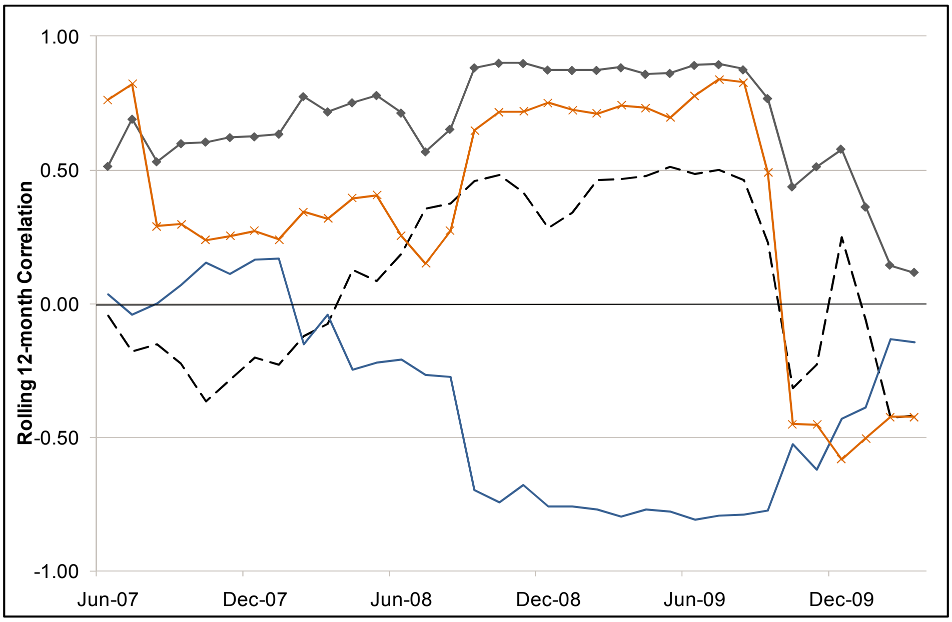
From our analysis, it is clear that correlation with equity markets can vary substantially across managers and through time. It is therefore essential for investors to do their homework to understand the types of exposures a manager may generate. Tracking the beta of the manager's portfolio may also be helpful.

FIGURE 5: CORRELATION OF MANAGER RETURNS WITH MSCI WORLD INDEX



Source: MSCI, Russell

FIGURE 6: CORRELATION OF MANAGER RETURNS WITH CHANGE IN VIX



Source: CBOE, Russell

3.4 FIT WITHIN A DIVERSIFIED PORTFOLIO

Above we have overviewed the types of volatility products currently available in the market, and the common strategies employed by managers. Any prospective investor must first understand the role they want volatility exposure to play in their portfolio. If it is to provide some type of protection against equity (or other listed) market declines, it is worth considering managers that offer portfolio protection products. If the aim is to generate excess returns, then an investor might favor managers who attempt to profit from either the volatility premium or arbitrage strategies. In this case, it becomes a little harder to assess a manager's merits from the surface. At any point, these managers may have long or short volatility exposure, depending on the view taken. Investors need to examine the manager's process and types of positions they hold, in order to gauge whether they are consistent with the preferred strategy.

The utilisation of products that derive their value from volatility is quite low for institutional investors (particularly in Australia). The main reasons include a lack of understanding of such products (e.g. what they offer, how they fit in a portfolio, etc); limited access to managers; and the 'peer risk' introduced by taking on a volatility exposure (especially for superannuation funds). Given these factors, volatility managers in general have a reasonable degree of free capacity. Most have capped the amount of monies they are willing to accept, but as yet funds invested are well below these levels.

SECTION 4: CONCLUSION

This report has investigated volatility exposure as an investment in its own right. It has examined the various products on offer, their payoffs, and how they might fit into a portfolio. It highlights opportunities in the volatility space for investors to both augment their portfolio returns and hedge their equity risk. Nevertheless, there is no one dominant strategy that will suit all. Indeed, investors *should* be approaching this area by evaluating how the various products and possibilities fit their own objectives and circumstances.

Investors with high tolerance for bearing short-run underperformance might consider shorting one-month variance swaps in order to capture the seemingly substantial volatility risk premium. Such investors may be in the minority, as a long investment horizon and a relatively secure base of funds invested are required. They also need to have the technical capability to trade volatility products, and ideally the flexibility to adjust positions in response to market developments. Return-seeking investors without the stomach for the short-term performance risk might consider managed volatility products. This would be subject to building sufficient confidence that the chosen manager(s) can reliably generate alpha after fees.

