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These reports related to the Market Impact of Derivatives Hedging, originally published as of the date stamp on each of them, are now presented as a single report within the Investment Strategies series of publications under number 79.

North America Equity Research
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Market Impact of Derivatives Hedging

How Index Options and Variance Swap Hedging Impact the Market Near the End of a Trading Day

INVESTMENT STRATEGIES: No. 79

Summary

- Index options are one of the most actively used instruments to manage equity exposure. Option market makers offset their market exposure by trading the underlying index. In a high volatility environment these hedging transactions can have an impact on the market itself. Hedgers of short option positions usually transact at the market close – they sell more equity index as the market drops and acquire additional long exposure as the market rallies.

- On average, hedgers of derivatives positions are short index puts. This is essentially due to the fact that most directional investors buy puts for portfolio protection. Many investors also sold variance swaps to dealers which resulted in additional short options positions for market makers. By estimating the risk exposure of outstanding derivatives, and combining it with a transaction cost model, one can estimate the theoretical market impact of the derivatives hedging activity on the S&P 500 index.

- Intraday data analysis reveals the anticipated market inefficiency related to end-of-day derivatives hedging. As the hedging impact increases with market volatility, the inefficiency has been particularly pronounced over the course of this year. The derivatives hedging market impact can be observed in both the S&P 500 and Euro Stoxx50 indices.

- A systematic trading strategy can be designed to provide liquidity in anticipation of hedging flows. Because of the high turnover, the strategy can be implemented by investors with very low or no transaction costs. It can also be implemented opportunistically during periods of high volatility to reduce the transaction costs of trading futures, or hedging index options. This year, such a strategy implemented with the S&P 500 index would have performed well as volatile conditions reduced market efficiency.

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See page 11 for analyst certification and important disclosures.

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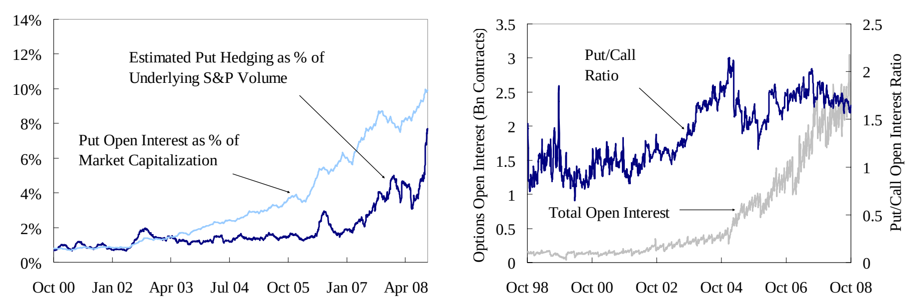
Hedging Index Options

Index options are one of the most actively used tools to manage equity exposure. The amount of exposure controlled by S&P 500 index options is currently $1.5T or about 15% of the total market capitalization. Since the beginning of the decade, the number of S&P 500 options contracts outstanding (open interest) has increased 20-fold. To hedge their options exposure, market makers trade the underlying index, usually at the close of every trading day. As options open interest increased, volumes of hedging-related index trades increased as well. Figure 1 (below, at left) shows the open interest of index put options as a percentage of the S&P 500 market capitalization, as well as the estimated fraction of total S&P 500 index volume (including cash, futures, and ETFs) traded by option hedgers[1]. During volatile market conditions, derivatives hedgers need to trade a larger dollar amount of the underlying index, and our estimates indicate that close to 5% of the index volume is currently traded by derivatives hedgers, largely in the final hour of a trading session. Over the past five years, there were on average 70% more put options outstanding than call options outstanding. Over that time period, the ratio of put to call open interest was in the 1.5-2 range, and is currently at 1.65 (Figure 2). There are also significantly more out-of-the-money put options outstanding than there are out-of-the-money call options outstanding. The put-call imbalance is largely a result of directional users of options buying puts for portfolio protection and market makers selling these puts and hedging their exposure. [2]

Fig. 1 (Left): Put Open Interest (as % of Market Capitalization); Estimated Percentage of S&P 500 Volume Traded by Option Hedgers
Fig. 2 (Right): Total Put and Call Open Interest (billions of contracts); Put to Call Open Interest Ratio



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

The growth of the variance swap market has contributed to an increased number of far out-of-the-money puts that are used to replicate and hedge these instruments. Market makers who are long variance swaps may acquire additional short put positions throughout the hedging process.[3]

The structural imbalance between the number of put and call contracts outstanding has caused the options hedging community to be on average short put options. These options

[1] We estimate the percentage hedging volume by calculating the total options gamma, then multiplying it by the daily percentage move, and dividing it by the volume of S&P 500 futures, cash and ETFs. An adjustment factor is included to account for un-hedged options. The charts show the 50-day moving averages. For more details, please see subsequent sections.

