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# Volatility as an asset

Goldman Sachs

## Equity volatility is an asset class

We believe equity index volatility meets the definition of an asset class: (1) selling index volatility offers significant, passively generated returns produced by facilitating hedging flow for equity and credit investors; (2) returns are large enough to justify a nontrivial allocation; and (3) volatility selling tends to outperform long equities in hostile markets, offering an appealing diversification benefit.

## High VRP drives outsized risk-adjusted returns

Volatility Risk Premiums (VRPs) have been very high over time, resulting in short S&P 500 variance strategies having Sharpe ratios 4X US equities and outperforming 12 of 13 CS/Tremont hedge fund indices on a risk-adjusted basis. Returns were so strong that even modest short volatility allocations in a portfolio resulted in significant expansion of the efficient frontier. We back-test over 50 systematic S&P 500 volatility strategies and rank-order performance and Sharpe ratios.

## Introducing REPs: A tool for sizing, risk analysis

We develop a new method for sizing and tracking the performance of volatility positions, which allows us to rank "best-in-class" volatility strategies across listed and OTC alternatives. Risk Equivalent Portfolios (REPs) represent a breakthrough in volatility strategy analysis, allowing investors to size a volatility position to meet specific risk targets.

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# Executive summary: Equity volatility as an asset class

**We believe equity index volatility meets the definition of an asset class and should be considered by investors within an asset allocation framework**. Equity index volatility selling strategies have generated consistently high returns, with high Sharpe ratios, often substantially outperforming major equity indices and hedge fund strategies, even at extremely modest levels of allocation. They have also tended to outperform long equity strategies in hostile markets.

Despite this attractive profile, we believe volatility selling strategies have been underutilized by investors due to a lack of performance data, little or no information on sizing, and a related lack of focus on risk management in a portfolio context. We address these issues and provide a framework to guide investors through strategy selection and proper sizing. While we focus on S&P 500 index volatility strategies in this report, our arguments hold true for other indices that are the subject of large investments and resulting hedging demand.

## Equity index volatility meets the definition of an asset

What defines a new asset class? In our view, at a minimum, there is the expectation that a passive position in that asset will produce significant returns above cash over time. Specifically, an asset should have:

- long-run returns that are not dependent upon the skill of the investor or manager,
- returns of sufficient magnitude to justify a nontrivial allocation, and
- significant diversification benefits in hostile markets.

**We show that equity index volatility meets all these criteria.** First, selling index volatility offers significant returns that are produced by facilitating hedging flow for both equity and credit portfolios. These returns do not depend on the skill of the manager; as we will show, passively selling various types of index volatility offers significant returns. Due to its highly attractive risk/return profile, even small allocations in short volatility strategies can have a significant impact on returns. Finally, volatility strategies tend to outperform long equity portfolios in hostile markets, offering an appealing diversification benefit.

## Sizing is key: Introducing REPs, a new method for calibrating risk

We develop a new method for sizing and tracking the performance of volatility positions that allows us to rank "best-in-class" volatility strategies across listed and OTC alternatives. Risk Equivalent Portfolios (REPs) represent a breakthrough in volatility strategy analysis, allowing investors to size a volatility position to meet specific risk targets and directly compare strategies across terms and notionals. We provide a sizing methodology to fit a continuum of risk budgets, rather than a "one-size-fits-all" solution.

REPs contain one risk-free asset (LIBOR) and one risky asset (a short variance swap), where the amount of variance sold is determined by our sizing equations such that the aggregate portfolio is calibrated to meet investor risk/return objectives.

For brevity, we focus on three S&P 500 short variance swap REPs: (1) LoVol REP (5% volatility per annum), designed to have similar or lower risk than many hedge fund alternatives, (2) MedVol REP (10% vol per annum), similar in risk to ATM option selling strategies such as the BXM, and (3) HiVol REP (15% vol), similar in risk to the S&P 500.

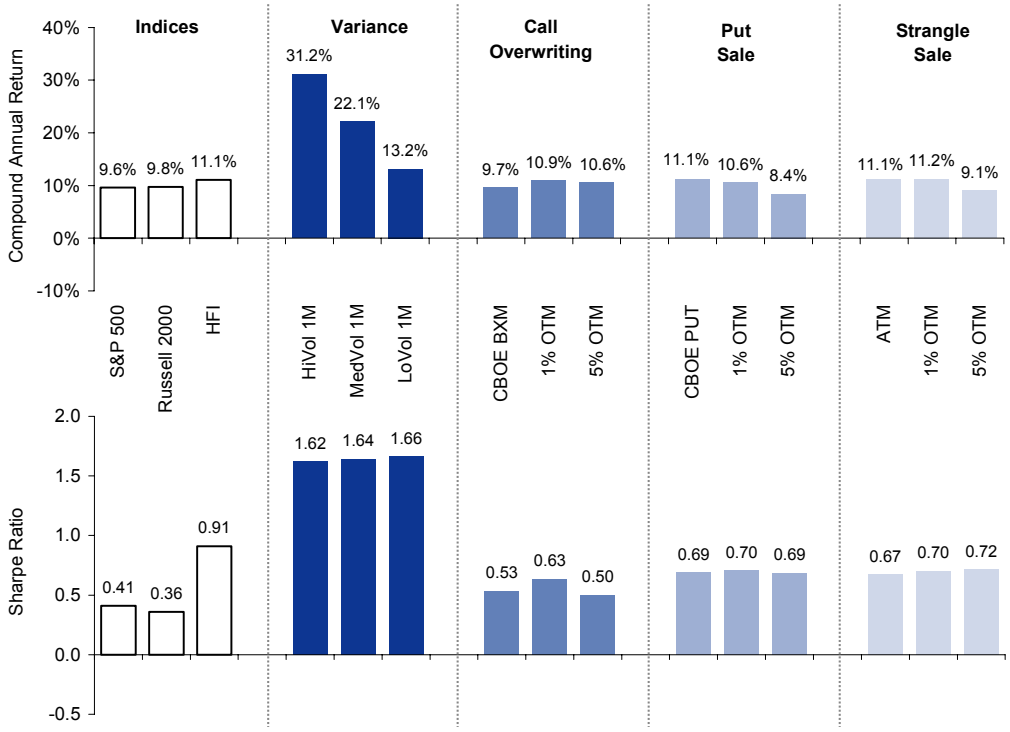
## 1. A substantial Volatility Risk Premium leads to strong passively generated returns

We find a substantial Volatility Risk Premium embedded in the S&P 500 options market. From January 1996 to September 2007, the average spread between S&P 500 ATM implied and subsequent realized volatility was 2.3 vol points across the months in our study, with a 10-point spread for deep OTM put options. We found strong risk-adjusted returns were obtained from a variety of option selling strategies due in part to the high volatility risk premium. We analyze the returns from a wide range of S&P 500 volatility selling strategies including, call overwriting, naked put and strangle selling, short variance swaps, and short forward variance strategies. We include the returns from the CBOE S&P 500 BuyWrite (BXM) and PutWrite Index (PUT) for independent comparison.

The rank order of strategy returns and Sharpe ratios follows a clear pattern in terms of the type of volatility exposure offered, with the highest returns accruing to strategies that directly capture the implied – realized Volatility Risk Premium via variance swaps.

- S&P 500 short one-month variance swap strategies, designed to be risk-equivalent to the S&P 500 in terms of the standard deviation of monthly returns, had monthly success rates of 81%, over 3 times the annual return of the S&P 500 (31.2% vs. 9.6%), and Sharpe ratios of 1.6. The strategy outperformed the BXM by 21.5% per annum and generated over 2.5 times the return from selling ATM puts or straddles. Rolling one-year returns never dropped below zero over the course of our study.
- S&P 500 variance strategies had Sharpe ratios 4 times higher than US equities and outperformed 12 of the 13 CS/Tremont hedge fund indices on a risk-adjusted basis.

**Exhibit 1: S&P 500 short variance strategies had 3 times the annual return of the S&P 500 with similar risk. Strong risk-adjusted returns were obtained from a variety of vanilla option selling strategies due in part to the high Volatility Risk Premium.**
One-month option selling strategies. Sharpe ratios based on monthly observations (1996–2007)




Note: HFI refers to Credit Suisse/Tremont Hedge Fund Index

*Source: CBOE, Goldman Sachs Research estimates.*

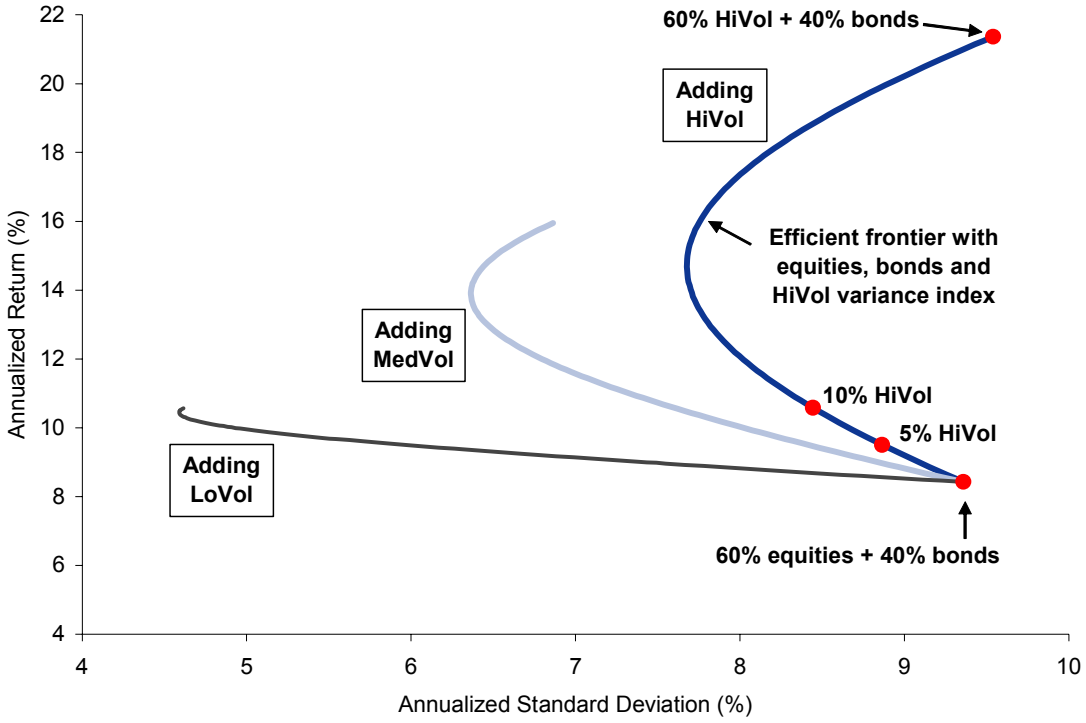
## 2. Volatility in an asset allocation framework: Strong returns lead to significant expansion of the efficient frontier

Given the strong risk-adjusted returns, it is not surprising that adding a short S&P 500 variance position to a traditional 60/40 equity bond portfolio leads to a significant expansion of the efficient frontier. Defining our equity exposure to be S&P 500 total returns and using the Ibbotson Long-Term Government Bond total return index as our bond proxy, we found:

- Replacing large-cap equity with a 5% investment in the HiVol variance REP outperformed a benchmark 60/40 equity-bond portfolio by 108 basis points per annum with a 50-bp reduction in risk. Sharpe ratios increased from 0.44 to 0.58.
- Across the 10 largest calendar-month declines in the S&P 500 from January 31, 1996 to September 30, 2007, the new portfolio outperformed the 60/40 equity-bond benchmark in 9 out of 10 months, with an average outperformance of 30 bp per month.

**Exhibit 2: Adding SPX variance to a 60/40 equity-bond portfolio leads to significant expansion of the efficient frontier**
compound annual returns; annualized volatility of monthly returns, January 31, 1996–September 30, 2007

| Portfolio Weights | | | w/ HiVol Variance Index | | | w/ MedVol Variance Index | | | w/ LoVol Variance Index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Equity | Bond | Variance Index | Return | Volatility | Sharpe Ratio | Return | Volatility | Sharpe Ratio | Return | Volatility | Sharpe Ratio |
| 60% | 40% | 0% | 8.42 | 9.36 | 0.44 | 8.42 | 9.36 | 0.44 | 8.42 | 9.36 | 0.44 |
| 59% | 40% | 1% | 8.64 | 9.26 | 0.47 | 8.55 | 9.24 | 0.46 | 8.46 | 9.23 | 0.45 |
| 58% | 40% | 2% | 8.86 | 9.15 | 0.49 | 8.68 | 9.13 | 0.48 | 8.50 | 9.11 | 0.46 |
| 57% | 40% | 3% | 9.07 | 9.06 | 0.52 | 8.80 | 9.02 | 0.50 | 8.53 | 8.98 | 0.47 |
| 56% | 40% | 4% | 9.29 | 8.96 | 0.55 | 8.93 | 8.91 | 0.52 | 8.57 | 8.86 | 0.48 |
| 55% | 40% | 5% | 9.50 | 8.87 | 0.58 | 9.05 | 8.80 | 0.54 | 8.60 | 8.74 | 0.49 |
| ⋮ | | | | | | | | | | | |
| 50% | 40% | 10% | 10.58 | 8.44 | 0.74 | 9.68 | 8.28 | 0.65 | 8.78 | 8.13 | 0.55 |




*Source: Ibbotson, Goldman Sachs Research estimates.*

## 3. High risk premium leads to outperformance in hostile markets

We dedicate a large portion of this paper to strategy risk. One appealing characteristic of S&P 500 call overwriting strategies is that they tend to outperform in bear markets, with the call premium providing a downside performance cushion. On average, we find even stronger hostile market results from short variance, put, and strangle selling strategies. **In fact, during the worst bear market in recent history (9/00-9/02), variance selling strategies calibrated to be risk-equivalent to the SPX were up 45% vs. a 45% decline in the SPX and achieved that performance with a volatility 4 points lower than the market, 14% versus 18%.**

For option-based trades, bear market strategy performance has historically been in line with the amount of premium sold, with wider breakevens for straddles leading to better performance in down markets. The argument is different for variance strategies, which are less dependent on market direction than on the path of the index (large moves versus a slow drift). **On average, we found S&P 500 variance swaps priced in a 3.3 vol point or 30% monthly increase in realized market volatility. The large risk premium provided a strong positive performance cushion across a wide range of potential index paths (in both up and down markets).**

In general, short variance strategies experience negative returns under a substantial re-pricing of risk. De-levering variance returns using our REP methodology helped reduced risk and minimize drawdowns.