Investors looking to hedge equity risk might consider going long forward variance swaps. Although the modestly positive returns observed on these products will probably not persist, they are nevertheless likely to deliver a cost-effective hedging mechanism due to a negative correlation with equity markets without direct exposure to the volatility risk premium. Aspects to take into account before adopting exposure include whether there are more effective ways to achieve the desired hedge, peer risk implications, consistency with long-term objectives, the level of volatility, and technical capability.

It should be borne in mind that investing in volatility is a new area. Some attributes may reflect the relative immaturity of the market, such as the magnitude of the (negative) volatility risk premium, the positive historical returns from forward variance swaps and the capacity of volatility managers to generate alpha. Nevertheless, there may still be gains for early movers. Opportunities may expand as volatility markets develop. However, it is important to monitor the amount of capital committed to various strategies relative to their capacity. Any time there appears to be excess returns available one should always be alert to the possibility that they will eventually be competed away.

APPENDIX A: DIRECTIONAL VOLATILITY PRODUCTS

Exposure to volatility has long been a feature of options markets. However, products aimed at providing a tradable and pure exposure to volatility are a more recent phenomenon. These products might be arranged into four groups:

1. ***Implied volatility futures*** – Volatility futures are forward contracts that settle to *implied* volatility at expiration date. These products give exposure to changes in the implied volatility reflected in option prices, adjusted for any forward premium or discount in the futures price. Traditionally the futures have traded at a premium on average, thus distracting from returns to long positions. Currently the most readily tradable volatility futures are available on the VIX, which measures the implied volatility for S&P 500 index options of one-month to expiry.[18] VIX futures have been traded on the Chicago Futures Exchange since March 2004. At the date of writing, there were two ETFs offered based around short-term (1-2 month) and medium-term (4-7 month) VIX futures.
2. ***Implied volatility options*** – Implied volatility options also settle to implied volatility at expiration date. Options over the VIX have been traded on the CBOE since February 2006.
3. ***Variance swaps*** – Variance swaps are contracts that settle based on the difference between *realised* variance over the contract term and the agreed swap rate. Because swap rates are typically set with reference to implied volatility in option markets, the return on a variance swap will also reflect any difference between implied and realised volatility over time. The historical tendency for implied volatility to exceed realised volatility has translated into negative returns from long positions in variance swaps on average. With respect to the S&P 500, variance swaps have been tradable in the over-the-counter market since at least 1996 and in the listed market since May 2004. Variance swaps are available on all major global indices, as well as some large individual stocks (Gregory, 2005). Investment banks also offer structured variance swap products. For example, one major investment bank offers a product that combines a variance swap with cash, calibrated such that the overall strategy is aimed towards a target total volatility (see Grant et al, 2007). Variance swaps are offered by investment banks rather than volatility swaps, as the latter are more difficult to price and hedge back into the options markets, given a need to constantly readjust the position to maintain the hedge. The CBOE offers three-month and 12-month S&P 500 variance futures contracts that are the equivalent of a variance swap. However, interest in these contacts has been low and dropped off sharply after large losses were incurred during the GFC. There were only 44 open positions as at 30 June 2010.
4. ***Forward variance swaps*** – The payoff on forward variance swaps reflects the difference between an agreed swap rate at which a variance swap may be purchased in the future, and the actual swap rate at the time of expiry. The payoff hence reflects changes in the variance swap rate. Forward variance swaps have no direct exposure to the difference between implied and realised volatility, which appears closely associated with the volatility risk premium. The Merrill Lynch Forward Equity Variance Rolling (FEVR) Index represents the return to a strategy comprising an investment in cash plus three-month forward contracts on three-month variance swaps that are rolled once a quarter (see Cheeseman, 2008).

[18] EUREX also offers futures over volatility indices for some European markets.

