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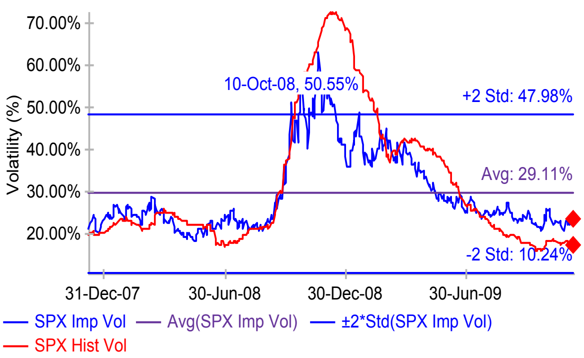
Derivatives Strategy

The factors behind single stock volatility

Key Points

- In this report, we show how assuming that the spread between implied and realized volatility reflects solely a "volatility risk premium", can be misleading and yield to substantial losses.
- Out of over 50 factors that could explain single stocks implied volatilities based on financial theory, only 8 (beta, long realised volatilities, earnings uncertainty, CDS, inverted market caps, sensitivity to LIBOR rates, 12-month return and dividend yield) are proved to be statistically significant. We used those factors to build a powerful linear model for single stock volatilities that exhibits an average r-squared of 76% since 2003.
- A preliminary backtest of the methodology using straddles indicates that an average P&L of 2.8 vol points could be extracted for every point of vega exposure.
- In a forthcoming piece, we will examine in details the potential vanilla option strategies designed to extract this volatility P&L efficiently.
- Volatility screens based on this new methodology will also be featured in our new morning daily, forthcoming in January 2010.

Exhibit 1: SPX 3M Implied vs Realised volatility



Source: Credit Suisse Locus

The dynamics of implied/realized vol

Implied vs realized volatility

Before we dig deeper into the factors driving implied volatilities, we think it is right to begin with a few basic definitions. The generic concepts discussed here will eventually structure the remainder of this report.

Volatility is a measure of the uncertainty of the return on an asset and has two facets: realized volatility, which is derived from historical data, and implied, which can be estimated from option quotes.

Realised volatility is related to a given tenor, that is the length of the historical period over which asset prices are observed:

$$\sigma_{i,T,N} = \sqrt{\frac{252}{N}\sum_{i=t-N}^{T} r_i^2}$$

where $\sigma_{i,T,N}$ stands for the realized volatility of stock i over the period from day T-N to T, and r_t stands for the log return of stock i on day t. In brief, realised volatility is the average squared return of a stock over a given period, annualized. Note the similarity with the standard deviation calculation, although realized volatility makes the assumption that average daily returns are 0 and does not need to be corrected for degrees of freedom (for more on this please refer to our US colleague Ed Tom's report *Volatility in Trending Markets*, dated 24 February 2009).

Implied volatility is estimated by finding the volatility that gives you the market's option price when used as an input in your pricing model. It is therefore related to a given maturity and strike level. In this report we focus on 3-month, at-the-money implied volatility, keeping other topics such as volatility skew or term structure for a separate report.

Whereas realized volatility is in essence a backward-looking measure, implied volatility on the contrary is a forward-looking measure: what the options market expects the volatility to be in the future. As shown on Exhibit 1, implied and realized volatility, although highly correlated, may sometimes differ widely. In early January 2009, the spread between 3-month implied and realized volatility on the SPX index reached an extreme of -33 volatility points, as the market was pricing in that the worst of the crisis was behind us. Today, the spread is now close to its highest since June 2008 as the still vivid memory of the 2008 market crash leads to higher market price of volatility, even though realized volatility has now receded to below 20%.

The Implied vs realized vol "mispricing"

How well does implied volatility predict future realized volatility? Looking at the average spread between 3-month implied and the following 3-month realized volatility since 2002 (Exhibit 2), we see that implied volatilities tend to overestimate future realized volatility by 1.9 vol points on indices, and 0.7 vol points only on single stocks.

Exhibit 2: Average index and stock 3M vols since '02

	3M Implied	Future 3M Realised	Spread
Equity Index	22.5	20.6	1.9
Single stock	31.9	31.4	0.7

Source: Credit Suisse Derivatives Strategy

Implied volatility can be thought of in insurance terms. Because demand for put options is partially driven from long-only institutions looking to insure their Equity holdings against the risk of Equity underperformance, implied volatilities are likely to incorporate a risk premium, as typical insurance contracts do. Volatility buyers would be ready to pay an extra premium for the purpose of their risk aversion, meaning that systematically selling implied volatility in the long run could yield positive P&L.