## Capturing the risk premium: All strategies are not created equal

Although a large volatility risk premium benefits many types of volatility selling strategies, we found large differences in returns across strategy types. In terms of risk-adjusted performance: S&P 500 variance outperformed vanilla options selling, which outperformed forward variance strategies. The primary return drivers are different for each of these strategies, with each offering a different exposure to volatility:

**Variance swaps** are the purest play on the volatility risk premium embedded in option prices and offer distinct advantages over traditional option strategies for capturing the implied versus realized spread: (1) the payoff is directly linked to the difference between implied and realized variance; (2) variance swaps require no delta hedge; and (3) variance strikes trade at a premium to ATM implied vol allowing for higher profit potential on the short.

**Non-delta-hedged vanilla option strategies** tend to be more highly correlated to directional market moves than a pure play on volatility (delta first, vol second). Our past research indicates that the success of vanilla option-based strategies can hinge as much on minimizing exercise cost as on capturing a rich option premium.

**Forward variance** trades are designed to express views on the direction of implied volatility. The most well-known example is the exchange-listed VIX future, a market-based expectation for future VIX levels. **Forward variance trades do not capture the implied versus realized volatility risk premium.** In our 2006 report "VIX futures over the last decade," we found long forward variance trades had (1) high payouts in periods of market stress, (2) high negative betas to the market; and (3) lower carry costs on long positions than many other long vol strategies—one reason we often recommend forward variance to express tactical views on volatility. Because forward variance trades capture a different exposure, which does not tend to trade at a substantial premium, we find forward variance trades often provide the best way to "get long" volatility. The increased liquidity in exchange-listed VIX options and VIX futures has made the VIX market a popular and transparent way of implementing tactical volatility trades.

# Why does the volatility risk premium exist?

The ability to hedge allows investment managers to externalize short-term equity market risk and focus on investing for the long term. As such, hedges are a useful tool, but are not free. In order to attain downside protection, investment managers must pay a premium for put hedges—one that is large enough to attract liquidity providers and/or investors to provide that protection. This cycle of supply and demand creates the Volatility Risk Premium (VRP) and drives the long-run returns for short index options strategies.

We are often asked why the VRP has not been "arbed" away. Historically, the supply from arbitrageurs has been small relative to hedging demand and there are limits to arbitrage. We believe investors are needed to fill in the gap. Even as investors become more involved in this market, as we show, only a small amount of short volatility exposure is needed to generate sizable returns within acceptable risk levels. This means that short volatility investors are unlikely to outsize the hedging market, in our view.

## Hedges provide real value to investors, reducing portfolio volatility

Hedging allows investment managers to reduce short-term equity risk and lower portfolio volatility. The ability to externalize short-term price risk allows investors to better utilize existing capital, either by: (1) retaining assets that should outperform over the long run but may experience short-term dislocations from fundamentals or (2) investing more aggressively. Investors ultimately benefit from the reduced portfolio volatility.

## Supply/demand: Investors tend to be net buyers of index volatility

Evidence of a supply/demand imbalance in S&P 500 options stemming from put hedges is apparent in flow data. In their 2004 paper, "Does Net Buying Pressure Affect the Shape of Implied Volatility Functions?", Bollen and Whaley found that a majority of S&P 500 index options trading involves puts. In fact, 55% of all index options trades over the time period they analyzed were in puts, vs. only 33% for single stock options. What's more, using tick data, they found that put activity is dominated by buyers, with the largest buying pressure in OTM and deep OTM puts. This confirms what we see in index skew data: the expensiveness of index put options is consistent with hedging supply/demand.

## Hedgers buy at a premium to attract sufficient investor capital

Hedging transfers risk from equity portfolio managers to other investors or liquidity providers. In order to hedge, money managers must, therefore, attract sufficient capital into the derivatives market to bear this unwanted risk. This is accomplished by purchasing options at a premium to the market's expected fair value.

Historically, broker-dealers have been the only real suppliers of hedges. The cost of managing the associated risk consists of: (1) the normal provision of capital for daily hedging costs, and (2) costs associated with managing the gap risk of a short option position, which cannot be entirely hedged away. Dealer risk profiles drive option prices higher, creating a premium in index option volatility. Bollen and Whaley note that "a market maker will not stand ready to sell an unlimited number of contracts in a particular options series. As his position grows large and imbalanced, his hedging costs and/or volatility-risk exposure also increase, and he is forced to charge a higher price." **Outsized hedging demand relative to supply keeps index options trading at a volatility premium. This volatility risk premium generates the long-run returns required to attract sufficient capital into the derivatives market to supply liquidity.**

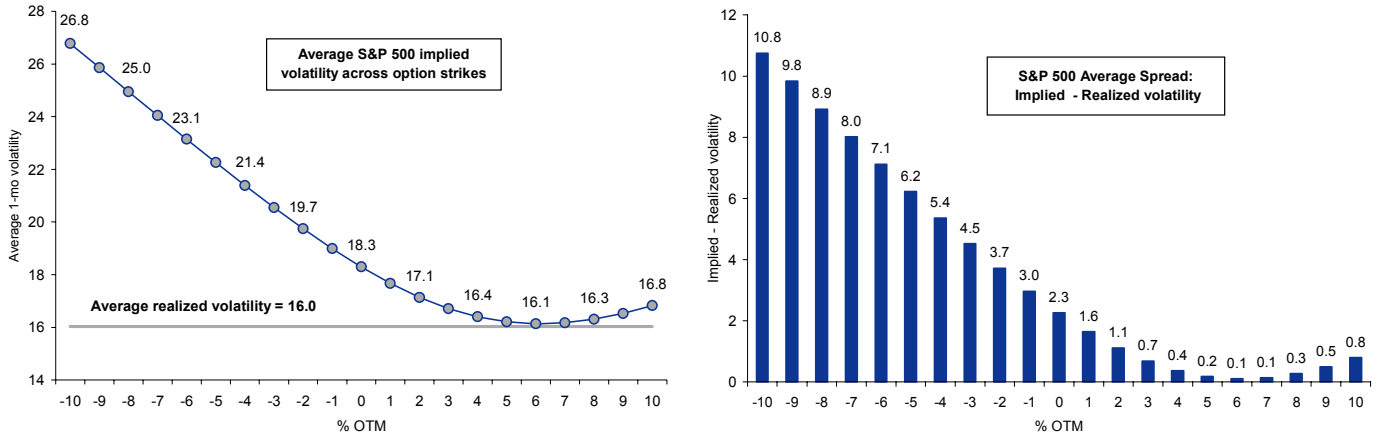
## The volatility risk premium is well-documented in academic studies

**A consistent VRP has been well-documented by academics and is confirmed by our analyses.** The VRP has existed since listed index options began trading in 1983. As early as 1973, Fisher Black and Myron Scholes commented that "the actual prices at which options are bought and sold deviate in certain systematic ways from the values predicted by the formula. Option buyers pay prices that are consistently higher than those predicted by the formula....There are large transaction costs in the options market, all of which are effectively paid by options buyers." Although printed more than 10 years before index options began trading in the listed market, the quote has remained true for more than 30 years.

**More recently, Bondarenko (2003) studied the "overpriced puts puzzle" and concluded that put options on the S&P 500 are systematically overpriced**, stating that "selling unhedged puts would have resulted extraordinary paper profits over the sample period." He finds significant returns from put selling strategies and comments that "for ATM puts to break even (i.e., to have the average excess return of zero), crashes of the magnitude experienced in October 1987 would have to occur 1.3 times per year." Similarly, Schneeweis and Spurgin (2001) and Bollen and Whaley (2004) found that implied index volatility traded rich relative to the volatility of realized market returns, generating strong returns from option selling strategies.

**Bakshi and Kapadia (2003) find evidence of a volatility risk premium by examining delta-hedged S&P 500 option strategies**, noting that "if option prices incorporate a nonzero volatility risk premium, then we can infer its existence from the returns of an option portfolio that has dynamically hedged all risks except volatility risk." They find that after controlling for underlying S&P 500 index moves, call buyers pay the seller a premium of about $0.43 per call and estimate the cumulative wealth transfer from buyers to sellers over the eight-year period analyzed (1988-1995) to be on the order of several billion dollars.

**Exhibit 3: Average S&P 500 implied volatility across option strikes is well above subsequent realized volatility**
monthly observations (January 1996–September 2007)




*Source: Goldman Sachs Research estimates.*

We find similar results in our performance data which we detail in the remainder of the paper. An analysis of the implied minus realized spread of index options over time clearly shows the VRP, as shown above in Exhibit 3:

**Implied vs. realized volatility spread:** The average spread between ATM implied and subsequent realized volatility was 2.3 vol points, with higher spreads for OTM puts. The difference for 5% OTM put options averaged 6.2 vol points and increased to 10.8 for 10% OTM puts. Calls sold 5%-8% OTM were essentially traded at fair volatility.

**Skew:** The pronounced implied volatility skew is apparent with the average implied volatility for 10% OTM puts at 26.8, about 46% higher than the implied vol for ATM options.

## Investors are needed to fill in the gap; few have taken advantage

**Why isn't the volatility premium "arbed away"? Few investors have stepped in to fill the gap between hedgers and liquidity providers, resulting in a high volatility risk premium to date. Specifically, we see the following factors contributing to the VRP:**

1. Historically, broker-dealers have been the primary suppliers of hedges. As previously discussed, there are costs associated with taking on risks related to outsized hedging demand. More recently, professional arbitrageurs have been involved in selling index options to take advantage of the rich VRP. However, (1) the supply from arbitrageurs has been small relative to the aggregate hedging demand in our view; and (2) we show excess returns can be generated from selling even small amounts of volatility. In other words, there are few participants and the notional amount of volatility sold to generate high returns is low relative to hedge demand.

2. Academics cite practical limits to the effect arbitrageurs can have in bringing prices back to theoretical "fair value." Shleifer and Vishny (1997) argue that "arbitrage is conducted by a relatively small number of highly specialized investors who take large positions using other people's money." They argue that investor capital is often allocated based upon past fund performance and arbitrage returns tend to be low precisely when the opportunity gap widens and future returns are expected to be high. Therefore, arbitrageurs risk losing capital when mispricings are large, limiting their ability to close the fair value gap. **So arbitrageurs can lean against the mispricing, but their ability to do so is limited due to leverage constraints and little access to new capital. Investors are needed to fill the gap.**

## The sustainability of long-run returns

Long-run returns for volatility strategies are therefore determined by the equilibrium between the market's desire to hedge and investors' willingness to bear the necessary risk. Thus for equity derivatives, as for any other asset, investor returns are determined by the demand and supply for risk capital. We believe the returns to short volatility strategies are likely to persist in the future and find that the implied vs. realized volatility spread has remained positive across volatility and market regimes. This will be true unless the community of investors willing to sell index volatility overwhelms the hedging demand. Given the size of the long-equity community and increased cross-over activity from credit investors, we believe that would be highly unlikely. In fact, as investors demand more transparency with stricter risk management controls, hedging with equity derivatives will arguably become an even more highly utilized tool in the investment process.

# Capturing returns from volatility strategies: The secret sauce is in the sizing, and volatility is a rich spice

**Appropriate sizing is crucial to analyzing volatility strategies within a traditional risk/return framework. We develop a sizing methodology that allows investors to: (1) target a risk level that fits within their investment framework, and (2) analyze the resulting performance in a portfolio context.** Although past research has focused on volatility strategies with the highest return profiles, we believe it is even more important to understand the risk profile of these trades. Sizing the trades appropriately is one of the most important (and most overlooked) factors driving risk-adjusted performance. The lack of focus on proper sizing has also likely contributed to the image problem of these strategies. Volatility is a rich spice; little needs to be added to a portfolio to achieve strong performance.

## Introducing REPs: Risk/Return Equivalent Portfolios

We develop a new method for sizing and tracking the performance of volatility positions that also allows us to rank "best-in-class" volatility strategies across a broad set of listed and OTC alternatives. We understand that investors have different risk preferences and provide a sizing methodology to fit a continuum of risk budgets. We focus on two key questions:

1. How much vol is needed on top of a cash portfolio to generate a short variance swap strategy that has 10% annualized volatility, or is risk-equivalent to the S&P 500 or a major hedge fund index?
2. Does the strategy still have a strong return profile after dialing down the risk?

REPs, Risk or return Equivalent Portfolios, allow us to size volatility strategies for different investor types. REPs contain one risk-free asset (LIBOR) and one risky asset (a short variance swap), where the amount of variance sold is determined by our sizing equations such that the aggregate portfolio is calibrated to meet investor objectives. REPs represent a breakthrough in volatility strategy analysis, allowing investors to:

- size a volatility position to meet specific risk or return targets,
- directly compare volatility strategies across different terms and notionals,
- analyze cross-asset strategies in a traditional mean-variance framework, and
- overlay volatility strategies onto existing asset streams to analyze aggregate portfolio profiles, which is essential for analyzing how a volatility strategy might fit within a broader asset allocation framework.

We illustrate REPs with a variance swap example, but extend the concept to generate forward variance portfolios later in the paper.

## Risk Equivalent Portfolios: SPX-like vol with 3X the return

**REPs that are risk-equivalent to the S&P 500 outperformed the index by 13%-21% depending upon the maturity of the swap.** The vertical shaded region in Exhibit 4 shows one- and three-month short variance strategies designed to be risk-equivalent to the S&P 500, based upon the standard deviation of monthly returns. Performance is striking: portfolios short only $0.81 of one-month variance per $100 of total portfolio value were risk equivalent to the S&P 500 in terms of standard deviation but generated over 3 times the performance, or 31.2% annualized returns versus 9.6% total return for the S&P 500.