Some readers might ask why not just 'trade the VIX'? The problem is that the VIX itself is not tradable: it is just a measure of the implied volatility that is priced into other tradable assets, i.e. index options. An investor may own these options, but cannot 'own' the implied volatility measure derived from those prices. (An equivalent concept is that you can own a stock, but it is nonsensical to talk about owning the dividend yield on the stock.) However, it is possible to bet on the future value of the VIX. This is done through entering a futures contract with another investor, where the payoffs depend on the future VIX value. Similar logic applies with respect to variance swaps and forward variance swaps, i.e. they are simply bets on the future value of some volatility metric.

Implementation issues are important when considering any of the above strategies. While this paper does not dwell on implementation issues in any depth, it is worth reminding that that they can be non-trivial, and that aspects such as trading costs and liquidity are important. Any investor considering directly investing in directional strategies will need to build the requisite knowledge and capabilities to manage the exposure.

As a rough guide, VIX futures had a total open interest of 73,620 as at 30 June 2010. Analysis presented in Table 5 is based around one VIX futures contract per US$1 million invested, which generates a 1.2% change in portfolio volatility. A moderate-sized investor with US$1 billion in equities that wished to reduce standard deviation by (say) 6% pa would need to buy in the order of 5,000 VIX futures contracts or about 7% of the quoted open interest. Clearly issues of capacity need to be considered for large scale investors.

APPENDIX B: SOME STYLISTIC FACTS ABOUT VOLATILITY

There is a large and growing body of academic literature examining the behaviour of volatility in asset markets. Below is a selection of the attributes identified that seem relevant for an investor contemplating adding volatility exposure to their portfolio. A key point regarding the available literature is that it tends to focus on variance swaps, and the period of analysis often does not cover the GFC when very large movements occurred. Hence it is necessary to remain circumspect over whether the payoff distribution for the pre-GFC period may give a misleading picture of the risk/return trade-off. (Refer Appendix C for a time series chart of payoffs to variance swaps.)

- **Negative risk premium** – It is well-recognised that a long exposure to volatility has generated negative returns on average.[19] In practice, a negative risk premium is the consequence of an upward-sloping forward term structure combined with an underlying (i.e. volatility) that has broadly moved sideways. As a result, the realised value of volatility has tended to average less than its forward value, whether based on implied option volatility, futures or swap rates. The academic literature has come to talk of these negative returns as a volatility (or variance) risk premium. In doing so, the implication is that there is a relation between volatility exposure and some systematic risk. In terms of magnitude of the premium, it is difficult to be definitive as it depends on the particular strategy and how returns are scaled, as well as the time period. As a guide, Carr and Wu (2009) report an average loss of -$2.74 per month on an S&P 500 variance swap contract with US$100 face value from January 1996 to February 2003. Similarly, Hafner and Wallmeier (2007) perform similar calculations for 45-day variance swaps on the DAX (1995-2004) and

[19] The negative volatility risk premium has been consistently observed across many studies examining various strategies, including buy-write option strategies (see Bakshi and Kapadia, 2003; Hill et al, 2006), implied payoffs to variance swaps (see Bakshi and Madan, 2006; Bondarenko, 2007; Grant el at, 2007; Hafner and Wallmeier, 2007; Carr and Wu, 2009), and forward variance swaps (see Cheeseman, 2008).

Euro STOXX 50 (2000-2004) indices, finding average losses per €100 face value of -€1.29 and -€1.89 respectively.