However, looking at the performance from systematically selling 3-month volatility going short delta-hedged straddles on Equity indices (Exhibit 3) and single stocks (Exhibit 4), we see that the cumulative performance generated from the "mispricing" of implied volatility versus future realized can easily be wiped out and beyond in very little time, making systematic short strategies more of a carry trade than an "arbitrage". Second, it undermines the theory that there may be a "volatility" risk premium that would tend to reward providers of portfolio insurance over the long term.

Exhibit 3: Cum. perf. of selling index 3M delta-hedged straddles

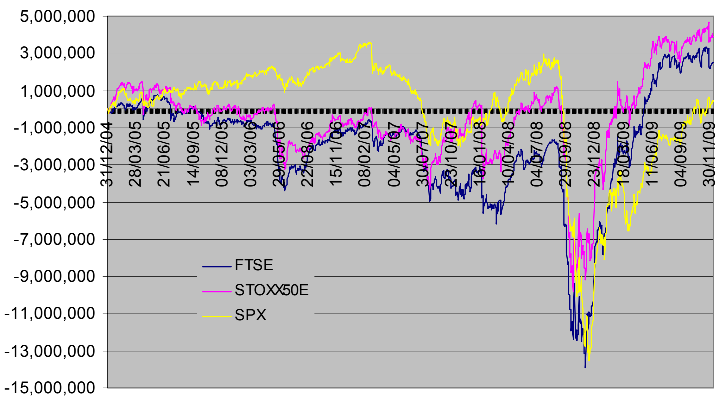
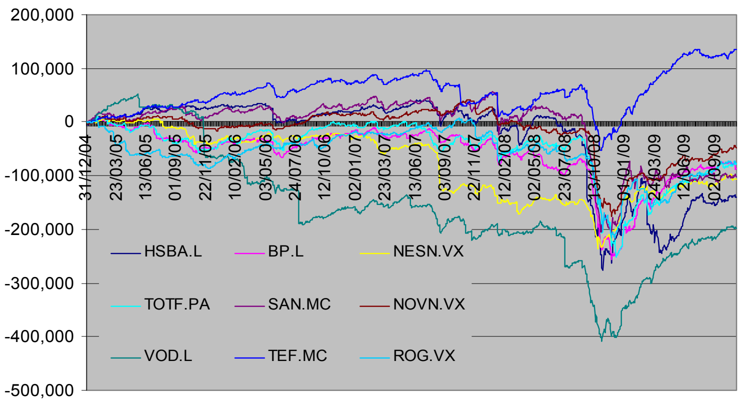


Exhibit 4: Same - single stocks



Source: Credit Suisse Derivatives Strategy

Visible and not-so-visible risks

The belief that past realized volatility captures all of an index or single stock risk, or assuming that the spread between implied and realized volatility reflects solely a "volatility risk premium", can be misleading. What if a given risk with a low probability hasn't realised over the observation period? Credit risk is a typical example.

We actually believe that implied volatility incorporates all of the following risks:

1. Visible risks: factors with a high probability of occurrence, which are reflected in day-to-day price moves, such as beta or valuation ratios. These factors are the reason why most of the time future realized volatility tends to be in-line with past realized volatility.
2. Invisible risks: factors with a low probability of occurrence and can be quantified – but don't show up in past realized volatilities. These are mainly digital risks with unknown timing such as credit, or other one-off events with a binary outcome. These mostly apply to single stocks.
3. The "unknown unknowns": factors that are completely out of sight and unquantifiable – would the 2008 market crash fall into that category?
4. Then, maybe, a risk premium

In a strategy based purely on the spread between implied and realised volatilities, an investor is likely to cash in on the spread between implied volatility and factors that fall in category 1, and potentially the risk premium. However, when factors in categories 2 and 3 broke loose in summer 2002, May 2006 and spectacularly in September 2008 the strategy suffered sudden and large losses. In the remainder of this report we therefore try to identify a large set of factors that statistically are proven to drive single stock volatility in order to capture as much of category 1 and 2 as possible. In a second report forthcoming early next year, we will also show how to build a successful arbitrage strategy based on calculated statistical signals.

Factor selection process

Equity factors

According to the dividend discount model, a company's share price should equate the sum of Equity dividends, discounted at the risk free rate rf plus a specific risk premium RP:

$$Share\Pr ice = \sum_{i=1}^{N} \frac{Dividend_i}{\left(1 + r_f + RP\right)^i} + \frac{Dividend_N}{r_f + RP - LTDivGrowth}$$

The notion of a risk premium is intrinsically linked to company risk and Equity volatility. Dividend discount models therefore generate a rich universe of potential factors to look at including (but not limited to) dividend yield, earnings yield, earnings forecasts risk, dividend growth and its constituents, dividend payout and Return on Equity.