[2] We will analyze the put-call imbalance in much greater detail in the following section.

[3] However, part of the gamma exposure from fixed-strike puts can be offset with the gamma of long variance positions. This risk-netting would enable a broker to manage a larger position in fixed-strike puts.

are then hedged by trading the underlying index. In the following paragraph we explain in simple terms the way hedging a short put option position increases the volatility of the underlying index. Readers who are familiar with options hedging may skip this paragraph and go to the next section in which we analyze the effects of derivatives hedging in greater detail.

Investors typically buy put options as protection for downside market moves. Market makers frequently take the other side of the trade and are therefore short put options. However, market makers do not want to take any directional view on the underlying index and will look to hedge out the market risk from their short put positions. For example, the value of an at-the-money put option typically will increase by approximately 50c for every $1 drop in the index (or decrease by 50c for every $1 increase in the index). Therefore, to offset the initial market exposure of a short put position, a hedger would need to sell 50c of the market for every $1 short at-the-money put exposure (this is called hedging the initial option 'delta'[4], and in this case the delta of an at-the-money put would be 50%). If the market suddenly drops, the put option would become in-the-money, and its value would then behave similarly to a short index position. For example, an in-the-money put option may increase in value by 80c for every $1 drop in the index (this put is said to have an 80% 'delta'). In order to be market neutral, a hedger of a short put position would now need to be short 80c worth of index to hedge a short $1'in-the-money' put exposure (the position delta has increased from 50% to 80%). To adjust the 'delta' hedge, the market marker would need to sell an incremental 30c of index for every $1 short put exposure. When adjusting the 'delta' hedge (the amount of index needed to be short for every put sold), a hedger would need to sell additional index as the index drops and could potentially amplify the down market move. A similar amplification may happen on an up move. For instance, following a down move that caused the put price to change 80c for every $1 move in index (80% 'delta' put) we could have a move up to the initial market level. This would cause the put to return to a 50% delta (at-the-money). Now, the correct hedge ratio (delta) would be 50c of short index position for every $1 of short put exposure, and the market maker would need to buy back 30c worth of index (delta has dropped from 80% to 50%). A market maker would therefore need to buy the index as the index rallies which could amplify an upside move as well[5]. Hedgers of options usually adjust their market hedges (deltas) once a day, near the market close based on the market move for that day (for instance, hedgers would adjust their delta in the last 10-30 minutes of a trading day to reflect the market move since their hedge adjustment on the prior day). As a result, these hedging flows can impact the behavior of the market near the close by amplifying market moves that occurred during the day.

Estimated Put Options and Variance Exposure and the Market Impact of Gamma Hedging

In order to estimate the aggregated market impact of S&P 500 derivatives hedging, we need to estimate the total risk exposure of hedgers, i.e. the total gamma of hedgers. The total gamma is the dollar value of the index that needs to be traded (to adjust all delta hedges) following a 1% move in the market. By knowing the approximate value of the

4 Delta represents the change in the derivative value for every $1 change in the underlying index level.
5 The same is true for hedging of a short call option position.