## Return Equivalent Portfolios: SPX-like returns, a fraction of the risk

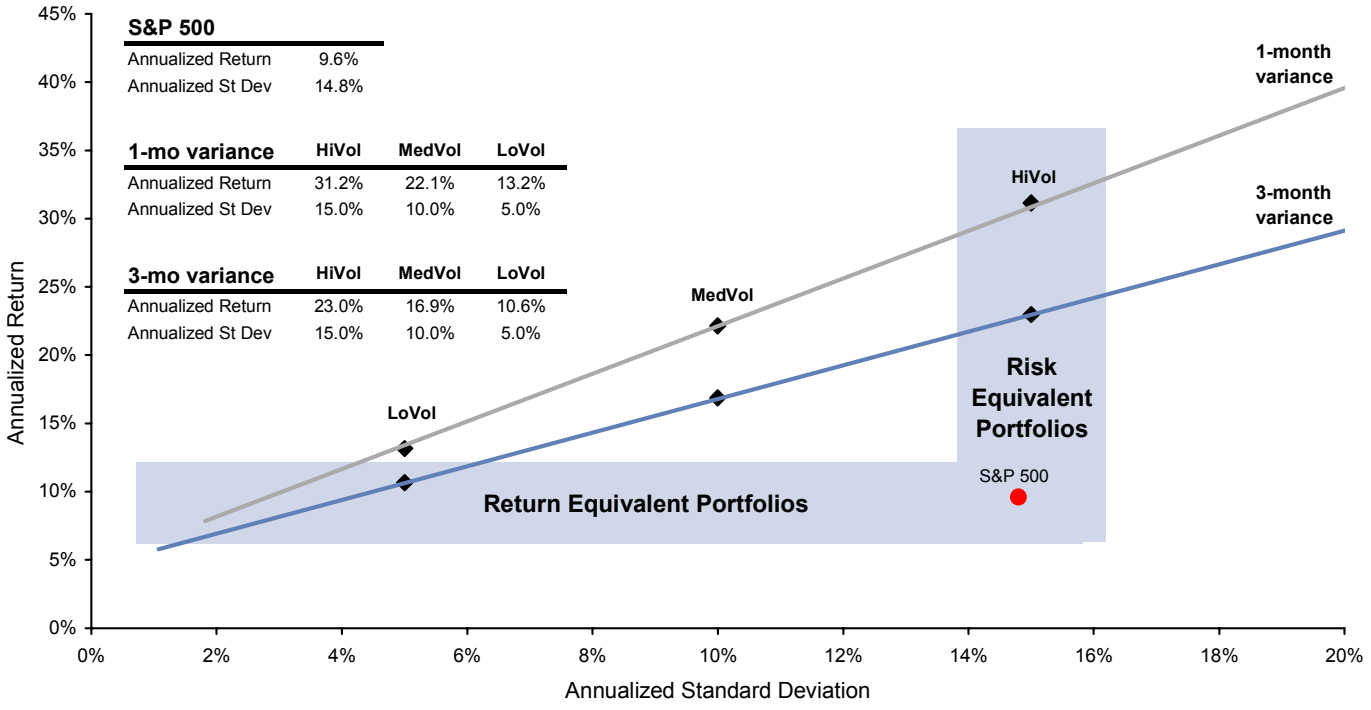
**The implied vs. realized volatility spread has historically been so wide that SPX-like returns were generated from variance portfolios at a fraction of the risk. These results highlight the significant volatility risk premium embedded in S&P 500 options and the potential use of variance swap strategies as a source of alpha.** The horizontal shaded region in Exhibit 4 indicates variance strategies that had annualized returns equivalent to the S&P 500. For example, one-month variance strategies with annual returns on par with the S&P 500 had one-fifth the risk (3%). These returns were generated from a portfolio with a modest $0.18 of variance per $100 invested.

**This framework can be used to generate portfolios that fit a target risk budget.** To create a portfolio with 5% annualized volatility we needed just $0.28 of one-month variance per $100 invested. This strategy had hedge fund like volatility with 13% annual returns. The linear relationship between risk and return for the variance portfolios is similar to the standard portfolio result using one risk-free and one risky asset. This sizing framework allows investors to better understand the volatility exposure necessary to dial up or down risk or target a specific return profile within a traditional mean-variance setting.

## Representative REPs: Risk-equivalent to SPX, BXM, hedge funds

For the remainder of the paper, we focus on three representative S&P 500 variance portfolios: (1) **LoVol REP,** calibrated to 5% annualized vol over the last decade, similar or lower risk than many hedge fund alternatives; (2) **MedVol REP** (10 vol), which has similar volatility to BXM-type strategies; and (3) **HiVol REP,** which has been risk-equivalent to the S&P 500 (15 vol) over the course of our study. All three had strong performance.

**Exhibit 4: REPs sizing methodology calibrates variance exposure to fit a continuum of risk budgets. Variance strategies with SPX-like vol had over 3 times the annual return. REPs with SPX-like returns had ~one-fifth the risk**
Risk and Return of S&P 500 variance portfolios for different volatility allocations (January 31, 1996–September 30, 2007)




*Source: Goldman Sachs Research estimates.*

# Strong passively generated returns; higher Sharpe ratios than hedge funds and global indices

We found that the substantial Volatility Risk Premium led to strong risk-adjusted returns for various types of volatility-selling strategies. We analyze the returns from a wide range of S&P 500 volatility selling strategies including call overwriting, naked put and strangle selling, short variance swaps, and short forward variance strategies.

**REPs review:**

- **LoVol REP – 5% vol per year, similar to hedge funds**
- **MedVol REP – 10% vol per year, similar to BXM**
- **HiVol REP – 15% vol; per year; similar to SPX**

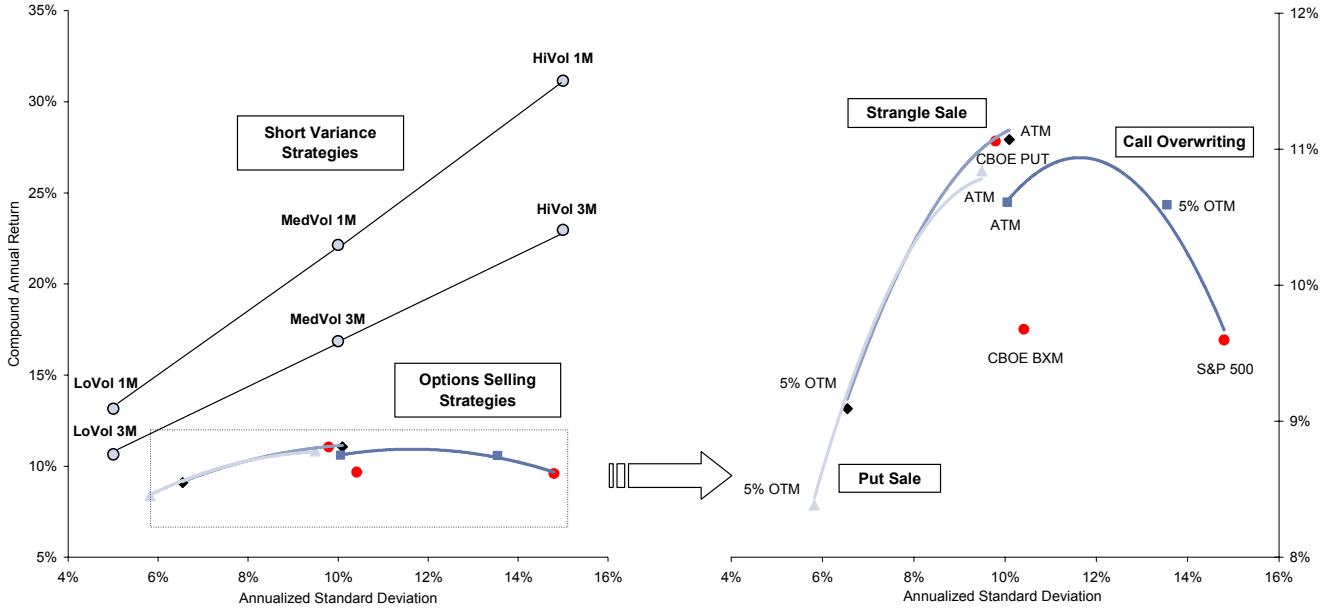
**The rank order of strategy returns and Sharpe ratios follows a clear pattern in terms of the type of volatility exposure offered, with the highest returns accruing to strategies that directly capture the implied – realized volatility risk premium via variance swaps. Three themes emerged from our performance results:**

**1. Variance strategies dominate due to direct capture of the implied - realized spread.** S&P 500 variance swap strategies had the highest risk-adjusted returns by far, followed by vanilla option strategies, with short forward variance positions, intended to capture changes in the level of implied volatility, coming in last. This makes forward variance the best for tactical long vol exposure (or for hedging short variance), in our view.

**2. For vanilla option trades, selling puts/strangles outperformed call selling.** Portfolios that dominate overwriting strategies in a risk-return framework can be obtained by selling puts, strangles, or equity variance swaps. Stated another way, we found overwriting strategies to be one of the least-efficient volatility strategies analyzed.

**3. Short-dated trades had higher Sharpe ratios** than longer-dated trades on average. We attribute this to the benefits of resetting strikes in rapid markets and the higher capture rate of the implied – realized volatility risk premium.

**Exhibit 5: S&P 500 variance strategies dominated vanilla-based option strategies, offering higher return for a given level of portfolio risk**
mean-variance analysis based on monthly returns January 31, 1996–September 30, 2007




*Source: CBOE, Goldman Sachs Research estimates.*

**Exhibit 6: Annualized performance of S&P 500 volatility selling strategies**
monthly returns January 31, 1996–September 30, 2007

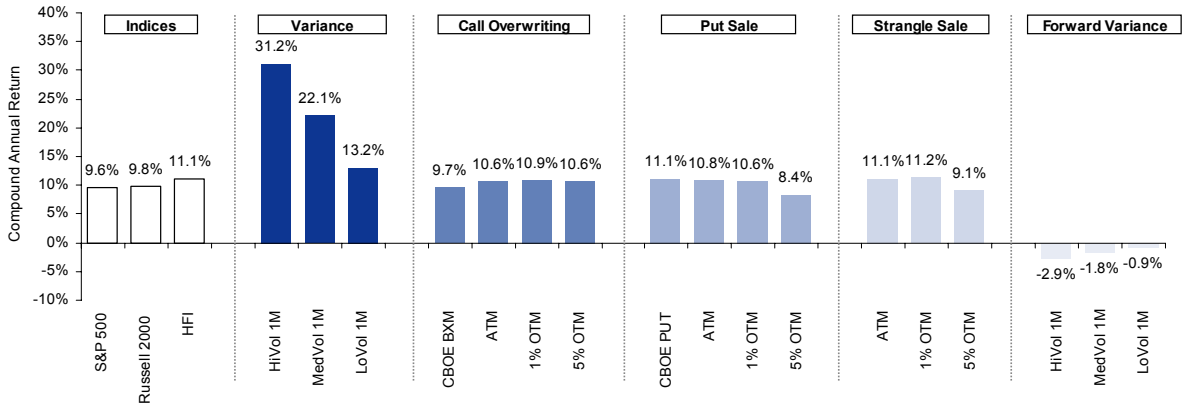
| | 1996 - 2007 (January 31, 1996 to September 30, 2007) | | | | |
|---|---|---|---|---|---|
| | Compound Annual Return | Standard Deviation | Sharpe Ratio | Success Rate | Max Monthly Drawdown |
| **S&P 500** | **9.6%** | **14.8%** | **0.41** | **64%** | **-14.5%** |
| **Russell 2000** | **9.8%** | **19.4%** | **0.36** | **61%** | **-19.4%** |
| **CS/Tremont Hedge Fund Index** | **11.1%** | **7.2%** | **0.91** | **73%** | **-7.5%** |
| **Short Variance Strategies (1-Month)** | | | | | |
| HiVol | 31.2% | 15.0% | 1.62 | 81% | -18.3% |
| MedVol | 22.1% | 10.0% | 1.64 | 84% | -12.0% |
| LoVol | 13.2% | 5.0% | 1.66 | 86% | -5.7% |
| **Short Variance Strategies (3-Month)** | | | | | |
| HiVol | 23.0% | 15.0% | 1.18 | 77% | -19.2% |
| MedVol | 16.9% | 10.0% | 1.19 | 79% | -13.0% |
| LoVol | 10.6% | 5.0% | 1.21 | 81% | -6.5% |
| **Call Overwriting (1-Month)** | | | | | |
| CBOE BXM Index | 9.7% | 10.4% | 0.53 | 69% | -11.8% |
| ATM | 10.6% | 10.1% | 0.64 | 74% | -11.7% |
| 1% OTM | 10.9% | 10.7% | 0.63 | 72% | -12.4% |
| 2% OTM | 10.8% | 11.5% | 0.58 | 69% | -12.8% |
| 3% OTM | 10.7% | 12.4% | 0.54 | 66% | -13.3% |
| 4% OTM | 10.9% | 13.0% | 0.54 | 64% | -13.6% |
| 5% OTM | 10.6% | 13.5% | 0.50 | 64% | -13.9% |
| **Put Sale (1-Month)** | | | | | |
| CBOE PUT Index | 11.1% | 9.8% | 0.69 | 75% | -13.1% |
| ATM | 10.8% | 9.5% | 0.69 | 74% | -11.7% |
| 1% OTM | 10.6% | 9.0% | 0.70 | 77% | -11.1% |
| 2% OTM | 10.3% | 8.1% | 0.73 | 79% | -10.2% |
| 3% OTM | 9.8% | 7.2% | 0.76 | 83% | -9.3% |
| 4% OTM | 9.0% | 6.3% | 0.73 | 88% | -9.0% |
| 5% OTM | 8.4% | 5.8% | 0.69 | 89% | -8.6% |
| **Strangle Sale (1-Month)** | | | | | |
| ATM | 11.1% | 10.1% | 0.67 | 68% | -11.6% |
| 1% OTM | 11.2% | 9.9% | 0.70 | 71% | -11.6% |
| 2% OTM | 10.8% | 9.1% | 0.71 | 69% | -11.4% |
| 3% OTM | 10.4% | 8.3% | 0.73 | 75% | -10.8% |
| 4% OTM | 9.9% | 7.3% | 0.76 | 79% | -10.2% |
| 5% OTM | 9.1% | 6.5% | 0.72 | 82% | -10.1% |
| **Short Forward Variance Strategies (1-Month)** | | | | | |
| HiVol | -2.9% | 15.0% | -0.41 | 57% | -26.9% |
| MedVol | -1.8% | 10.0% | -0.56 | 57% | -18.7% |
| LoVol | -0.9% | 5.0% | -1.00 | 57% | -9.7% |