Exhibit 5: Single Stock 3M implied vol vs Div Yield (Dec 2009)

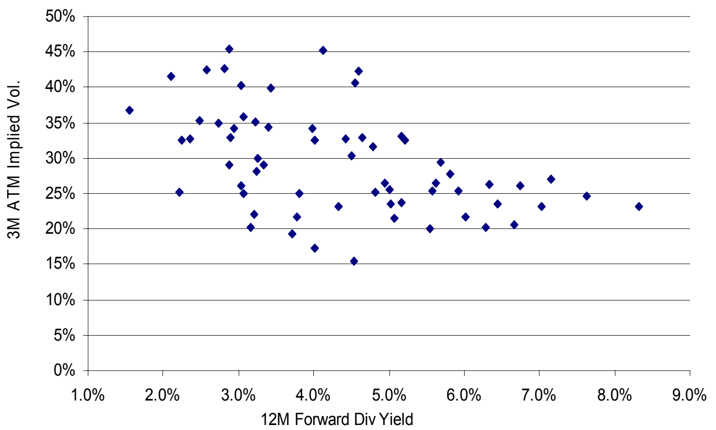
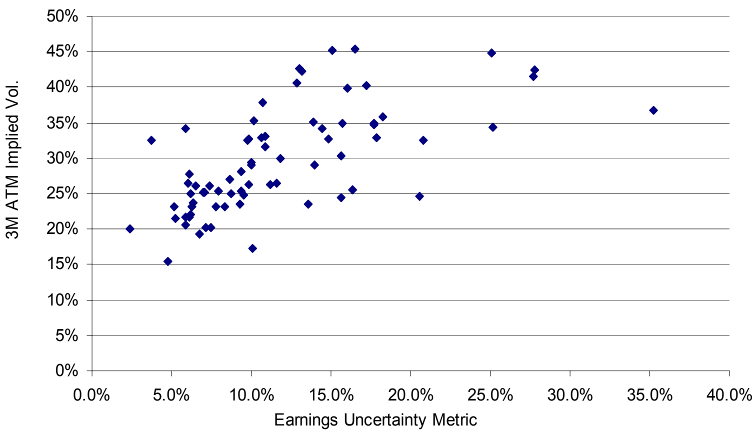
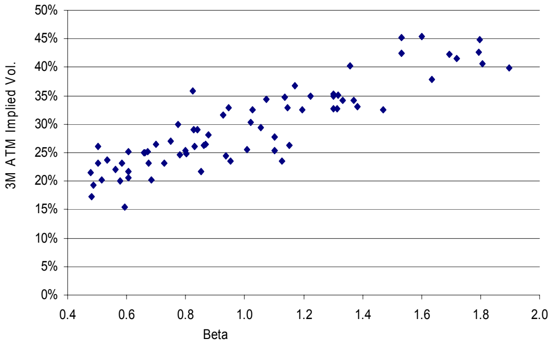


Exhibit 6: Same – vs St Dev of Earnings Forecasts



Source: Bloomberg, IBES, Credit Suisse Derivatives Strategy

Exhibit 7: Stock 3M Implied vol vs Beta



Source: Credit Suisse Derivatives Strategy

The popular Capital Asset Pricing Model may provide another indicator, a stock's beta. According to the CAPM, equity performance is determined by 2 drivers: market systematic risk, which disseminates through a stock's beta, and idiosyncratic risk, which can be diversified away in large portfolios:

$$Stock.return = Alpha + Beta * \left(Index.return - r_f\right) + residuals$$

Which leads to (assuming that residuals are uncorrelated to index returns):

$$\sigma_i = \sqrt{Beta^2 * \sigma_{index}^2 + \sigma_{residuals}^2}$$

A stock's beta is usually calculated by linearly regressing a stock's returns versus a reference index:

$$Beta_i = \frac{Co\,\mathrm{var}(stock.return, index.return)}{\sigma_{stock}\sigma_{index}}$$

Last, factorial models such as Fama and French, which relate equity returns to a number of other factors such as market cap or momentum, suggest that other Equity factors can also be used:

Exhibit 8: Single Stock 3M implied vol vs Market Cap

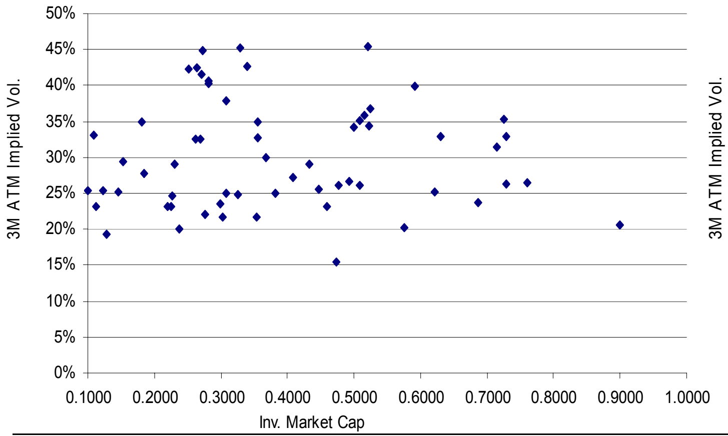
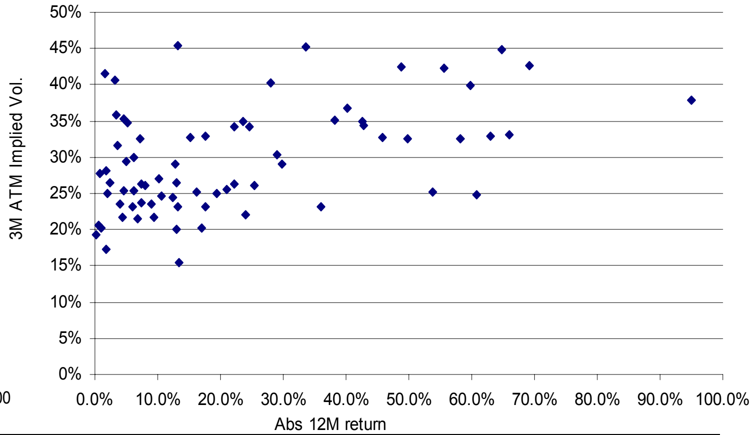


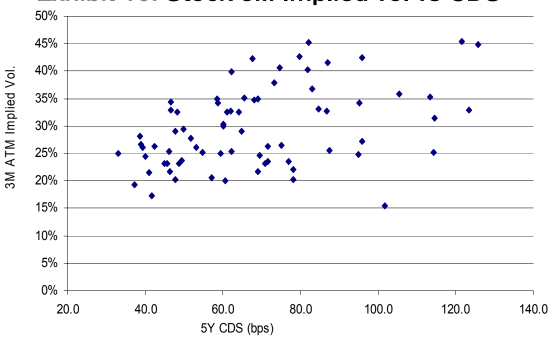
Exhibit 9: Same – vs 1Y absolute return



Source: Bloomberg, Datastream, Credit Suisse Derivatives Strategy

Credit factors

Exhibit 10: Stock 3M Implied vol vs CDS



Source: Credit Suisse Derivatives Strategy

According to Merton's famous capital structure model, a company's value can be simplified as the sum of its debt and equity market capitalization:

Company Value = Debt + Equity Market Cap

At "maturity", which is undetermined in practice, the value of the company's equity is what is left after liquidating assets and paying out debt:

Liquidating Equity Value = Max(Company Value – Debt, 0)

The Equity of a company can therefore be modeled as a call option written on the company's assets, with a strike equal to the face value of the debt – meaning that Equity volatility is linked to the value and volatility of its debt, therefore the probability of default and the estimated recovery rate of debtors. This leads to a number of credit factors to investigate: debt and interest cover ratios. Most of this information is actually summarized in the value of a company's Credit Default Swap, an instrument designed to insure its holder against losses deriving from a company's "Credit Event" (which includes, but is not limited to default).

Market factors

Last, market dynamics may have an impact on a stock's implied volatility. If the underlying is not liquid, a large position in a single stock option may be difficult to hedge in delta, resulting in a higher or lower implied volatility being charged by the option seller. Factors could include daily turnover or option open interest.

This is particularly true of options with short maturities: during expiration week, options with strikes that have a large build-up of open interest around the spot price (near-the-money) can sometimes affect the behavior of underlying stocks. When call open interest for a near-the-money option is high and market makers have a significant long position, the underlying stock price tends to gravitate towards that strike level (stock pin) because of trading desks hedging (long gamma). By contrast, when open interest is high but market makers have a significant short position, the stock price tends to accelerate away from that strike (slippery strike). An option trader would typically buy volatility at a lower price in the former case, and sell it at a higher price in the latter.

A potential way to spot long or short volatility positions amongst market makers is to look at the imbalance between put and call open interests. A high open interest for put options may indicate a strong demand for put protection and higher premium for volatility as market makers are likely to be short. Conversely a high open interest for call options may indicate a strong flow of overwriters, making market makers long volatility. Factors that could signal position overhangs include put call open interests, volatility skews or volatility term structures. A high put/call open interest ratio, a high volatility skew, or an inverted term structure would all imply that the market is a buyer of short term volatility.