- **An equity market hedge** – A long volatility exposure has provided an equity market hedge. At a basic level, this is seen in a negative correlation and beta for returns to volatility relative to equity market returns. For example, Carr and Wu (2009) report a beta of -4.5 for monthly returns on variance swaps versus the S&P 500. The negative correlation with equities has also been larger and more consistent than other hedge assets, such as commodities (see Jacob and Rasiel, 2008). Further, the relation also appears to be non-linear in a manner that enhances the effectiveness of the hedge. Specifically, volatility exposure has tended to deliver large positive returns when the market declines and modest negative returns in up-markets. Indeed, the relation between equities and volatility has been described both as a quadratic function (Jacob and Rasiel, 2008) and as mimicking a put option (Hafner and Wallmeier, 2007). As a guide, Whaley (2009) estimates a beta for the VIX versus the S&P 500 of about -3 when the S&P 500 rises, but about -4.5 when it declines. Hafner and Wallmeier (2007) estimate a beta for variance swaps against the DAX and Euro STOXX 50 of about -4.2 to -5.0 in down markets, but 0 to +0.8 in up markets.
- **Premium is only partly explained by known risk factors** – The negative correlation between volatility exposure and equities provides a solid reason for the negative volatility risk premium. Nevertheless, the magnitude of the premium appears to be larger than can be explained by exposure to many risk factors used in the finance literature. For instance, excess returns are found to prevail after accounting for exposure to market beta (i.e. CAPM), the Fama-French three-factor model,[20] its four-factor extension including momentum, and after allowing for loading on the term structure and the default spread (see Bondarenko, 2007; Hafner and Wallmeier, 2007; Carr and Wu, 2009).
- **Non-normal returns may be playing a role** – One possibility is that the volatility premium reflects risk-averse investors paying up for protection because they fear a higher probability of negative returns than implied by variance alone. Bakshi and Madan [2006] present a theoretical model to demonstrate how skewness and kurtosis may impact the pricing of volatility exposure. Another possibility is that the market may be pricing for a latent, unobserved possibility of extreme events, also known as a 'Peso problem' effect. Nevertheless, Bondarenko [2008] argues that the Peso problem is unable to account for the excess returns available on index put options.
- **Supply and demand pressures seem to matter** – Another explanation for the volatility risk premium is that it reflects supply and demand pressures in options markets, specifically the inability of market-makers to absorb the demand to buy options. Bollen and Whaley (2004) provide strong evidence that the prices of options are influenced by buying pressure. Demand for puts appears to dominate pricing in index options (particularly following the 1987 crash), while demand for calls is more important for individual stocks. Further, they find signs that buying pressure has a transitory impact on option prices, thus providing a possible reason to expect mean-reversion in pricing. Grant et al (2007) discuss the need for hedgers to pay a premium to fair value for index put options in order to attractive sufficient capital to the derivatives market.

[20] Of interest, Carr and Wu (2009) found that volatility had a positive loading on the return spread between small and large stocks, i.e. SMB.

- **Higher volatility *probably* flags higher expected returns** – The expected relation between volatility and expected returns is not defined by the theory,[21] and the earlier literature delivered some mixed results (for a discussion, see Glosten et al, 1993). Nevertheless, recent literature has uncovered a tendency for measures of implied volatility and the volatility risk premium to signal higher future risk premiums. For instance, Whaley (2009) demonstrates that the VIX has some predictive power for S&P 500 returns over the next month, while Bollerslev, Tauchen and Zhou (2009) find that the variance risk premium helps predict excess returns on the S&P 500 over the next one to six months. Bollerslev, Tauchen and Zhou (2009) also document some dynamic dependencies suggesting that increases in the volatility risk premium and implied volatility are both associated with higher equity market returns. Bakshi and Kapadia (2003) find that the variance risk premium is higher during times of high volatility; while Todorov (2010) finds that market 'jumps' are followed by increases in both market volatility and the variance risk premium that persist for the best part of a month.
- **Short-term persistence; longer-term mean-reversion; and jumps** – The behaviour of volatility itself is described as being persistent over the shorter term ('volatility-clustering'), but mean-reverting over the longer term (Engle, 2004). It is also subject to occasional jumps. These features seem to be mimicked in implied volatility (Dotsis et al, 2007) and variance swaps (Egloff et al, forthcoming). It would seem that persistence is relevant at higher frequencies (e.g. daily data), but mean reversion operates over lower frequencies of months to years. For instance, Glosten et al (1993) fail to find the persistence in volatility uncovered by earlier literature, and attribute the difference to the fact that they examine monthly rather than daily returns.
- **Relation to the 'volatility smile'** – The volatility smile refers to the relation between implied volatility under the Black-Scholes model and exercise price, specifically the tendency for higher implied volatilities as exercise price moves further from the prevailing market price. Two reasons for the smile include the possibility that prices do not follow a log-normal distribution (as the Black-Scholes model assumes) and supply-demand pressures. In the case of equity index options, the fact that the implied volatility smile tilted downwards towards puts after the 1987 crash has been attributed to mismatch in the demand and supply for hedging (Bollen and Whaley, 2004). As prices for volatility products such as variance swaps are based on a wide spectrum of exercise prices, the smile does not directly enter the pricing of these products. Nevertheless, to the extent that out-of-money options are over-priced, this area of the exercise price spectrum may be the prime source of the volatility risk premium.