*Source: CBOE, Credit Suisse/Tremont, Goldman Sachs Research estimates.*

**Variance selling: Strong performance across risk levels**

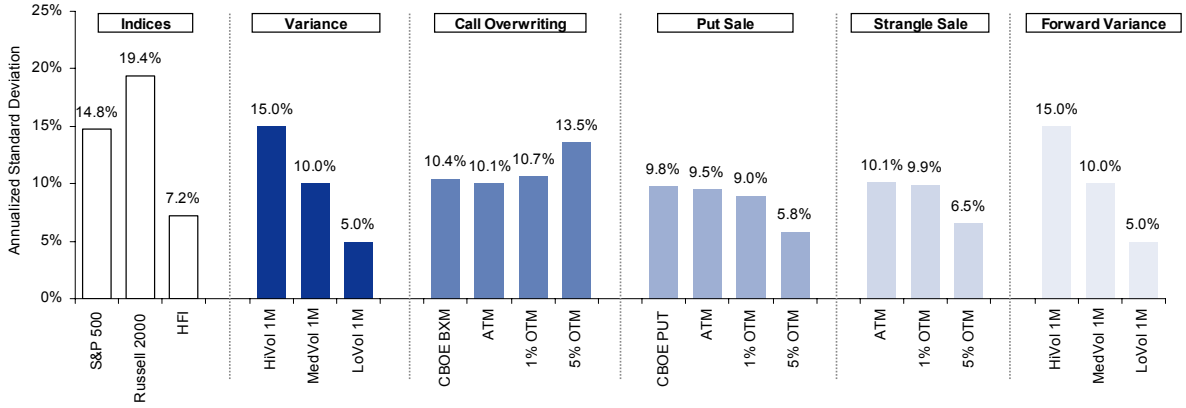
- **LoVol REP – 1.4X SPX returns with one-third the risk; outperformed BXM by 3.5%/year with one-half the risk. Higher returns and lower max drawdown than Credit Suisse/Tremont Hedge Fund Index (HFI).**
- **MedVol REP – Outperformed BXM by 12%/year with similar risk; 2X the return of put and straddle sales.**
- **HiVol REP – 3X SPX return with similar risk; average monthly performance of 240 bps. Rolling 1-, 3-, 5-year returns never negative.**

**Exhibit 7: Annualized performance: S&P 500 1-mo variance strategies had 2-3 times the performance of vanilla option-based strategies**
monthly returns January 31, 1996–September 30, 2007



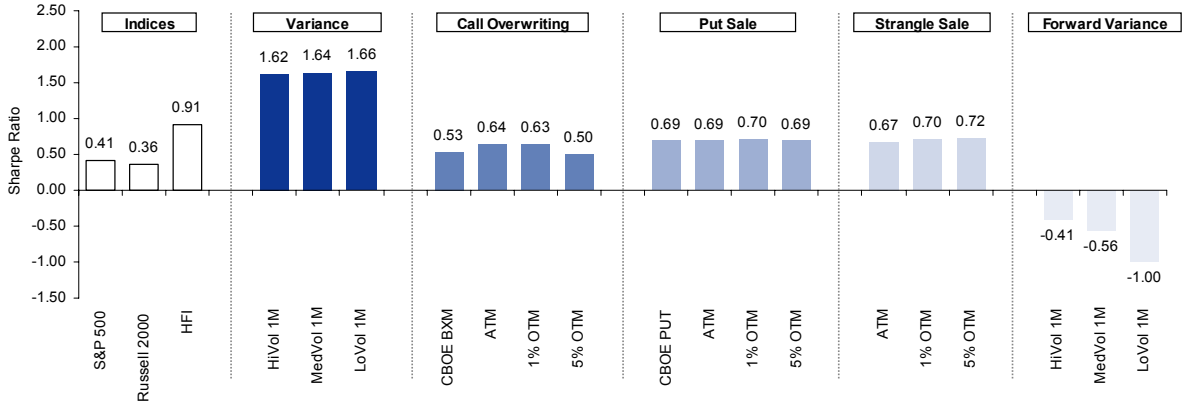

*Source: CBOE, Credit Suisse/Tremont, Goldman Sachs Research estimates.*

**Exhibit 8: Standard deviation: ATM vanilla option based strategies had ~two-thirds the risk of the S&P 500**
monthly observations January 31, 1996–September 30, 2007




*Source: CBOE, Credit Suisse/Tremont, Goldman Sachs Research estimates.*

**Exhibit 9: Sharpe ratios of SPX variance strategies ~1.6, BXM 0.53, put and strangle sales 0.69-0.72**
monthly observations January 31, 1996–September 30, 2007




*Source: CBOE, Credit Suisse/Tremont, Goldman Sachs Research estimates.*

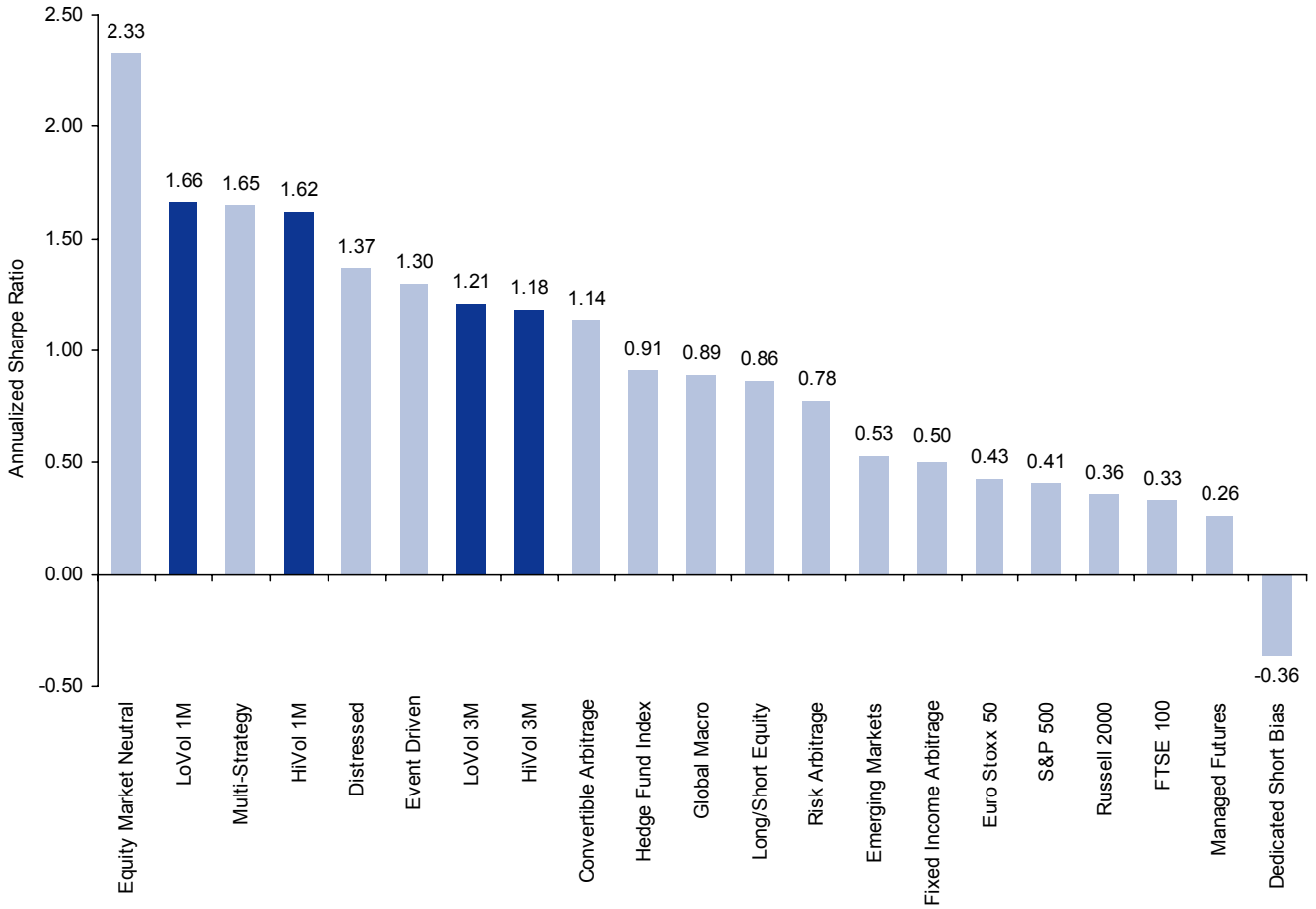
## Variance swap strategies: Higher Sharpe ratios than hedge funds and global equity indices

Variance swap strategies exhibit strong returns across target risk levels, due to the rich implied minus realized volatility spread. Exhibit 10 compares the Sharpe ratios of our variance swap indices against the CS/Tremont hedge fund and major global equity indices.

**Comparison to hedge fund indices:** The one-month LoVol variance REP had higher Sharpe ratios than 12 of the 13 hedge fund indices. Only equity market-neutral funds yielded a higher risk-adjusted return; 2.3 versus 1.65 and 1.19 for one- and three-month variance strategies, respectively.

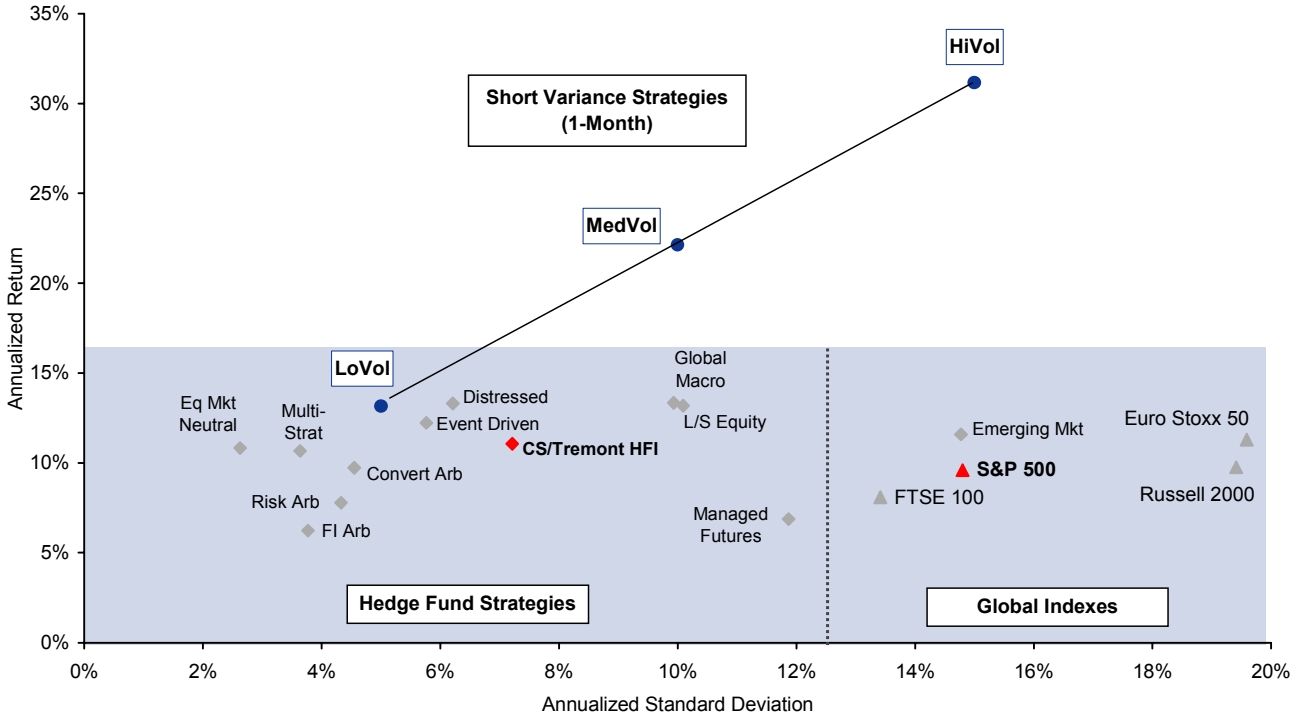
**Comparison to global equity indices:** The one-month HiVol REP had a Sharpe ratio of 1.6, in contrast to the S&P 500 and Russell 2000 indices, with Sharpe ratios of 0.41 and 0.36, respectively. To put that in perspective, the one-month HiVol variance REP generated Sharpe ratios 4 times higher than the S&P 500 and Russell 2000 indices.

**Exhibit 10: S&P 500 variance strategies had higher Sharpe ratios than 12 of the 13 CS/Tremont Hedge Fund Indices**
Monthly observations (January 31, 1996–September 30, 2007)




*Source: Credit Suisse/Tremont, Goldman Sachs Research estimates.*

**Exhibit 11: Annualized risk and return of S&P 500 variance strategies versus hedge fund and global equity indices**
annualized return and standard deviation (January 31, 1996–September 30, 2007)




*Source: Credit Suisse/Tremont, Goldman Sachs Research estimates.*

## Strong returns from listed options strategies; strangle sales lead

Although variance strategies outperformed all vanilla option-based strategies, if we limit the strategy universe to listed options, we found overwriting strategies to have the lowest risk adjusted returns. In terms of Sharpe ratios: Overwriting < Put Selling < Strangle Selling.