Cross sectional analysis and factor selection

The interesting thing when working with single stocks is that at any point in time you can screen through dozens of observations, allowing you to capture the immediate pricing dynamics by doing a cross-sectional analysis without sacrificing statistical significance. This is not the case with Equity indices for instance, where you have to choose the lesser of two evils: either do a cross-sectional analysis on a handful of indices with no statistical significance, or do a time series analysis and incorporate pricing environments that may have absolutely nothing in common with current market dynamics. How could you compare 2005's great moderation with the high-vol environment of late 2008?

Every month since Nov 2002, we did a cross-sectional correlation analysis of single-stock 3-month implied volatilities versus a set of no less than 51 different factors based on the above analysis. For each factor in the list we calculated a statistical measure of relevancy, the t-statistic, for every month in our history. The t-statistic indicates the sign of the correlation between implied volatilities and the factor, together with relevancy: a t-stat of over 1.96 would indicate that implied volatility is linearly related to this factor with 95% probability. For the best factors, we show on Exhibit 11 the mean, minimum and maximum t-statistic, together with the percentage of months where the factor was statistically significant.

Exhibit 11: **Top factor correlations with single-stock 3-month implied vols**

	Mean t-Stat	Median	STDev	Min	Max	Pct Signif 90%	Pct Signif 95%
Beta	**9.23**	**8.52**	**4.02**	**3.39**	**22.49**	**100%**	**100%**
Long Realised Vol	**5.77**	**5.43**	**3.56**	**0.12**	**18.63**	**85%**	**90%**
Short Realised Vol	2.91	2.68	2.23	-1.73	13.12	65%	69%
Earnings Uncertainty	**3.82**	**3.23**	**3.89**	**-3.18**	**19.89**	**70%**	**76%**
CDS	**2.77**	**2.48**	**1.94**	**-1.15**	**9.46**	**62%**	**71%**
Inv. Market Cap	**2.18**	**1.78**	**1.69**	**-0.76**	**7.52**	**48%**	**55%**
Sens. to LIBOR	**5.63**	**4.62**	**3.75**	**-0.9**	**14.3**	**85%**	**86%**
12Mth Return	**4.08**	**2.95**	**4.57**	**-2.76**	**15.44**	**56%**	**57%**
1Mth Return	2.23	1.75	2.98	-2.78	11.36	48%	50%
Dividend Yield	**-2.34**	**-2.94**	**2.55**	**-7.33**	**5.88**	**68%**	**70%**
Book to Price	2.19	2.32	1.04	-0.58	4.99	60%	68%
Margin	-2.09	-2.05	1.18	-4.85	1.98	52%	60%
ROE	-2.56	-2.5	1.77	-6.91	0.76	64%	68%
Turnover	2.47	2.4	1.98	-2.58	9.27	57%	68%

We select factors which exhibit a strong, stable relationship with implied volatilities over time. Typically those would show a very high or very low mean t-stat, with a strong proportion of months where it is significant at a 90% or 95% confidence. Results show that amongst all factors we tested, only a dozen would meet our constraints. Turnover for instance, exhibits an unstable t-stat, with a minimum of -2.58 for a maximum of 9.27. 1-month return is statistically significant less than half the months since 2002.

Last, when two factors were highly correlated between themselves, such as short realized vol with long realized vol, or book-to-price, margin and ROE with dividend yield, we selected only the best factor based on mean t-stat. All factors that were eventually selected are bolded out on Exhibit 11: beta, long realised volatilities, earnings uncertainty (based on standard deviation of analysts' estimates), CDS, the inverse of market caps, sensitivity to LIBOR rates, 12-month return and dividend yield.

A successful linear model for single stock volatilities

Dynamic universe of European stocks

Every month since January 2003, we dynamically selected the constituents of the FTSE Eurotop 100 index in order to avoid the bias associated with the selection of an ex-post static universe, which would ignore any corporate action such as M&A activity, corporate issuance, or even bankruptcy, and would therefore artificially inflate the performance of the model.

The FTSE Eurotop 100 index consists of the largest 100 free-float market caps in Europe based on FTSE calculations, and gives us a universe of stocks with a large selection of countries, currencies and sectors, with a liquid option market. The total size of our universe varies between 100 and 104 stocks (more than one share class may be included in the index), for which we calculate all factors shown in bold on Exhibit 11. Implied volatilities are based on Credit Suisse own marks or, when unavailable, on Bloomberg.

Stocks with missing data are excluded from the later computations. Over the last few years this typically led to a universe of around 80 stocks. However prior to 2005, fewer IBES or CDS data led to a reduced universe of sometimes around 50 stocks in the analysis.