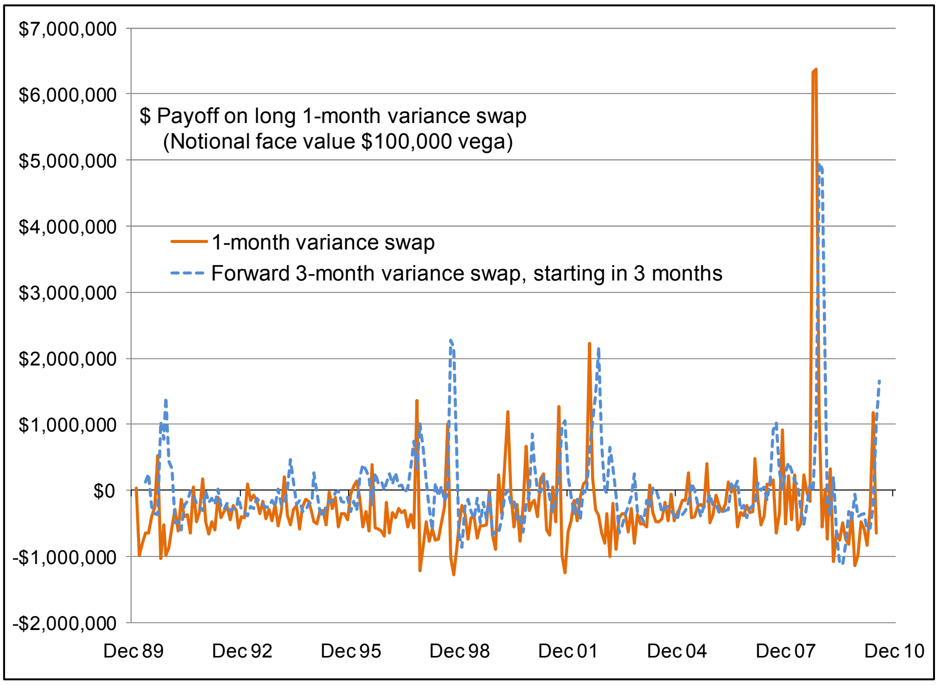
APPENDIX C: TIME SERIES OF VOLATILITY PAYOFFS

Figures 7 and 8 provide a guide to the time series of payoffs on volatility exposure. Figure 7 plots the payoffs on one-month variance swaps and three-month forward three-month variance swaps with a notional face value of US$100,000 vega. Figure 8 plots payoffs on one-month VIX futures and three-month VIX futures (rolled monthly), which have a multiplier of US$1,000 per volatility point (i.e. approximately 1/100 the magnitude of the variance swap). There are two noteworthy points. First is that the payoffs on long positions reside in negative territory over the majority of months. Second is the relative magnitude of gains on long volatility positions (and losses on short positions)

[21] The initial intuition that higher volatility reflects higher risk and hence should be associated with higher returns is just one possibility. The alternative is that higher risk induces investors to save (higher precautionary demand), which lowers expected returns.

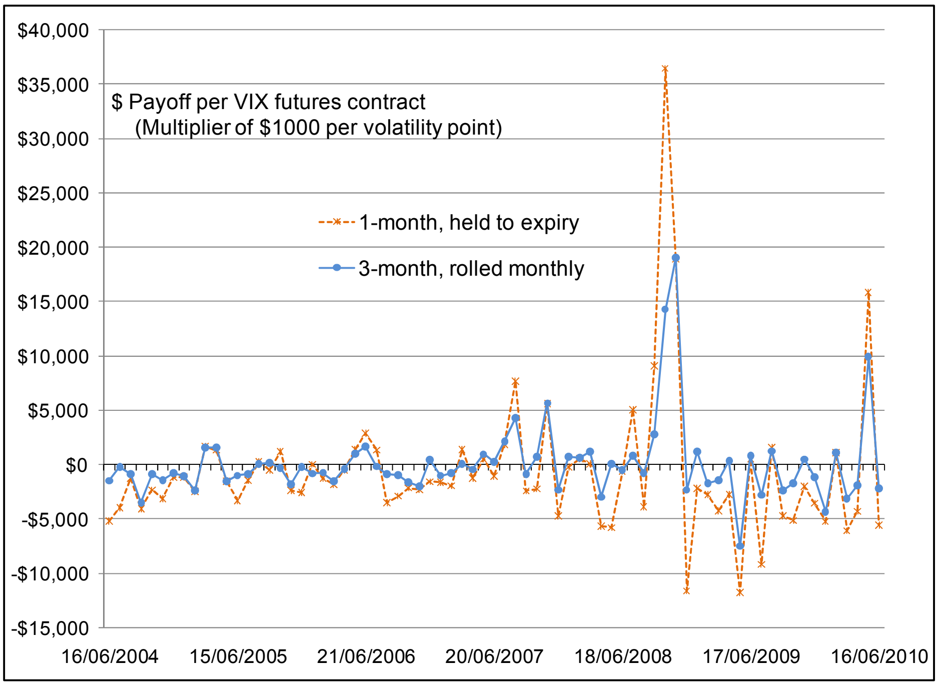
that were incurred during the GFC, which serves to highlight the unusual nature of this particular period.