**Selling strangles had the best performance and highest Sharpe ratios.** Selling ATM straddles 12 times per year generated significant income, with an average monthly premium of 3.7%, resulting in 69% of months having a positive strategy return. We improved performance and Sharpe ratios by varying strikes:

- **Best performance from ATM/slightly OTM options:** Selling 1% OTM strangles had the highest annualized return at 11.2%, 40 bp higher than selling ATM puts, 60 bp above ATM covered call sales. Similarly for covered call and put sales, where the highest returns came from selling near-the-money options.
- **Highest Sharpe ratios for OTM options:** Selling 4% OTM strangles had the highest Sharpe ratio among our listed options trades at 0.76. Options 4% OTM were roughly 1-standard deviation OTM across our study. Although the returns from selling options were lower than ATM options, these strategies had much lower risk, leading to the highest Sharpe ratios among our listed option trades.

**Selling covered calls:** Selling ATM calls added 100 bp in annual performance to an S&P 500 portfolio and lowered the risk by one-third. The average monthly premium collected was ~1.9% and calls were exercised 54% of the time. The highest returns and Sharpe ratios were generated by selling ATM to slightly OTM call options.

**Selling puts:** ATM put sales generated an 11% annual return, outperforming the ATM call sales by 20 bp with lower risk (10.1% versus 9.5%). The average premium collected was 1.78% and ATM puts were only exercised 35% of the time, resulting in 74% of months having a positive return. Selling puts 3% OTM had the highest Sharpe ratio among put trades at 0.76, and generated an average monthly premium of 104 bp.

## Options strategies are more view-based; choosing strike matters

Although the premium from selling options contributes to strategy performance, and a consistent implied – realized volatility spread suggests superior risk-adjusted performance might be achievable, the return lost from options expiring in-the- money (ITM) can easily overwhelm both. Despite the potential magnitude of this cost, especially for near-the-money option strikes, discussions of option selling strategies often ignore this component.

**The success of vanilla-based option strategies, therefore, hinges as much on minimizing exercise costs as on capturing a rich option premium.** Because option strategies that are not delta-hedged do not directly capture the implied versus realized vol spread, we see them as view-based strategies (delta first, vol second), with strategy performance differentiated across market environments and different stages of the business cycle. For example, an investor who expects a positive risk premium associated with equities implicitly expects ATM calls to expire in-the-money. To reduce the expected exercise loss, the investor should consider OTM strikes and make a trade-off between the reduction in expected exercise cost and the reduction in call premium associated with moving from an ATM to an OTM option.

Exhibit 12 shows the average level of one-month S&P 500 put, call, and strangle premiums earned as a percentage of the underlying S&P 500 index value for ATM to 10% OTM options as well as the exercise rates for each strike.

## Forward variance: No systematic bias, better for tactical vol plays

Using our REP technology we construct high, medium, and low volatility short forward variance indices. Forward variance strategies capture changes in implied volatility, the most well-known example being the exchange listed VIX future, a market-based expectation for future VIX levels.

As we have shown in Exhibit 6, a program of systematically selling forward variance had the lowest returns of any of the strategies in our study with returns of -2.9% per annum on the HiVol index and -0.9% on the LoVol index with Sharpe ratios of -0.41 and -1, respectively**. While the spread between implied and realized volatility tends to be wide and profitable, shifts in the term structure captured by forward variance tend to be more fairly priced by the market.**

## Tactical trading implications of our results

**Our performance results have strong implications for designing tactical long or short volatility positions and indicate the potential benefits of combined long/short volatility portfolios.**

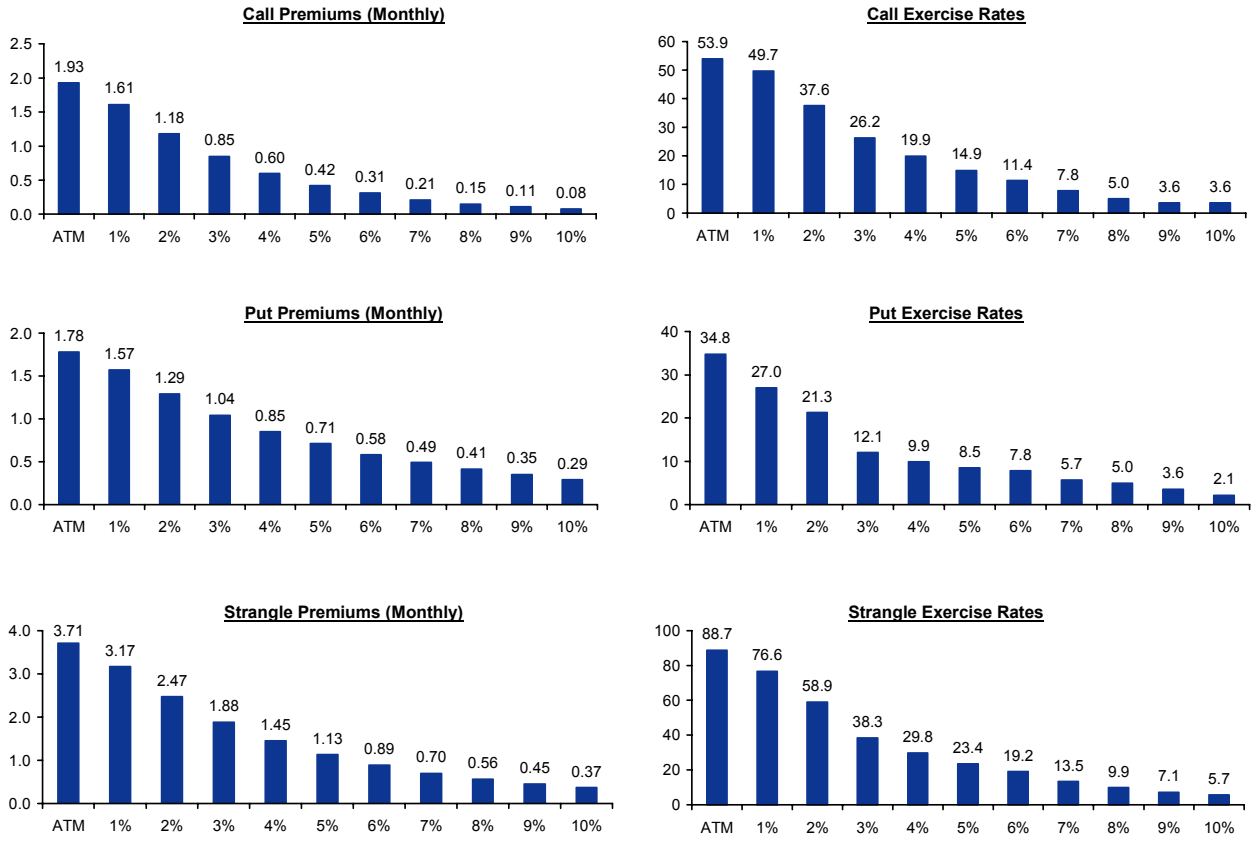
**Selling variance has been the best-performing short volatility strategy.** As we show in this report, even a small amount of short variance tends to generate substantial returns above cash, one reason we prefer short variance trades for systematic alpha. That makes it harder to take long volatility positions via S&P 500 variance consistently through time or use variance swaps as a convexity hedge for equity portfolios. Tactical long variance positions can perform well when the timing is right, but the carry is typically high.

Long one-month variance positions lost money across 86% of the months in our study. That is far lower than the success rates on long forward variance and outright put hedges.

**There are times to be long volatility. Buying forward variance (implied vol) has been the least expensive long volatility strategy.** Forward variance, which captures the market's expectation for the future level of implied volatility, has traded at a much smaller premium than other types of exposures. For investors who want to position long volatility, forward variance trades have on average been less expensive to carry, offered high negative betas to the market, and had high payouts in periods of market stress. The simplest example being the rise in short-dated VIX futures over the past few equity pullbacks.

**Exhibit 12: Premiums generated from selling S&P 500 options**
average monthly premium from selling options 0-10% OTM (January 1996–September 2007)

| Option Strike | Option Premiums ( % Spot ) | | | | | | % of Months Option Exercised | | |
|---|---|---|---|---|---|---|---|---|---|
| | Calls | | Puts | | Strangles | | | | |
| % OTM | Monthly | Annl. | Monthly | Annl. | Monthly | Annl. | Calls | Puts | Strangles |
| ATM | 1.93 | 25.8 | 1.78 | 23.6 | 3.71 | 54.8 | 53.9 | 34.8 | 88.7 |
| 1% | 1.61 | 21.1 | 1.57 | 20.6 | 3.17 | 45.4 | 49.7 | 27.0 | 76.6 |
| 2% | 1.18 | 15.1 | 1.29 | 16.6 | 2.47 | 34.0 | 37.6 | 21.3 | 58.9 |
| 3% | 0.85 | 10.7 | 1.04 | 13.2 | 1.88 | 25.0 | 26.2 | 12.1 | 38.3 |
| 4% | 0.60 | 7.4 | 0.85 | 10.7 | 1.45 | 18.9 | 19.9 | 9.9 | 29.8 |
| 5% | 0.42 | 5.2 | 0.71 | 8.9 | 1.13 | 14.4 | 14.9 | 8.5 | 23.4 |
| 6% | 0.31 | 3.8 | 0.58 | 7.2 | 0.89 | 11.2 | 11.4 | 7.8 | 19.2 |
| 7% | 0.21 | 2.5 | 0.49 | 6.0 | 0.70 | 8.7 | 7.8 | 5.7 | 13.5 |
| 8% | 0.15 | 1.8 | 0.41 | 5.0 | 0.56 | 6.9 | 5.0 | 5.0 | 9.9 |
| 9% | 0.11 | 1.3 | 0.35 | 4.3 | 0.45 | 5.5 | 3.6 | 3.6 | 7.1 |
| 10% | 0.08 | 1.0 | 0.29 | 3.5 | 0.37 | 4.5 | 3.6 | 2.1 | 5.7 |




Note: We used nearest OTM calls and nearest OTM puts for the ATM straddles, so the call and put strikes might not be the same.

*Source: Goldman Sachs Options Research estimates.*

# Volatility in an asset allocation framework: Expands efficient frontier

Although volatility strategies have generated impressive passive returns over time that seem of sufficient magnitude to justify a nontrivial allocation for investment managers, the next step is to examine how the asset would have performed in a portfolio context. In this section, we analyze how a volatility overlay would have affected the risk-return characteristics of an equity-bond portfolio as well as a simple long S&P 500 portfolio. Throughout this section, we define our equity exposure to be S&P 500 total returns and use the Ibbotson Long-Term Government Bond total return index as our bond proxy.

We focus on three primary questions to analyze the potential diversification benefits:

1. If we start with an equity-bond portfolio and perform a classic portfolio optimization, what allocation do we obtain for volatility?
2. What is the effect of adding small amounts of volatility to a standard 60/40 equity-bond portfolio?
3. How do modest volatility allocations affect the risk-return profile of an S&P 500 portfolio?

We analyze short S&P 500 one-month variance swap strategies in this section as they had the highest risk-adjusted returns across volatility strategies, but the same concepts can be applied to vanilla options strategies as well. Ibbotson Associates (2004) found that the BXM significantly expanded the efficient frontier when combined with conventional equity-bond portfolios. We found much stronger results from variance strategies with a substantial increase in Sharpe ratios from even modest allocations.

## 1. Volatility in a classic portfolio optimization: Significant expansion of efficient frontier

Our historical results indicate that investors have obtained over three times the annualized S&P 500 total return with "equity-like" risk for trades that directly capture the volatility risk premium through variance swaps. Given the strong risk-adjusted performance, it is not surprising that a classical portfolio optimization suggests a relatively high allocation to variance within a portfolio of equities and bonds.

In fact, based upon the returns on our HiVol S&P 500 one-month variance index and correlations from January 31, 1996, to September 30, 2007, a classic portfolio optimization would suggest that of the fraction of the portfolio not held in cash,

- 71% should be allocated to variance,
- 0% to equities, and
- 29% to government bonds.

**The addition of volatility to the asset allocation mix leads to significant expansion of the efficient frontier, allowing the investor to achieve higher average returns for any given level of portfolio risk, as measured by portfolio volatility (Exhibit 14). As seen by the slope of the capital markets line, adding variance would have increased the portfolio Sharpe ratio from 0.46 to 1.82 over the years 1996-2007.**

While we are clearly not advocating that investors should swap out of large portions of equity exposure into variance swap strategies, the framework does illustrate just how

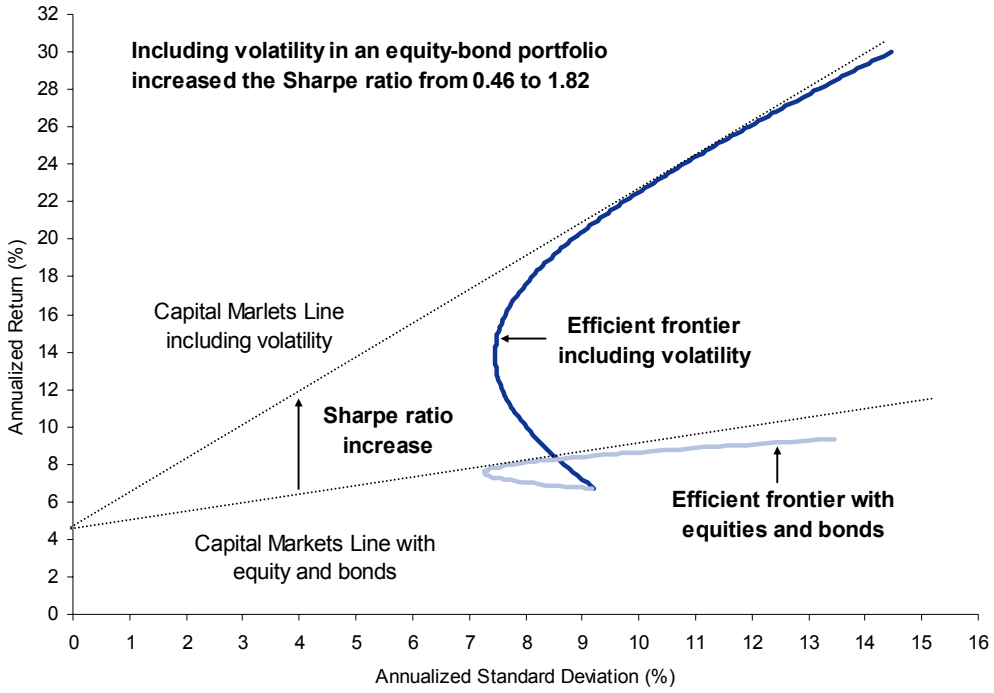
powerful a volatility overlay can be. We show in the next two sections that even a small allocation can have a powerful effect on portfolio performance.