The cross-sectional regression

Every month we perform a cross-sectional regression of single stock volatilities in our universe of stocks numbered 1 to N, versus our selected factors numbered 1 to P, as follows:

$$\begin{pmatrix} IVol_1 \\ IVol_2 \\ \ldots \\ IVol_N \end{pmatrix} = \alpha + \beta_1 \begin{pmatrix} Factor_{1,1} \\ Factor_{1,2} \\ \ldots \\ Factor_{1,N} \end{pmatrix} + \ldots + \beta_P \begin{pmatrix} Factor_{P,1} \\ Factor_{P,2} \\ \ldots \\ Factor_{P,N} \end{pmatrix} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \ldots \\ \varepsilon_N \end{pmatrix}$$

We apply particular care to the issue of multicolinearity. Multicolinearity (a common source of error in linear regressions) describes a situation when some of the explanatory variables are highly correlated, which is a serious numerical issue. Multicolinear models tend to exhibit good performance statistics overall but this is only misleading because the calculated coefficients are unstable and unusable in practice.

We deal with multicolinearity in two ways:

- From our factor selection stage, we chose to ignore factors highly correlated with another similar factor with higher explanatory power
- Before calculating the linear regression itself, we depolluted all factors from the influence of beta, which we use as a proxy for market-induced baseline risk

Every month we performed two statistical tests for multicolinearity: Variance Inflection Factor and Klein. Both tests were negative on every month in our historical sample.

Linear model performance

As shown on Exhibit 12 the performance of the model is impressive for a financial series with an average r-squared of 76%.

In order to check for the actual relevancy of all factors in our selection we also performed a "stepwise" regression – using a variable selection algorithm, we select the subset of factors in our selection that provides the best trade-off between r-squared and number of variables (this is measured with the Akaike Information Criterion).

Results show that on average about 4 factors would be enough to replicate the results from the full model, the most frequently selected ones being realized volatility and beta. However all factors were deemed as significant one month or another, which is why we ultimately believe that the best fit in the long run will be obtained with the full selection. This is confirmed by backtest results. This also sustains our claim that using only realized volatility or beta, as explained in the first part of the report, gives a misleading picture of volatility richness/cheapness.

Exhibit 12: Volatility model r-squared statistic

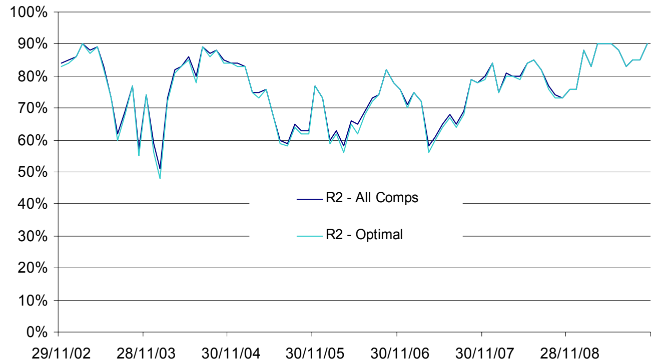
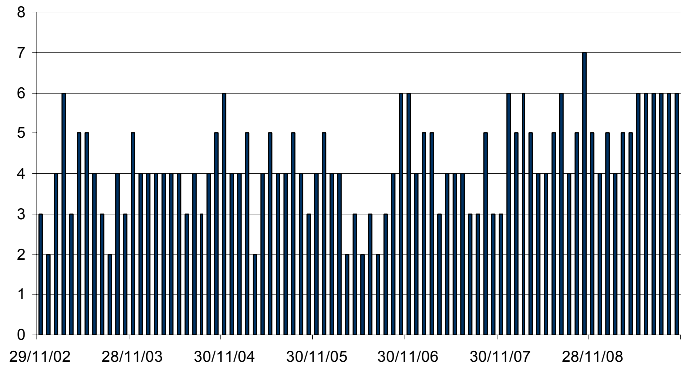


Exhibit 13: Optimal number of factors from stepwise regression



Source: Credit Suisse Derivatives Strategy

The backtest

Every month we calculate theoretical volatilities for single stocks in our universe based on the previous linear model. Stocks are then ranked based on the difference between actual and theoretical implied volatilities.

We created 10 portfolios from lowest spreads (long volatility candidates with actual implied vol lower than theoretical) to highest (short volatility candidates). We then compared the average implied volatilities for all portfolios to the realized volatility in the three following months. The average spread for each dynamic portfolio is shown on Exhibit 14.