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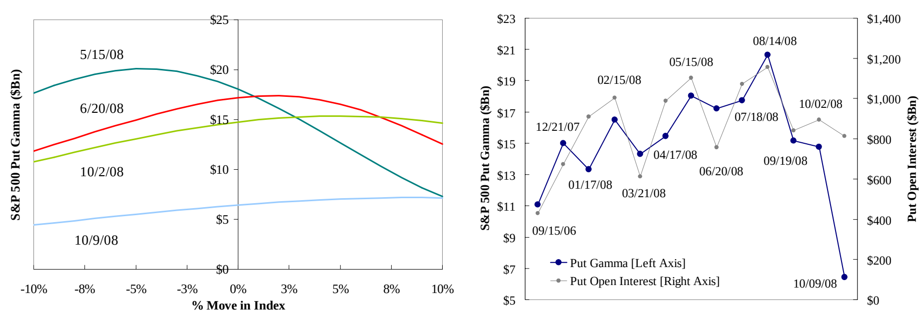
total gamma of hedgers, we could then estimate the market impact of hedging transactions. As there is no data available for the exact positioning and hedging techniques of market makers, we use both qualitative evidence as well as a quantitative analysis to estimate the total gamma and assess the market impact in the final 10-30 minutes of a trading day. Our analysis is not intended to predict the exact market impact, but to give a rough estimate and describe its qualitative features. In the next section of this report, we will then compare our market impact estimates with the observed behavior of intraday market prices.

Figure 3 (below) shows the total gamma of S&P 500 put options as a function of the index level for four different dates over the course of this year. We note that both the total size of the dollar gamma as well as the spot dependence of gamma change over time. The chart at right shows the total put gamma for 2008. The total put gamma ranged from $15Bn to $20Bn, but recently dropped to as low as $7Bn. The distribution of the put gamma by index level depends on market conditions. For instance, if the market falls below the strikes of puts with the largest open interest, the total gamma would drop and there would be more gamma risk to the upside – this is what we have witnessed over the past couple of weeks as gamma dropped from $15Bn to $7Bn without a significant drop in put open interest. Similarly, if market makers decide to reduce the risk due to market conditions (by exiting trades and reducing the amount of new trades) the overall gamma of the market would fall.

Fig. 3: Distribution of Put Option Gamma for Several Dates During 2008 (Left); Total Put Gamma and Put Open Interest Since the Beginning of 2008 (Right)



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

Most directional investors buy put options (or put spreads) as part of portfolio protection programs. Dealers who take the other side of the trade usually do not take directional views and hedge their short put positions. Based on institutional trading flows that we have observed over the past several years, we estimate that, on average, 65%-80% of index put option transactions are initiated by directional investors buying protection. The rest of the transactions may involve selling puts for yield-enhancement (underwriting), selling puts as part of put spread programs, index dispersion trades, etc. This observation would imply that about 30%-60% of the outstanding puts are bought by directional investors and are hedged in some form by market makers. Further evidence of a short puts bias of this magnitude is put-call parity. This year, there were on average 1.7 put option contracts outstanding for every call option contract outstanding. Call option flows are typically more balanced between buyers and sellers, with perhaps an even light bias

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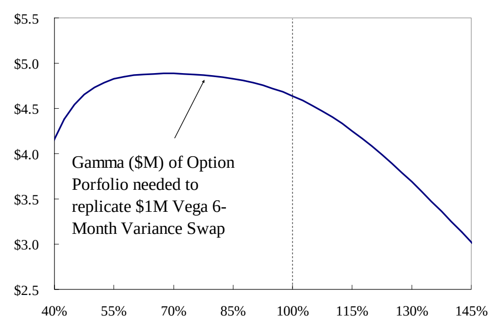
towards call selling[6]. Assuming that the excess open interest of puts over calls is caused solely by the demand for index protection, the put-call open interest ratio would imply that ~40% of the puts are bought outright and therefore need to be hedged by market makers. While there is no way to know the exact aggregated gamma risk of the hedging community (and the number changes with market conditions), we assume that the aggregated gamma that is hedged is equal to approximately ~40% of the total gamma of listed fixed-strike puts. Given that the average gamma exposure of listed fixed-strike puts was $15Bn during 2008, we believe that there was roughly $7Bn of market exposure to be sold/bought near the market close for every 1% down/up move on the day. The relationship between the dollar amount of hedging flows and the number of percentage points that the market moves is not exactly linear, as the gamma distribution tends to be lumped around certain market levels (option strikes).

Variance swaps are other derivative instruments that are often mentioned in the context of end-of-day hedging. During the declining volatility regime of 2003 to 2007, many investors sold variance swaps as part of dispersion trades or outright income-generating short variance programs. Variance swap market makers who purchase swaps from directional investors usually hedge their long swap positions by selling the replicating portfolio of puts and calls. The replicating portfolio is then delta hedged at the market close. As the variance swap payoff is calculated based on the closing levels of the cash index, it is important that a dealer hedges the replicating portfolio at the market close. The delta hedging process of a short options portfolio (to replicate/hedge a variance swap bought from a customer) will amplify the market moves as described previously.