FIGURE 7: PAYOFFS ON VARIANCE SWAPS



Source: Various investment banks, Russell

FIGURE 8: PAYOFFS ON VIX FUTURES

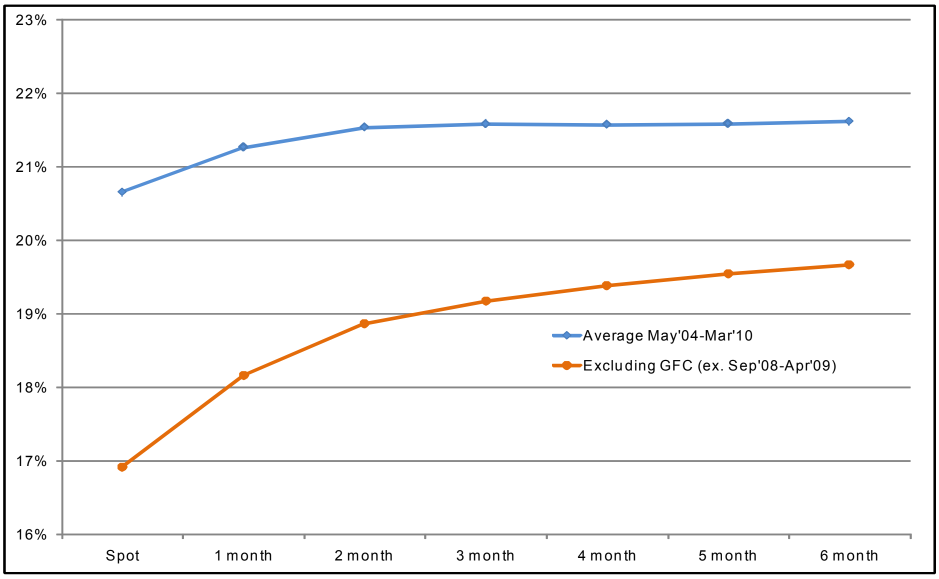


Source: CBOE, Russell

APPENDIX D: THE VOLATILITY TERM STRUCTURE

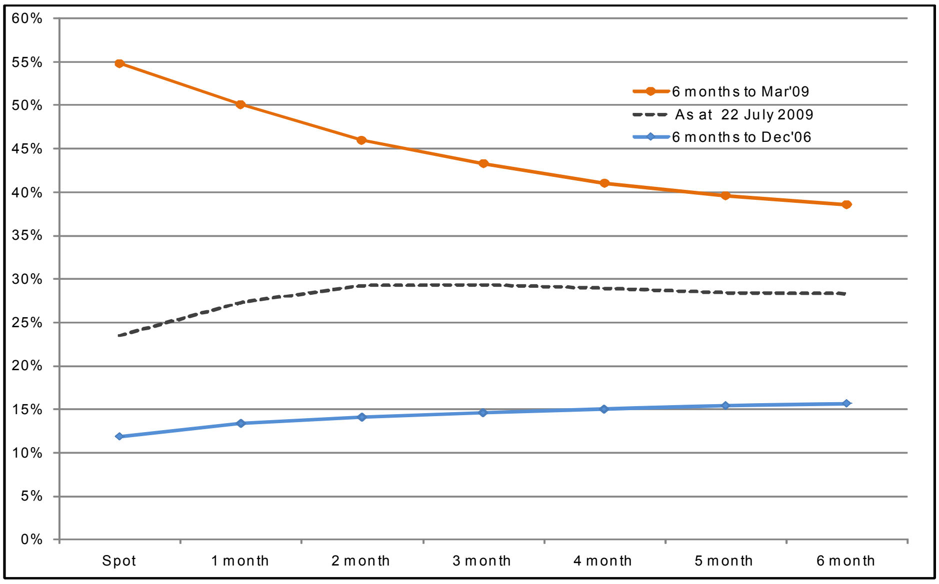
The charts below are built from VIX futures data from. Figure 9 reveals that the average term structure was upward-sloping over this period. However, this period includes the global financial crisis (GFC), where the VIX spiked to well over 50 in the wake of the Lehman collapse and the VIX futures traded in backwardation. While there is no guarantee that such an event will not happen again, it is probably the case that such a limited data period is being distorted by this unusual event. Figure 9 also shows the term structure excluding the months during the GFC when the VIX was greater than 35. This series might be taken as more representative of the term structure during 'normal' times. Figure 10 illustrates how the volatility term structure may take on a variety of shapes by plotting selected periods.