On average subsequent realized volatility tends to exceed implied volatility by over 3.5 vol points for our dynamic long portfolio (portfolio 1), where as for our short portfolio (portfolio 10), realized volatility tends to be below implied by a little over 3 volatility points. As shown on Exhibit 15, this volatility P&L is not a reward for greater risk taken as all portfolios exhibit more or less the same level of risk. Figures include a 1.5 vol point bid ask spread on implied volatilities.

Exhibit 14: Subportfolio performance (long vol in vol pts)

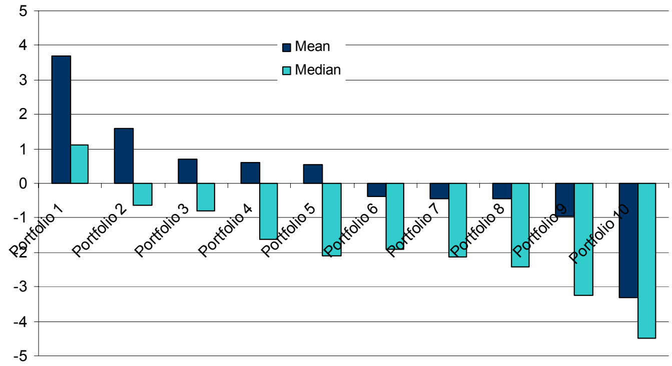
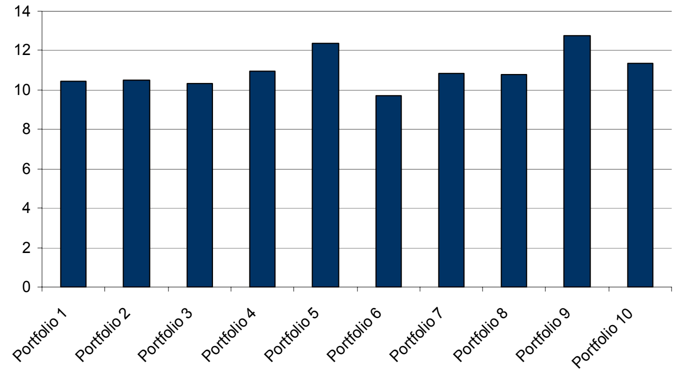


Exhibit 15: Stdev of portfolios' performance (in vol pts)



Source: Credit Suisse Derivatives Strategy

The natural strategy is to go long portfolio 1 versus going short portfolio 10. We compared the results from this strategy to two "naïve" strategies: the first one ("naïve realized") where stocks are ranked based on the spread between implied and 10-day realized volatility, a metric commonly used by option traders. The second one ("naïve implied") is a naïve carry strategies which goes long the lowest implied volatilities and short the highest.

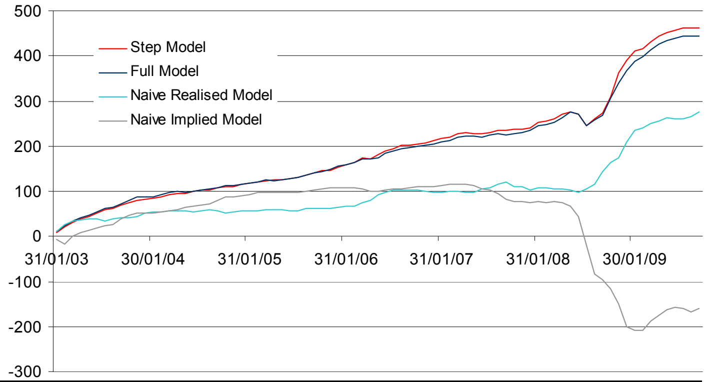
We show on Exhibits 16 some performance statistics for every monthly selection, while Exhibit 17 shows a hypothetical cumulative performance in vol points. A systematic 1.5 vol point bid ask spread is applied. The so-called Step Model is the linear model achieved after stepwise regression and shows marginally inferior results compared to our full model. The naïve realized and implied volatilities are clearly dominated. Also note how the naive implied strategy (a typical carry trade) plunges in September/October 2008.

Overall, those results suggest that by applying our linear model systematically the potential P&L could be of up to 2.9 vol points per point of volatility exposure with 90% of trades closed at a profit. However this would assume that you can receive perfect volatility exposure at no further cost than the volatility bid-ask spread – which is highly unlikely. As of today you will instead have to build elaborate, delta hedged option portfolios such as straddles or strangles to extract the volatility P&L – usually giving you imperfect exposure and additional friction costs due to the trading of the options' delta.