**Exhibit 13: Asset risk, returns and correlations (January 31, 1996–September 30, 2007)**
annualized compound monthly returns; annualized volatility of monthly returns

| | Annual Return | Annual Volatility | Correlation | | | |
|---|---|---|---|---|---|---|
| | | | S&P 500 | Bond | Cash | HiVol |
| **S&P 500** | 9.6% | 14.8% | 1.00 | -0.15 | 0.01 | 0.48 |
| **Bond** | 6.7% | 9.2% | | 1.00 | -0.03 | -0.11 |
| **Cash** | 4.3% | 0.5% | | | 1.00 | -0.01 |
| **HiVol** | 31.2% | 15.0% | | | | 1.00 |

*Source: Ibbotson, Goldman Sachs Research estimates.*

**Exhibit 14: Including volatility in the asset allocation decision can lead to substantially improved risk-adjusted performance in a classic portfolio optimization**
compound annual returns; annualized volatility of monthly returns




*Source: Ibbotson, Goldman Sachs Research estimates.*

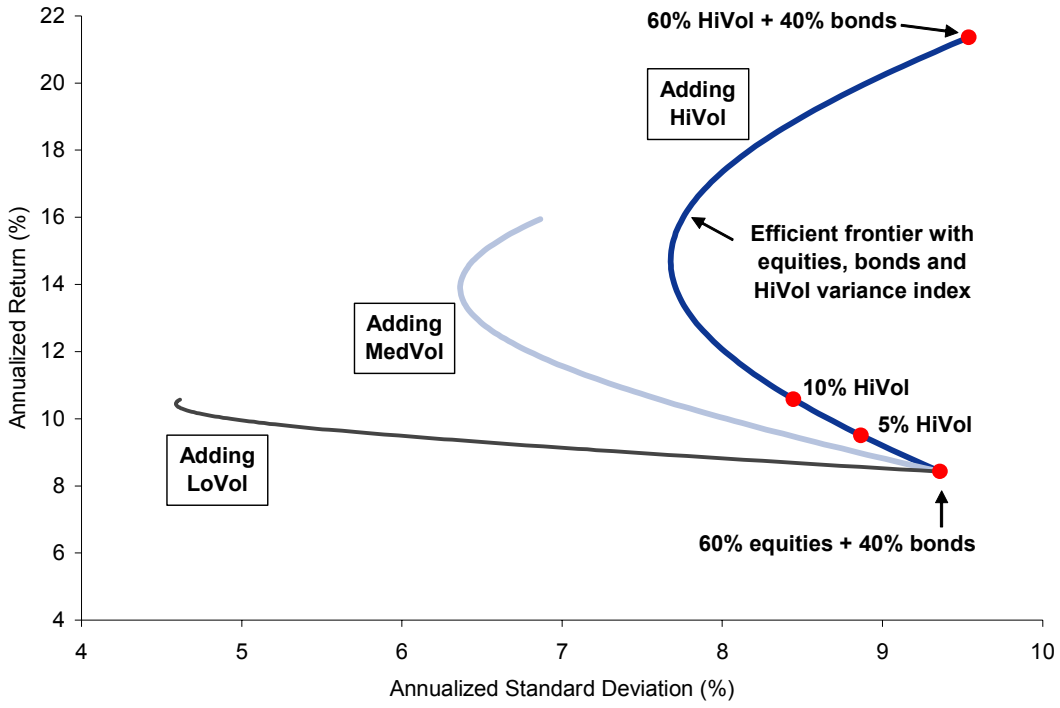
## 2. Combining volatility with a 60/40 equity-bond portfolio

Given that traditional investment managers are unlikely to replace large portions of their equity holdings with variance strategies, we show that even small allocations have a big enough impact on risk-adjusted returns to justify an investment. We examine the effect of replacing modest amounts of large-cap equity with variance in a 60/40 equity-bond portfolio:

- Replacing S&P 500 exposure with a 5% investment in the HiVol one-month variance REP outperformed the benchmark 60/40 portfolio by 108 bp per annum with a 49 bp reduction in risk. The portfolio had return of 9.50% per annum with a standard deviation of 8.87%.
- Increasing the allocation in the HiVol index to 10% led to a portfolio that outperformed the benchmark 60/40 portfolio by 216 bp per annum with a 92-bp reduction in risk. The resulting portfolio had an annual return of 10.58% with a standard deviation of 8.44% and increased the Sharpe ratio versus the benchmark portfolio from 0.44 to 0.74.

**Exhibit 15: Adding SPX variance to a 60/40 equity-bond portfolio leads to significant expansion of the efficient frontier**
compound annual returns; annualized volatility of monthly returns

| Portfolio Weights | | | w/ HiVol Variance Index | | | w/ MedVol Variance Index | | | w/ LoVol Variance Index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Equity | Bond | Variance Index | Return | Volatility | Sharpe Ratio | Return | Volatility | Sharpe Ratio | Return | Volatility | Sharpe Ratio |
| 60% | 40% | 0% | 8.42 | 9.36 | 0.44 | 8.42 | 9.36 | 0.44 | 8.42 | 9.36 | 0.44 |
| 59% | 40% | 1% | 8.64 | 9.26 | 0.47 | 8.55 | 9.24 | 0.46 | 8.46 | 9.23 | 0.45 |
| 58% | 40% | 2% | 8.86 | 9.15 | 0.49 | 8.68 | 9.13 | 0.48 | 8.50 | 9.11 | 0.46 |
| 57% | 40% | 3% | 9.07 | 9.06 | 0.52 | 8.80 | 9.02 | 0.50 | 8.53 | 8.98 | 0.47 |
| 56% | 40% | 4% | 9.29 | 8.96 | 0.55 | 8.93 | 8.91 | 0.52 | 8.57 | 8.86 | 0.48 |
| 55% | 40% | 5% | 9.50 | 8.87 | 0.58 | 9.05 | 8.80 | 0.54 | 8.60 | 8.74 | 0.49 |
| ⋮ | | | | | | | | | | | |
| 50% | 40% | 10% | 10.58 | 8.44 | 0.74 | 9.68 | 8.28 | 0.65 | 8.78 | 8.13 | 0.55 |




*Source: Ibbotson, Goldman Sachs Research estimates.*

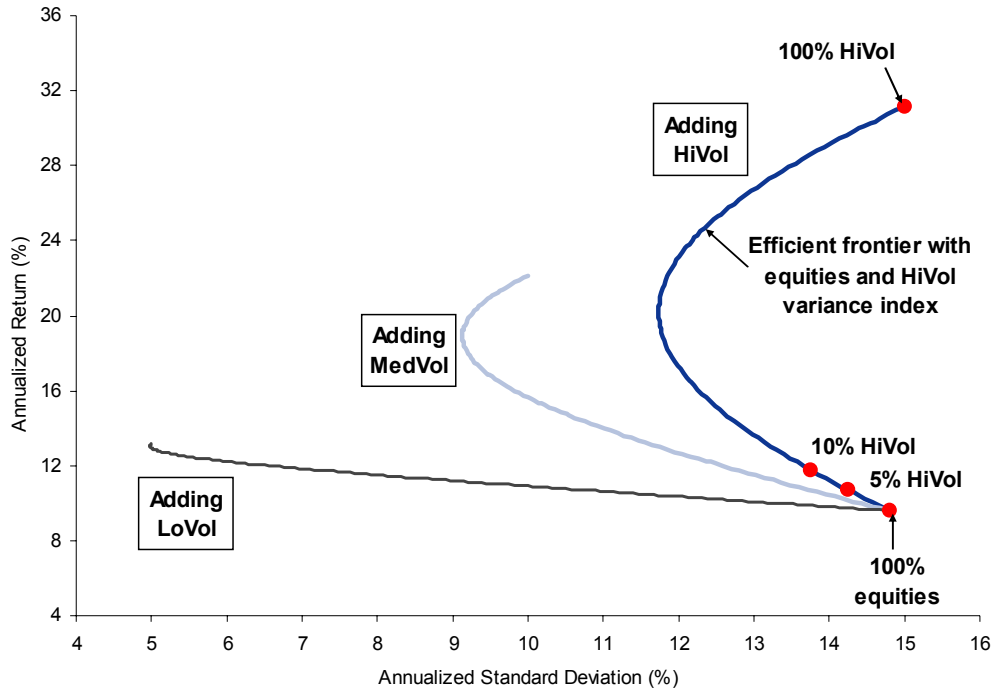
## 3. The benefits of combining S&P 500 and volatility portfolios

Exhibit 16 shows the risk, return, and Sharpe ratios of adding increasing weights of variance exposure on top of an S&P 500 portfolio. A substantial increase in risk-adjusted performance can be achieved with even modest allocations of variance:

- A portfolio 90% S&P 500 + 10% HiVol variance REP outperformed the S&P 500 215 bp per annum with a 104-bp reduction in risk. Sharpe ratios increased from 0.36 to 0.54.
- For investors with lower risk budgets, we found a portfolio 90% SPX + 10% LoVol REP outperformed an S&P 500 portfolio by 35 bp per annum with a 135-bp reduction in risk. Sharpe ratios increased from 0.36 to 0.42.

**Exhibit 16: Adding 10% HiVol variance index exposure to an S&P 500 equity portfolio increased performance by 214 bp per annum, reduced volatility by 105 bp, and increased Sharpe ratios from 0.36 to 0.54**
compound annual returns; annualized volatility of monthly returns January 31, 1996–September 30, 2007

| Portfolio Weights | | w/ HiVol Variance Index | | | w/ MedVol Variance Index | | | w/ LoVol Variance Index | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Equity | Variance Index | Return | Volatility | Sharpe Ratio | Return | Volatility | Sharpe Ratio | Return | Volatility | Sharpe Ratio |
| 100% | 0% | 9.60 | 14.80 | 0.36 | 9.60 | 14.80 | 0.36 | 9.60 | 14.80 | 0.36 |
| 99% | 1% | 9.81 | 14.69 | 0.37 | 9.72 | 14.68 | 0.37 | 9.63 | 14.66 | 0.36 |
| 98% | 2% | 10.03 | 14.58 | 0.39 | 9.85 | 14.55 | 0.38 | 9.67 | 14.53 | 0.37 |
| 97% | 3% | 10.24 | 14.47 | 0.41 | 9.97 | 14.43 | 0.39 | 9.70 | 14.39 | 0.37 |
| 96% | 4% | 10.46 | 14.36 | 0.43 | 10.10 | 14.31 | 0.40 | 9.74 | 14.26 | 0.38 |
| 95% | 5% | 10.67 | 14.26 | 0.44 | 10.22 | 14.19 | 0.41 | 9.77 | 14.12 | 0.39 |
| ⋮ | | | | | | | | | | |
| 90% | 10% | 11.75 | 13.76 | 0.54 | 10.85 | 13.60 | 0.48 | 9.95 | 13.45 | 0.42 |




*Source: Goldman Sachs Research estimates.*

# High risk premium leads to outperformance in hostile markets

We believe it is particularly important to understand the risks of volatility selling strategies in hostile markets. We therefore analyze their performance: (1) across the top 10 calendar-month declines in the S&P 500, (2) during the worst bear market in recent history (September 2000-September 2002), (3) conditional upon S&P 500 monthly performance, and (4) at their worst.

We find that, on average, volatility selling strategies tend to outperform in market declines as the upfront premiums serve as a downside cushion. That said, volatility strategies can fall sharply when risk re-prices dramatically. We analyze the drawdowns and emphasize de-levering variance positions using our REP technology to target manageable risk levels.

## Returns across the top 10 calendar-month declines in the S&P 500

We show the 10 largest S&P 500 calendar-month declines from January 1996 to September 2007 and the corresponding returns for each of our volatility portfolios in Exhibit 17. The S&P 500 was down an average of 8.4% across the top 10 calendar-month declines, accompanied by an average 6.6-point increase in the VIX.

- **Variance selling strategies had the strongest average returns:** Although our HiVol variance index was calibrated for SPX-like volatility, it did not have SPX-like drawdowns in most cases, with an average monthly return of -1.9%. Option-based strategies outperformed the S&P 500 but suffered larger losses relative to variance. BXM was -6.5% on average, ATM puts -6.0%, and straddles -3.4%.
- The HiVol variance index had a positive return in 6 of the 10 months, while the BXM and PUT indices were down at least -1.3% in each month. The variance strategy did have the largest drawdown, however. During the Russian debt default (July-August 1998), the HiVol REP fell 15.3% vs. -14.5% for the S&P 500.
- Long S&P 500 and 60/40 equity-bond portfolios that replaced S&P 500 exposure with a 5% investment in the HiVol variance REP performed well. The 95% SPX/5% HiVol REP outperformed the long-only portfolio in 8 out of 10 months by an average of 30 bp.
- Note that call overwriting can underperform the S&P 500 in a down calendar month. In September 2001, the S&P 500 fell after 9/11 and the BXM rolled its strike at market lows. The S&P 500 then rallied 8%, causing the BXM to underperform.