FIGURE 9: AVERAGE VOLATILITY TERM STRUCTURE (BASED ON VIX FUTURES)



Source: CBOE, Russell

FIGURE 10: VOLATILITY TERM STRUCTURE IN SELECTED PERIODS



Source: CBOE, Russell

APPENDIX E: PORTFOLIO ANALYSIS

This appendix reports the results for portfolios formed through combining the S&P 500 with selected volatility strategies, as discussed in Section 2.5. Table 5 reports risk and return measures for portfolios involving positions of one variance swap contract with a notional US$100,000 vega face value per

US$100 million portfolio value, and one VIX futures contract per US$1 million value. Risk measures include standard deviation, tracking error, the lowest return decile and maximum loss. The latter two risk measures recognise the non-normal nature of payoffs. The Sharpe ratio is also reported. Table 6 presents selected statistics across varying number of contracts for one-month variance swaps and forward three-month variance swaps starting in three months' time. A positive (negative) number of contracts indicates a long (short) volatility position.

Table 5 reveals that a long volatility exposure generally reduces portfolio return and risk. The opposite occurs for short volatility exposures. Outcomes vary across volatility products, with forward variance swaps and one-month variance swaps generating the most attractive results on the long and short side respectively. Table 6 indicates that the impact of volatility positions scale in approximate proportion to position size for moderate levels of exposure. However, the proportionate relation breaks down once exposure reaches levels at which the variance position begins to dominate the outcome. This is reflected in the standard deviations for one-month variance swaps in excess of long +4 contacts and at +10 contracts for the three-month forward variance swaps.

TABLE 5: EQUITY PORTFOLIO PERFORMANCE WITH VOLATILITY EXPOSURE

3-month rolling returns	**Compound Returns (pa)**	***Change vs S&P 500***	**Standard Deviation (pa)**	***Change vs S&P 500***	**Sharpe Ratio**	**Tracking Error**	**Lowest Decile**	**Maximum Loss**
Variance Swaps Jan'90-Mar'10								
Scaling: 1 Contract per $100 million								
S&P 500	8.38%	*0.00%*	15.79%		0.181		-8.4%	-29.6%
S&P 500 + Long Volatility								
1-month Variance Swaps	5.20%	*-3.2%*	14.02%	*-1.8%*	0.086	3.1%	-8.3%	-18.4%
3-month Variance Swaps	7.49%	*-0.9%*	14.95%	*-0.8%*	0.158	1.7%	-8.4%	-24.3%
3-month Forward 3-month Variance Swaps	8.54%	*0.2%*	15.19%	*-0.6%*	0.189	1.1%	-8.2%	-26.3%
S&P 500 + Barclay US Bond Agg. (5%)	8.37%	*0.0%*	15.03%	*-0.8%*	0.186	0.8%	-8.0%	-28.3%
S&P 500 - Short Volatility								
1-month Variance Swaps	11.56%	*3.2%*	17.88%	*2.1%*	0.253	3.0%	-8.3%	-40.3%
3-month Variance Swaps	9.22%	*0.8%*	16.77%	*1.0%*	0.199	1.7%	-8.8%	-35.0%
3-month Forward 3-month Variance Swaps	8.20%	*-0.2%*	16.45%	*0.7%*	0.172	1.1%	-8.7%	-33.0%
VIX Futures (Bootstrap#)								
Scaling: 1 Contract per $1 million								
S&P 500	7.2%		13.9%		nm *		-4.5%	-36.3%
S&P 500 + Long Volatility								
1-month VIX Futures	5.9%	*-1.3%*	12.7%	*-1.2%*	nm *	1.6%	-4.7%	-31.2%
3-month VIX Futures, Rolled Monthly	6.9%	*-0.3%*	13.3%	*-0.6%*	nm *	0.9%	-4.4%	-33.6%
S&P 500 - Short Volatility								
1-month VIX Futures	8.5%	*1.3%*	15.1%	*1.2%*	nm *	1.6%	-4.4%	-41.1%
3-month VIX Futures, Rolled Monthly	7.5%	*0.3%*	14.5%	*0.6%*	nm *	0.9%	-5.0%	-39.0%