Figure 4 (below, at left) depicts the dollar gamma of a replicating portfolio for a 6-month $1M vega variance swap. The table at right shows the dollar gamma for a replicating portfolio of $1M vega variance swaps for different maturities.

Fig. 4: Variance Swap Gamma (Left); Gamma of Swaps for Different Maturities (Right)



S&P 500 Variance		
#	Maturity	$Gamma
1	Nov 08	$43.4
2	Dec 08	$12.1
3	Jan 09	$7.6
4	Mar 09	$4.8
5	Jun 09	$3.3
6	Sep 09	$2.5
7	Dec 09	$2.3
8	Jun 10	$1.6
9	Dec 10	$1.3

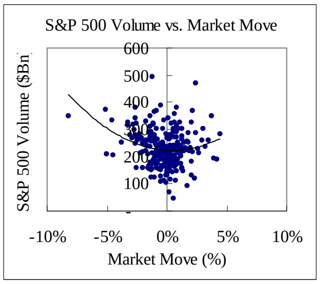
Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

As with put options, in order to estimate the impact of variance swap hedging we need to estimate both the size of the variance swap market, as well as the net bias of directional swap investors (e.g., investors being short/dealers being long and hedging via short fixed-strike puts). This will be at best approximate as variance swaps largely trade over-the-counter. We believe a rough estimate of the daily variance swap volumes over the past two years is $5-10M vega per day (this number is mostly anecdotal). Assuming that

[6] S&P 500 calls are sold as part of popular index overwriting programs (e.g., CBOE BXM overwriting index) or as part of dispersion trades. Calls are purchased to gain leveraged market exposure, or as part of short-term market direction speculation.

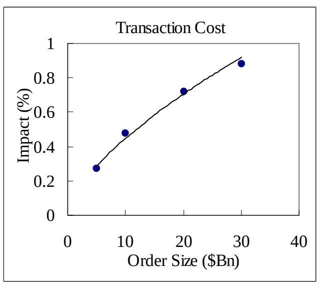
the average variance swap duration is ~6 months[7] would point to a market size of ~$1-2bn vega.[8] The directional bias of the variance swap market that needs to be replicated and hedged via listed options is more complex to estimate. Based on the observed variance swap flows, we believe that about two-thirds of the variance swaps are sold by directional investors as part of index dispersion trades (shorting implied correlation) or outright short index variance programs, and about one-third are bought to hedge equity or credit risk. This would represent a net short exposure of ~$300-$400M vega. Assuming that the average swap duration is ~6 months (a 6-month swap of $1M vega has ~$5M gamma), the total gamma of the net short variance exposure would be ~$1.5-$2Bn. In the previous paragraph we estimated that the total put option gamma is ~$7Bn. The variance swap gamma contribution is therefore a smaller part of the total gamma outstanding. In addition, dealers may offset part of the short gamma exposure of fixed-strike puts with long variance positions.[9]

Fig. 5: Volume in S&P 500 (Cash, ETFs, Futures) Is Higher During Days with Large Percentage Moves



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

Fig. 6: Modeled Market Impact (in % points) of Large Orders Executed Over the 30 Min Time Period



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

The short gamma exposure is not constant over time as it depends on the distribution of open interest and the spot price, the variance swap long/short imbalance, etc. In order to assess the market impact of the hedging activity, one needs to closely monitor the gamma-weighted open interest as well as the most recent intraday price patterns that can point to the net position of hedgers. Next we derive a theoretical estimate of the impact of gamma hedging, assuming a constant gamma exposure estimated from the combination of put open interest and variance swap imbalance estimates. Under the assumption that the average total market short gamma is ~$7Bn, we can proceed and estimate the impact on the market caused by hedging transactions. For a 1% move in the market, hedgers would need to trade ~$7Bn of the index, and for a 2% market move, they would need to trade ~$14Bn of the index, and so on[10]. Hedging transactions are assumed to occur in the last 30 minutes of the trading day, based on the move of the market from the previous day's close to 3:30PM. For a given percentage move, we calculate the size of hedging transactions. To estimate the market impact of the hedging activity, we used a proprietary transaction cost model as well as the market impact of observed S&P 500 cash transactions over the past year[11,12] (Figure 6). The modeled gamma hedging impact is shown in Figure 7 (below). Based on our assumptions stated above, the market impact of gamma hedging during the last 30 minutes of a trading day (from 3:30PM to 4:00PM) is estimated to amplify the market move from the previous day's close to 3:30PM by an additional ~15%. For instance, if the S&P 500 moves by 5%, the impact of gamma hedging is estimated to lead to an additional 75bps move in the same direction.