**Exhibit 17: Volatility strategy returns across the top 10 S&P 500 calendar month declines**
January 1996–September 2007

| | | | | Variance Based Strategies | | | Option Based Strategies | | | | Asset Allocation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start Date | End Date | S&P 500 Return | VIX change | HiVol 1M | MedVol 1M | LoVol 1M | CBOE BXM | CBOE PUT | Straddles | 5% OTM Strangles | 100% SPX | 95% SPX + 5% HiVol | 60/40 portfolio | 55/40 + 5% HiVol |
| 31-Jul-98 | 31-Aug-98 | **-14.5%** | 19.5 | -15.3% | -10.2% | -4.9% | -11.8% | -10.3% | -9.0% | -6.6% | -14.5% | -14.5% | -6.8% | -6.9% |
| 31-Aug-02 | 30-Sep-02 | **-10.9%** | 7.0 | 2.2% | 1.5% | 0.8% | -7.3% | -6.1% | -3.0% | -1.6% | -10.9% | -10.2% | -4.9% | -4.2% |
| 31-Jan-01 | 28-Feb-01 | **-9.1%** | 6.3 | -2.4% | -1.5% | -0.5% | -5.6% | -4.0% | 0.4% | -0.6% | -9.1% | -8.8% | -4.7% | -4.4% |
| 31-Aug-01 | 30-Sep-01 | **-8.1%** | 7.0 | 0.4% | 0.5% | 0.4% | -10.5% | -13.1% | -11.6% | -10.1% | -8.1% | -7.6% | -4.5% | -4.1% |
| 31-Oct-00 | 30-Nov-00 | **-7.9%** | 6.0 | 0.8% | 0.8% | 0.7% | -2.9% | -1.3% | 4.0% | 2.0% | -7.9% | -7.4% | -3.5% | -3.0% |
| 30-Jun-02 | 31-Jul-02 | **-7.8%** | 6.6 | -8.7% | -5.9% | -2.9% | -8.3% | -8.8% | -8.0% | -6.4% | -7.8% | -7.8% | -3.5% | -3.5% |
| 31-May-02 | 30-Jun-02 | **-7.1%** | 5.4 | 0.6% | 0.5% | 0.3% | -5.4% | -6.3% | -3.2% | -1.5% | -7.1% | -6.7% | -3.5% | -3.1% |
| 28-Feb-01 | 31-Mar-01 | **-6.3%** | 0.3 | 0.3% | 0.4% | 0.4% | -5.6% | -5.2% | -3.3% | -2.1% | -6.3% | -6.0% | -4.1% | -3.8% |
| 31-Jul-01 | 31-Aug-01 | **-6.3%** | 3.3 | 5.0% | 3.5% | 1.9% | -3.8% | -1.8% | 0.7% | 0.5% | -6.3% | -5.7% | -2.9% | -2.4% |
| 31-Mar-02 | 30-Apr-02 | **-6.1%** | 4.5 | -1.6% | -1.0% | -0.4% | -4.0% | -3.1% | -0.8% | 0.0% | -6.1% | -5.8% | -2.0% | -1.8% |
| **Average** | | **-8.4%** | **6.6** | **-1.9%** | **-1.2%** | **-0.4%** | **-6.5%** | **-6.0%** | **-3.4%** | **-2.6%** | **-8.4%** | **-8.1%** | **-4.0%** | **-3.7%** |
| Min | | -14.5% | 0.3 | -15.3% | -10.2% | -4.9% | -11.8% | -13.1% | -11.6% | -10.1% | -14.5% | -14.5% | -6.8% | -6.9% |
| Max | | -6.1% | 19.5 | 5.0% | 3.5% | 1.9% | -2.9% | -1.3% | 4.0% | 2.0% | -6.1% | -5.7% | -2.0% | -1.8% |

*Source: CBOE, Ibbotson, Goldman Sachs Research estimates.*

## Bear market performance (September 2000 to September 2002)

Nine out of the top 10 SPX calendar-month declines in our study occurred between August 31, 2000, and September 30, 2002. In fact, this period was the worst bear market since the Great Depression as the market experienced the bursting of Tech Bubble, the effects of the 9/11 attacks, and the corporate accounting scandals of 2002, causing the S&P 500 Index to decline 45% in two years.

**While the S&P 500 was down 45% over the period, the HiVol variance REP was up 45% and achieved that performance with a volatility 4 points lower than the market, 14% versus 18%.**

Between September 2000 and September 2002, S&P 500 month returns were only positive 36% of the time, with an average monthly return of -2.2%. In contrast, the HiVol REP was profitable 72% of the time, with an average monthly return of 1.6%.

The BXM and Put indices outperformed the market by more than 15% during the pullback but were still down 30% and 28%, respectively, with volatility on par with the HiVol index. Of the option-based strategies, only straddles and strangles had positive returns.

**Exhibit 18: Bear market performance: S&P 500 variance and option based strategies outperformed from August 31, 2000, to September 30, 2002**

| | | Variance Based Strategies | | | Option Based Strategies | | | | Asset Allocation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monthly Returns | S&P 500 Return | HiVol 1M | MedVol 1M | LoVol 1M | CBOE BXM | CBOE PUT | Straddles | 5% OTM Strangles | 100% SPX | 95% SPX + 5% HiVol | 60/40 portfolio | 55/40 + 5% HiVol |
| Average | **-2.2%** | 1.6% | 1.2% | 0.7% | -1.3% | -1.2% | 0.2% | 0.1% | -2.2% | -2.0% | -1.0% | -0.8% |
| Min | **-10.9%** | -8.7% | -5.9% | -2.9% | -10.5% | -13.1% | -11.6% | -10.1% | -10.9% | -10.2% | -4.9% | -4.4% |
| Max | **7.8%** | 9.6% | 6.6% | 3.4% | 3.5% | 3.4% | 4.5% | 3.0% | 7.8% | 7.7% | 3.0% | 3.3% |
| % positive | **36%** | 72% | 72% | 72% | 48% | 52% | 60% | 72% | 36% | 36% | 40% | 44% |
| **Cumulative return** | **-44.7%** | **44.6%** | **32.5%** | **20.2%** | **-30.2%** | **-27.6%** | **1.9%** | **1.5%** | **-44.7%** | **-41.9%** | **-22.0%** | **-18.1%** |
| **Annualized return** | **-24.8%** | **19.4%** | **14.5%** | **9.2%** | **-15.8%** | **-14.3%** | **0.9%** | **0.7%** | **-24.8%** | **-22.9%** | **-11.2%** | **-9.1%** |
| **Annualized volatility** | **18.0%** | **14.0%** | **9.5%** | **4.9%** | **14.3%** | **14.9%** | **14.0%** | **10.2%** | **18.0%** | **17.4%** | **9.0%** | **8.5%** |

*Source: CBOE, Ibbotson, Goldman Sachs Research estimates.*

## Performance conditional on S&P 500 monthly returns

Across the 140 calendar months in our study, we found a one-standard deviation monthly SPX move to be approximately 4%. In Exhibit 19, we analyze the average performance for the volatility indices conditional on S&P 500 returns being in 4 buckets: (1) return < -4%; (2) -4% < = return < = 0; (3) 0 < return < = 4%; (4) return > 4%.

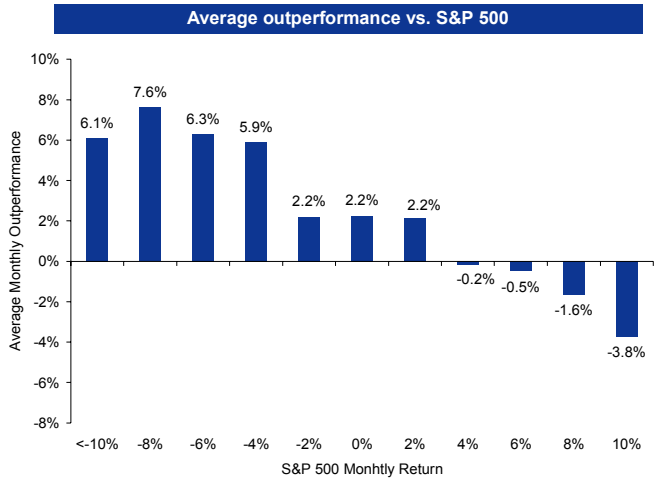
- **SPX down over 4% (1 standard deviation move):** Variance and options selling strategies outperformed the market, with the LoVol REP performing the best. Consistent with our prior research, long forward variance strategies had strong positive returns.
- **SPX down 0 to 4%:** The S&P 500 was down 1.9% on average and the variance indices had a positive average return of 30 bp. Straddle selling did best.
- **SPX up 0 to 4%:** All strategies were positive on average, but the HiVol variance index had double the return of the Put and BXM strategies with an average outperformance of 180 bp versus straddles, 140 bp versus the market.
- **SPX up over 4%:** All the volatility strategies significantly underperformed the market. The HiVol REP and the BXM had the best performance among vol strategies.

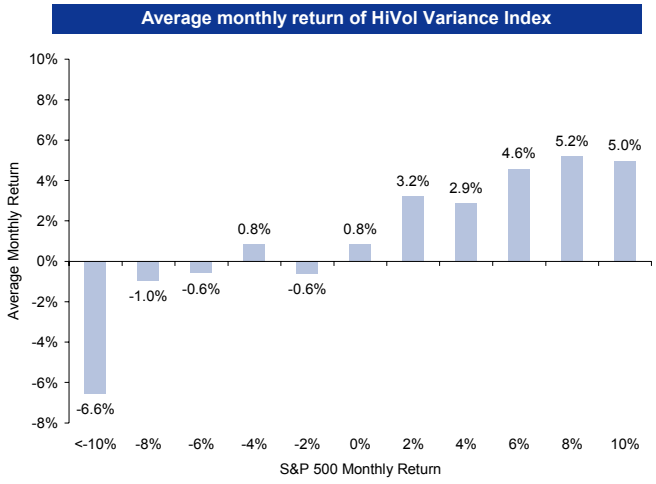
**Exhibit 19: Variance selling performed well in down markets on average; long forward variance strategies had strong positive returns in large SPX downmoves**
average monthly performance conditional on S&P 500 price return (January 31, 1996-September 30, 2007)

| | S&P 500 monthly return | | | | Overall Monthly Average |
|---|---|---|---|---|---|
| | <-4% | -4% to 0% | 0% to +4% | >+4% | |
| **S&P 500** | **-7.1%** | **-1.9%** | **1.7%** | **6.1%** | **0.9%** |
| **Short Variance Strategies** | | | | | |
| HiVol 1M | -0.9% | 0.3% | 3.1% | 4.8% | 2.4% |
| MedVol 1M | -0.5% | 0.3% | 2.2% | 3.4% | 1.7% |
| LoVol 1M | 0.0% | 0.3% | 1.3% | 1.9% | 1.0% |
| HiVol 3M | -2.2% | 0.4% | 2.5% | 4.1% | 1.8% |
| MedVol 3M | -1.4% | 0.4% | 1.8% | 2.9% | 1.3% |
| LoVol 3M | -0.5% | 0.4% | 1.1% | 1.7% | 0.9% |
| **Long Forward Variance Strategies** | | | | | |
| HiVol 1M | 6.8% | -0.1% | -1.2% | -2.7% | -0.4% |
| MedVol 1M | 4.4% | -0.1% | -0.8% | -1.8% | -0.3% |
| LoVol 1M | 2.2% | 0.0% | -0.4% | -0.9% | -0.1% |
| **Option Selling Strategies** | | | | | |
| CBOE BXM | -4.5% | -0.5% | 1.4% | 3.7% | 0.8% |
| CBOE PUT | -3.9% | -0.1% | 1.5% | 3.3% | 0.9% |
| ATM Straddles | -0.9% | 1.2% | 1.3% | 0.9% | 0.9% |
| 5% OTM Strangles | -1.0% | 0.8% | 0.9% | 1.2% | 0.7% |
| **Number of obs** | **16** | **34** | **57** | **33** | **140** |

*Source: CBOE, Goldman Sachs Research estimates.*

**Exhibit 20: S&P 500 HiVol REP: Outperformed the S&P 500 across a wide range of market returns**
based on average monthly performance of one-month HiVol variance REP conditional on S&P 500 price return (January 31, 1996–September 30, 2007)




| SPX Monthly Return | <-10% | -10% to -8% | -8% to -6% | -6% to -4% | -4% to -2% | -2% to 0% | 0% to 2% | 2% to 4% | 4% to 6% | 6% to 8% | 8% to 10% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # observations | 2 | 2 | 6 | 6 | 13 | 21 | 38 | 19 | 18 | 11 | 4 |
| Success Rate (%) | 50% | 50% | 67% | 67% | 54% | 57% | 95% | 95% | 100% | 91% | 75% |
| % Outperform SPX | 50% | 100% | 83% | 100% | 77% | 76% | 84% | 32% | 44% | 36% | 25% |

*Source: Goldman Sachs Research estimates.*

## Largest monthly drawdowns for volatility selling strategies

Although volatility selling strategies have on average outperformed the S&P 500 in down markets, they can experience large monthly drawdowns. In this section, we analyze the maximum monthly drawdown for each of our volatility indices.

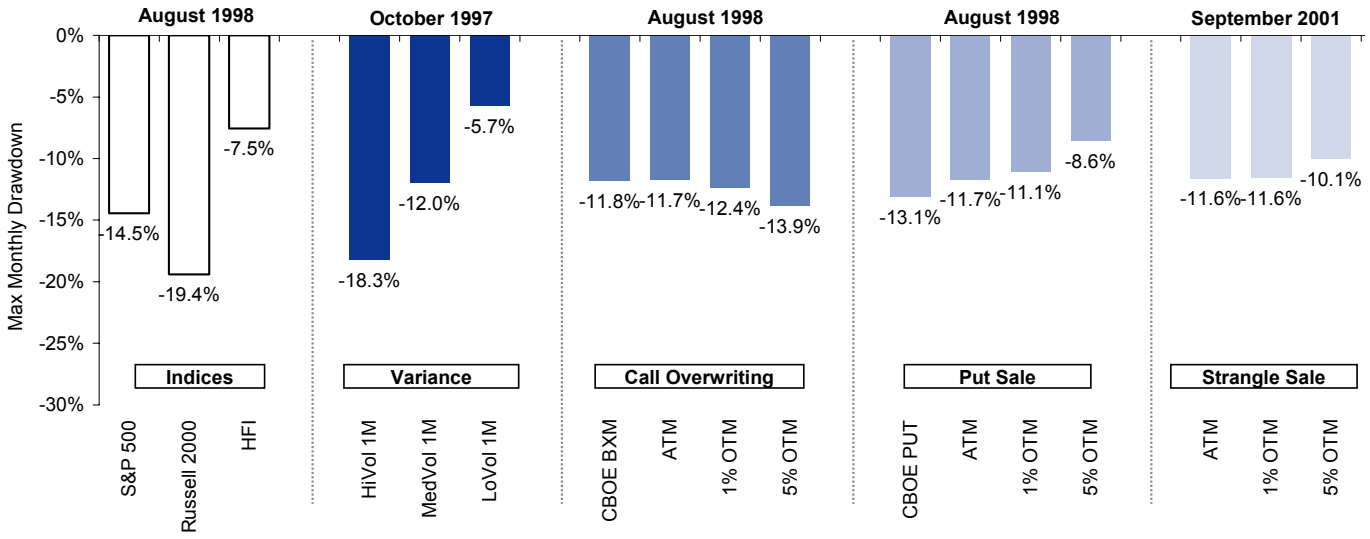
**Cross-strategy comparisons:** Strategies with similar vol had similar drawdowns. Selling ATM options via the BXM, the PUT index, or ATM straddles all had annualized volatilities of ~10% and generated similar max drawdowns of ~11.7%. The MedVol variance index had an annualized volatility in line with these strategies and experienced a similar draw-down (-12%).