Bootstrap based on period May 2000 to March 2010, probability of drawing data from GFC period downweighted to equivalent of 1 in 20 years.

* *Not meaningful, as Sharpe ratio is negative over the data period*

Source: Barclays, CBOE, S&P, various investment banks, Russell

TABLE 6: IMPACT OF POSITION SIZE

Number of Contracts	Portfolio Attributes (S&P 500 ± Volatility Exposure) Compound Return, pa	Standard Deviation, pa	Maximum Loss (3-month)	Tracking Error, pa	Change vs Base Compound Return Difference	Standard Deviation Difference	Information Ratio (Return Difference / Tracking Error)
1-month VarSwaps							
-5	23.9%	27.3%	-73.5%	14.2%	15.5%	11.5%	1.09
-4	20.9%	24.9%	-66.5%	11.5%	12.5%	9.1%	1.09
-3	17.9%	22.5%	-58.7%	8.8%	9.5%	6.7%	1.08
-2	14.7%	20.1%	-50.0%	6.0%	6.3%	4.4%	1.07
-1	11.6%	17.9%	-40.3%	3.0%	3.2%	2.1%	1.05
0	8.4%	15.8%	-29.6%	0%			
1	5.2%	14.0%	-18.4%	3.1%	-3.2%	-1.8%	-1.02
2	2.0%	12.8%	-19.6%	6.4%	-6.4%	-3.0%	-1.00
3	-1.1%	12.3%	-20.7%	9.7%	-9.5%	-3.5%	-0.98
4	-4.2%	12.8%	-21.8%	13.2%	-12.6%	-3.0%	-0.96
5	-7.3%	14.3%	-22.9%	16.8%	-15.7%	-1.5%	-0.93
3-month Forward VarSwaps							
-10	5.0%	24.4%	-63.8%	11.8%	-3.42%	8.6%	-0.29
-8	6.0%	22.3%	-56.7%	9.3%	-2.36%	6.5%	-0.25
-6	6.8%	20.4%	-50.0%	6.9%	-1.54%	4.7%	-0.22
-5	7.2%	19.6%	-46.6%	5.7%	-1.20%	3.8%	-0.21
-4	7.5%	18.7%	-43.2%	4.6%	-0.89%	2.9%	-0.20
-3	7.8%	17.9%	-39.8%	3.4%	-0.62%	2.1%	-0.18
-2	8.0%	17.2%	-36.4%	2.3%	-0.39%	1.4%	-0.17
-1	8.2%	16.4%	-33.0%	1.1%	-0.18%	0.7%	-0.16
0	8.4%	15.8%	-29.6%	0%			
1	8.5%	15.2%	-26.3%	1.1%	0.16%	-0.6%	0.14
2	8.7%	14.7%	-22.9%	2.2%	0.29%	-1.1%	0.13
3	8.8%	14.2%	-19.5%	3.3%	0.40%	-1.6%	0.12
4	8.9%	13.8%	-16.1%	4.4%	0.49%	-2.0%	0.11
5	8.9%	13.5%	-15.7%	5.5%	0.55%	-2.3%	0.10
6	9.0%	13.3%	-15.5%	6.6%	0.60%	-2.5%	0.09
8	9.0%	13.0%	-15.1%	8.8%	0.65%	-2.7%	0.07
10	9.0%	13.2%	-14.8%	10.9%	0.64%	-2.6%	0.06

Source: S&P, various investment banks, Russell

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