[7] Not accounting for the long-dated volatility market (5-10 years) that is dominated by insurance hedging activity and does not have equivalent listed options.

[8] Variance swaps were initially developed as instruments that enabled dealers to buy back their volatility exposure from traded options. As the size of the S&P 500 listed option market is ~$1.6bn vega, our volume-based estimate of the variance swap market size looks reasonable.

[9] However, variance swaps are usually hedged at the market close so their market impact per dollar gamma may be higher than with put options that can be hedged in a more flexible way.

[10] In fact, the dollar gamma changes with the spot price as outlined in Figure 3. Therefore the amount of underlying index that needs to be traded is an integral of the gamma curve over the size of the market move prior to the hedging transaction.

[11] We take into account that during highly volatile days, the average daily volume tends to be larger – see Figure 5. This would somewhat reduce the large market impact of hedging transactions.

[12] Please call us for more information on our transaction cost model.

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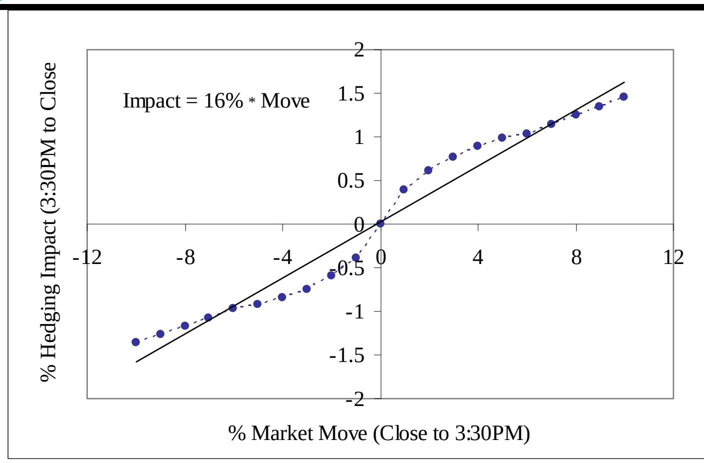
Fig. 7: Theoretical Market Impact of Gamma Hedging (3:30PM to Close) vs. Market Move from Previous Day's Close to 3:30PM



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

Observed Market Impact and Related Trading Strategies

In the previous section, we estimated the theoretical impact of gamma hedging on the S&P 500 index. The price move in the last 30 minutes of a trading day is estimated to be proportional to the move on the day (from the previous day's close to 3:30PM), and its size is expected to be ~15% of that move. Our analysis contained a number of estimates that could change over time. In this section we adopt a more practical approach and analyze intraday price data for the S&P 500 and EuroStoxx 50 indices to look for evidence of the gamma hedging impact on the level of the index. Short gamma hedgers transact near the market close, and amplify the market move that was realized from the previous day's close (actually the previous day's hedging time) to the time they trade the hedge for the current day. As we do not precisely know the time when an average hedger executes his trades, we will examine the potential market impact in three different time-intervals: from 3:30PM to close, from 3:40PM to close, and from 3:50PM to close (i.e., the last 30, 20, and 10 minutes of the trading day)[13]. The market impact of short gamma hedging would be revealed in a regression of market returns during these hedging time intervals vs. the market return for the day prior to the hedging cutoff time. To quantify the effect, we studied these intraday regressions over the past four years and found evidence of the hedging impact that is consistent with our theoretical estimates from the previous section.