**Variance swaps:** Our variance indices were calibrated for 5%, 10%, and 15% volatility per annum and the max monthly losses followed a clear mathematical pattern at -5.7%, -12.0%, -18.3%, respectively. For example, using the LoVol index as a baseline (5% vol per annum), the MedVol variance index with double the vol had double the drawdown.

**BXM and overwriting strategies:** In terms of maximum monthly drawdowns we found that overwriting performed the worst of all the option-based strategies. Maximum monthly drawdowns ranged from -11.8% for ATMs to -13.9% for 5% OTM overwriting strategies. These strategies are S&P 500 overlays and so are fully exposed to market downturns, with lower premiums for selling OTM options providing less cushion in periods of market weakness.

**Put and strangle strategies:** Selling closer-to-the-money options increased maximum monthly drawdowns. The worst drawdowns for put selling ranged from -11.7% for ATMs, to -8.6% for 5% OTM strategies. Straddle and strangle drawdowns ranged from -11.6% to -10.1%.

**Exhibit 21: Largest monthly drawdowns across S&P 500 variance and vanilla option-based strategies**
January 31, 1996–September 30, 2007




Note: HFI refers to Credit Suisse/Tremont Hedge Fund Index
CBOE PUT had its largest monthly drawdown during September, 2001

*Source: CBOE, Goldman Sachs Research estimates.*

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# Appendix: Data and methodology

One of the biggest limitations to the analysis of volatility-based strategy performance has been access to data and the lack of available benchmarks across a wide range of volatility strategies. In this study, we construct a variety of indices for listed and OTC volatility strategies in order to evaluate and compare strategy performance.

## Data sources

**For option-based strategies**
The historical S&P 500 index option prices in this report were obtained using the IVY database from OptionMetrics, which contains bid/offer option pricing on all US exchange listed index and equity options.

**For variance swap strategies**
The variance swap levels used in this report were generated from Goldman Sachs volatility trading surfaces from January 2003 to September 2007. Previous variance swap levels were generated from the replicating portfolios for fair variance levels using listed option prices. The methodology used to construct variance levels from listed option prices is similar to that used in the VIX calculation. For methodology details, please see the CBOE VIX white paper, which can be obtained on the Chicago Board Options Exchange website: www.cboe.com/micro/vix/vixwhite.pdf

## Calculation of S&P 500 Variance Swap Indices

Each variance index is comprised of two legs:

(1) a short position in an S&P 500 variance swap and

(2) a cash investment.

**Methodology:** Each variance swap is sold short and held to maturity. One-month strategies expire on the close, each monthly option expiration, generally the third Friday of each month. Three-month strategies expire on a December, March, June, September option expiration cycle. At expiration, a new trade is initiated where the vega notional of variance sold is set to be a fixed proportion of the total dollar value of the portfolio. Every one or three months, upon expiration of the variance swap, the index value is invested at the prevailing one- or three-month US dollar LIBOR rate. Portfolios are marked-to-market every trading day. Returns are then calculated from index levels with an initial index value of 100 on January 19, 1996. We assume a 0.35 spread from mid to bid at trade initiation for each variance swap sold.

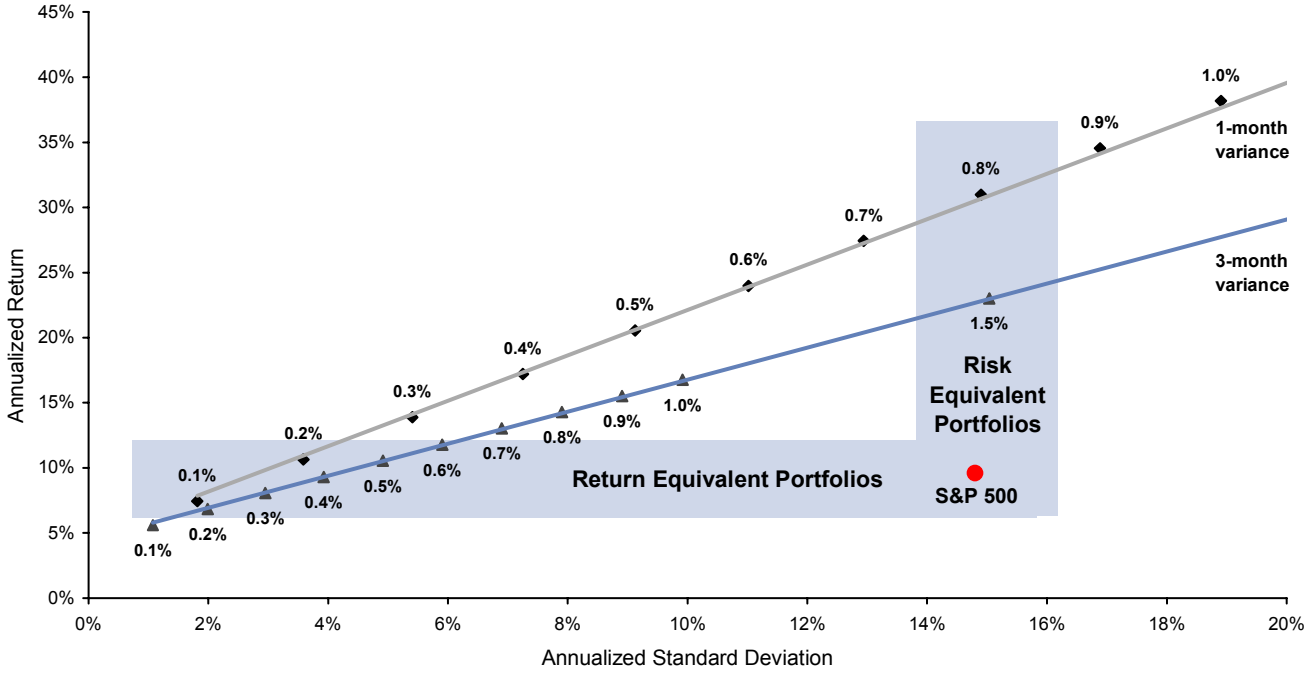
The table below (Exhibit 22) lists the annual performance and standard deviation of a variance portfolio obtained by selling different fixed proportions of S&P 500 variance each month or quarter (January 31, 1996–September 30, 2007). For example, our one-month HiVol variance REP sold $0.80 of vega per $100 of the total dollar value of the portfolio and had a standard deviation of monthly returns of 15%.

**Exhibit 22: Sizing of the short S&P 500 variance strategies**
January 31, 1996, to September 30, 2007

| S&P 500 | |
|---|---|
| Annualized Return | 9.6% |
| Annualized St Dev | 14.8% |

| 1-mo variance | 0.1% | 0.2% | 0.3% | 0.4% | 0.5% | 0.6% | 0.7% | 0.8% | 0.9% | 1.0% | 1.5% | 2.0% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Annualized Return | 7.4% | 10.6% | 13.9% | 17.2% | 20.6% | 24.0% | 27.4% | 31.0% | 34.5% | 38.2% | 57.0% | 76.9% |
| Annualized St Dev | 1.8% | 3.6% | 5.4% | 7.3% | 9.1% | 11.0% | 12.9% | 14.9% | 16.9% | 18.9% | 29.7% | 42.0% |

| 3-mo variance | 0.1% | 0.2% | 0.3% | 0.4% | 0.5% | 0.6% | 0.7% | 0.8% | 0.9% | 1.0% | 1.5% | 2.0% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Annualized Return | 5.6% | 6.8% | 8.1% | 9.3% | 10.5% | 11.8% | 13.0% | 14.3% | 15.5% | 16.8% | 23.0% | 29.3% |
| Annualized St Dev | 1.1% | 2.0% | 3.0% | 3.9% | 4.9% | 5.9% | 6.9% | 7.9% | 8.9% | 9.9% | 15.0% | 20.3% |




*Source: Goldman Sachs Research estimates.*

## Calculation of option-based strategy returns

### Call-overwriting

Strategy returns for our call overwriting indices were calculated as follows:

$$R_{t-1,t} = \frac{S_t + D_t - S_{t-1}}{S_{t-1}} + \frac{C_{t-1} \times \left(1 + \frac{L_{t-1}\tau}{360}\right)}{S_{t-1}} - \frac{C_t}{S_{t-1}}$$

Where

$S_t$ = the S&P 500 value at the close of day t
$D_t$ = cash dividends on stocks that went ex dividend on day t, expressed in S&P 500 index points
$C_{t-1}$ = call premium (bid price) received on the Thursday before expiration (time t – 1)
$C_t$ = call premium (ask price) used to buy back the option. Paid on the Thursday before the next expiration (time t).
$\tau$ = investment horizon (1 month or 3 months)
$L_{t-1}$ = annualized US dollar LIBOR rate at time t – 1 for the investment horizon

For the one-month strategy, t – 1 to t covers one-month, from the Thursday before expiration to the Thursday before the next expiration; for the three-month strategy, it covers from the Thursday before the expiration to the next calendar quarter expiration. Our call-overwriting indices are similar in nature to the CBOE BXM created by the Chicago Board Option Exchange (CBOE) with two primary differences: (1) we rolled at the close of the Thursday before option expiration instead of Friday intraday; (2) we invest the call premium at US dollar LIBOR instead of using it as a reduction of the initial capital required. Like the BXM, on each roll date we search for the listed option strike which is closest to the desired moneyness dictated by the strategy (0%-10% OTM). A complete methodology for the CBOE S&P 500 BuyWrite Index (BXM) can be obtained on the Chicago Board Options Exchange website: http://www.cboe.com/micro/bxm/BXMDescription-Methodology.pdf

### Put, straddle, strangle sales

For put, straddle, and strangle selling, each index is designed to track the performance of an investment strategy that overlays a short S&P 500 options position over a money market account. The same roll rules and expiration cycles used in our call-overwriting index are applied. The notional value of options sold is set to be the full dollar notional value of the index on the roll date. This corresponds to selling ($ value of option index / S&P 500 level) put options on each roll date.

Using the 1% OTM put index as an example: On Thursday January 18, 1996, the inception date, $100 was invested at the one-month US dollar LIBOR rate. In addition, we sold $100 notional or ($100 / S&P 500 index level) puts with a strike nearest to 1% out-of-the-money. The cash proceeds from the put sale were invested at the prevailing one-month US dollar LIBOR rate.

At the close of every business date, the value of our put selling index is equal to the value of LIBOR account less the mark-to-market value of the puts.

We roll our put strikes on the business day before the next option expiration (usually Thursday). On a roll date, any mark-to-market loss on the puts sold is financed by the LIBOR account. A new batch of puts is sold (new portfolio level / S&P 500 index level), and we invest the cash and the proceeds from the puts sold at the prevailing 1-month US dollar LIBOR rate. This cycle repeats from thereon. Positions are marked to market every day and returns are then generated off the index levels.

A complete methodology for the CBOE S&P 500 PutWrite Index (PUT) can be obtained on the Chicago Board Options Exchange website: http://www.cboe.com/micro/put/putwrite.pdf

# Risks

Selling calls: Investors who sell covered calls (own the underlying security and sell a call) risk limiting their upside to the strike price plus the upfront premium received and may have their security called away if the security price exceeds the strike price of the short call. Additionally, the investor has full downside participation that is only partially offset by the upfront premium taken in. Investors short naked calls (i.e. sold calls but don't hold underlying security) risk unlimited losses of security price less strike price. Investors who sell naked call spreads (i.e. sell a call and buy a farther out-of-the-money call with no underlying security position) have a maximum loss of the difference between the long call strike and the short call strike, less the upfront premium taken in, if the underlying security finishes above the long call strike at expiration. The maximum gain is the upfront premium taken in, if the security finishes below the short call strike at expiration.

Selling puts: Put sellers commit to buying the underlying security at the strike price in the event the security falls below the strike price. The maximum loss is the full strike price less the premium received for selling the put. Put sellers who are also long a lower dollar-strike put face a maximum loss of the difference between the long and short put strikes less the options premium received.

Selling strangles or straddles: Investors who are long a security and short a strangle or straddle risk capping their upside in the security to the strike price of the call that is sold plus the upfront premium received. Additionally, if the security trades below the strike price of the short put, the investor risks losing the difference between the strike price and the security price (less the value of the premium received) on the short put and will also experience losses in the security position if he owns shares. The maximum potential loss is the full value of the strike price (less the value of the premium received) plus losses on the long security position. Investors who are short naked strangles or straddles have unlimited potential loss since if the security trades above the call strike price, the investor risks losing the difference between the strike price and the security price (less the value of the premium received) on the short call. In addition, they are obligated to buy the security at the put strike price (less upfront premium received) if the security finishes below the put strike price at expiration. Strangle/straddle sellers risk assignment on short put positions that become in the money. Additionally, they risk having stock called away from short call positions that become in the money.

Investors who sell a variance swap risk unlimited losses if the realized volatility of the security exceeds the reference strike of the swap at expiration.

Investors who buy a variance swap risk a maximum loss equal to the square of the variance strike times the variance notional, (variance units * variance strike2), if realized volatility goes to zero.

Most spreads and all uncovered strategies must be effected in a margin account. Multiple leg strategies, including spreads, straddles, and strangles will incur multiple commission charges. Supporting documentation for any claims, comparison, recommendations, statistics, or other technical data, will be supplied upon request. Returns cited might be achieved only if the parameters described can be duplicated and there is no certainty of doing so.

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We, Maria Grant, CFA and Krag Gregory, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

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