Exhibit 16: Performance of Credit Suisse vs "naïve" models

	Step Model	Full Model	Naive Realised Model	Naive Implied Model
Mean	5.65	5.39	3.3	-1.92
Median	4.13	3.42	1.75	0.72
Stdev	8.77	7.74	7.11	13.72
Min	-26.32	-25.68	-9.12	-64.27
Max	52.65	38.25	36.04	19.97
% Pos	90	87.5	65	61.25

Exhibit 17: Hypothetical cumulative performance (vol pts)



Source: Credit Suisse Derivatives Strategy

Further developments

Volatility Statistical Arbitrage

We believe that the preceding results show that it is possible to design a statistical model that can calculate and predict implied volatilities better than simple realized volatility models. Such a model would allow investors to calculate an implied volatility for non-exchange-traded options or options with low liquidity, on top of designing "arbitrage" long short volatility strategies.

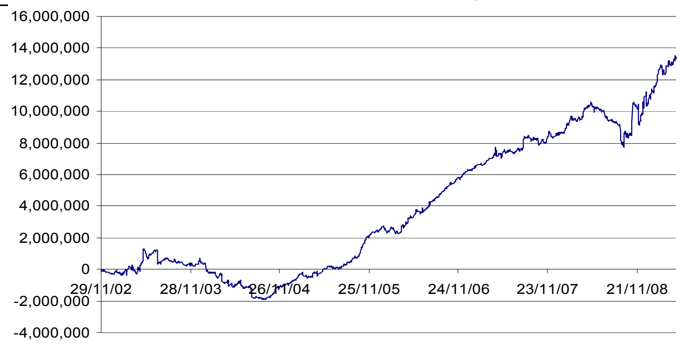
However, implementation is difficult in an environment where variance swaps, the purest volatility trading vehicles, are now scarcely traded. Vanilla strategies such as straddles do not provide a perfect volatility exposure. First, they need to be hedged in delta regularly, which may create additional friction costs. Second, straddles and strangles need to be re-balanced when the stock has significantly diverged from strike or when the option is nearing expiry because the options' sensitivity to stock movements can quickly fade. However, even if options are not rebalanced, results shown in Exhibits 18 and 19 show that a successful strategy can be implemented (backtest of the previous stock selection strategy using delta-hedged straddles for a total 100k vega exposure). Poor results prior to May 2005 when compared to theoretical P&L on exhibit 17 show the difficulty of capturing volatility mispricings through vanilla options (in particular when lack of data restricts our available universe, as was the case prior to May 2005).

A detailed report in January 2010 will examine how to extract the above volatility P&L more efficiently using vanilla options.

Exhibit 18: Straddle strategy performance statistics

Monthly PNL	Mean	Median	STDev	Min	Max
All	173,922	133,676	417,011	-695,108	1,306,210
Since May 2005	294,936	292,295	446,883	-695,108	1,306,210

Exhibit 19: Cumulative P&L for 100kvega exposure



Source: Credit Suisse Derivatives Strategy

Exhibit 20: Stock 3M Implied vol vs CDS

RIC	3M ATM Implied Vol	Model Volatility	Likely Mispricing Factor	Rich/Cheap
IMT.L	15.38	23.26	CDS	Cheap
ENEI.MI	23.61	28.39	CDS	Cheap
NG.L	20.19	24.03	CDS	Cheap
NOVN.VX	17.23	20.08	Earnings Risk	Cheap
IBE.MC	23.46	26.93	Beta	Cheap
SSE.L	20.62	23.55	CDS	Cheap
PRU.L	39.94	45.49	Beta	Cheap
ROG.VX	19.36	22.02	Earnings Risk	Cheap
REP.MC	25.56	28.08	CDS	Cheap
NDA.ST	34.91	38.32	Realised Vol	Cheap
SGEF.PA	34.22	31.37	Realised Vol	Rich
SGOB.PA	45.35	41.57	Earnings Risk	Rich
FTE.PA	23.1	21.11	Beta	Rich
BAYGn.DE	29.11	26.46	Beta	Rich
CARR.PA	29.13	26.2	Beta	Rich
UNc.AS	24.97	22.45	Beta	Rich
LVMH.PA	32.45	28.61	Earnings Risk	Rich
CAGR.PA	45.28	39.22	Earnings Risk	Rich
ERICb.ST	35.78	30.95	Beta	Rich
KPN.AS	26.11	21.42	Beta	Rich

Source: Credit Suisse Derivatives Strategy

Volatility signals in Credit Suisse's Equity Trading Daily

From January 2010 we will revamp our Equity Trading daily and feature our top ten long and top ten short volatility candidates based on the methodology discussed in this report. On top of calculating volatility signals, we will also provide an explanation as to why a given volatility appears rich or cheap based on the contribution of factors in the model.

As of last update (see Exhibit 20), the linear model exhibits an r-squared of almost 91%, with the most important factors to look at being beta, realized volatility, earnings risk and CDS.

Credit Suisse Derivatives Strategy

Europe

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