Figure 8 (below) shows the S&P 500 regression charts for 2008, as well as a summary of statistics over the past four years. For 2008, the magnitude of the effect was the largest for the move from 3:30PM to market close – the average market impact was 16% of the market move prior to the hedging cutoff time (slope of the regression). The statistical significance was the highest for the 3:50PM hedging cutoff time with the correlation between the signal and the impact at 62% (t-statistic of 11). The effect is significant, and closely matches our theoretical expectations both qualitatively and quantitatively – for

[13] For the EuroStoxx 50, our cutoff times were 4:00PM, 4:10PM, and 4:20PM GMT.

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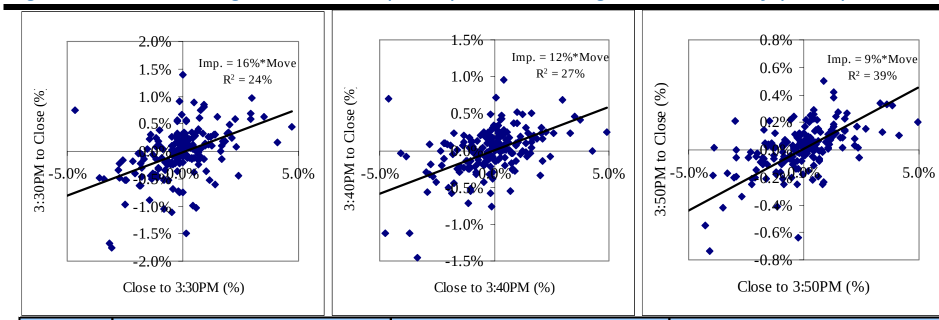
instance, during the 2007-2008 time period, the observed amplification was ~13%, while our theoretical estimate was 16% (Figure 7, above).

Fig. 8: 2008 S&P 500 Regression Charts (Above); 2005-2008 Regression Summary (Below)



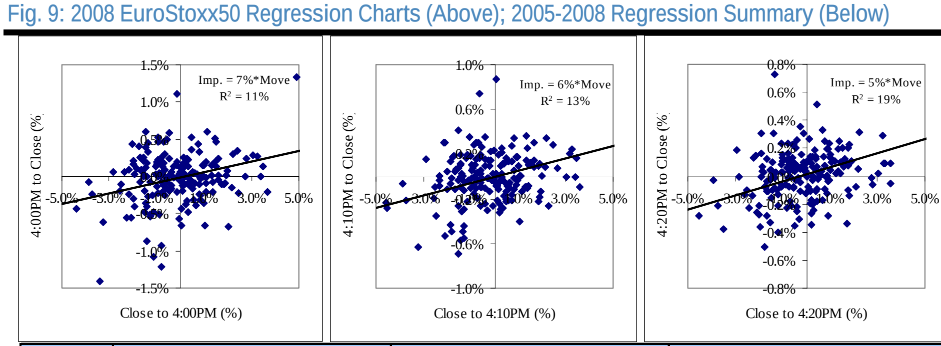
Year	Slope			Correlation			T-stat		
	3:30	3:40	3:50	3:30	3:40	3:50	3:30	3:40	3:50
2005	5%	6%	3%	16%	24%	21%	3	4	3
2006	1%	2%	1%	4%	8%	4%	1	1	1
2007	11%	7%	9%	29%	23%	44%	5	4	8
2008	16%	12%	9%	49%	52%	62%	8	8	11
All	8%	6%	5%	25%	24%	30%	6	6	8

Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

In 2006 the effect was not significant, and in 2005 it was significant but weaker than it has been in 2008. This result was expected as higher volatility causes larger market moves and leads to larger gamma hedging transactions as well as a larger market impact.

A similar effect was observed in the EuroStoxx 50 index. Figure 9 (below) shows the regressions for 2008 and the table summarizes the effect over the past four years. The hedging cutoff times were 4:00PM, 4:10PM, and 4:20PM GMT.

Fig. 9: 2008 EuroStoxx50 Regression Charts (Above); 2005-2008 Regression Summary (Below)



Year	Slope			Correlation			T-stat		
	4:00	4:10	4:20	4:00	4:10	4:20	4:00	4:10	4:20
2005	5%	4%	4%	23%	24%	29%	4	4	5
2006	8%	6%	4%	28%	31%	34%	5	5	6
2007	7%	6%	5%	29%	33%	40%	5	6	7
2008	7%	6%	5%	34%	37%	43%	5	6	7
All	7%	6%	5%	31%	34%	40%	10	11	13

Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

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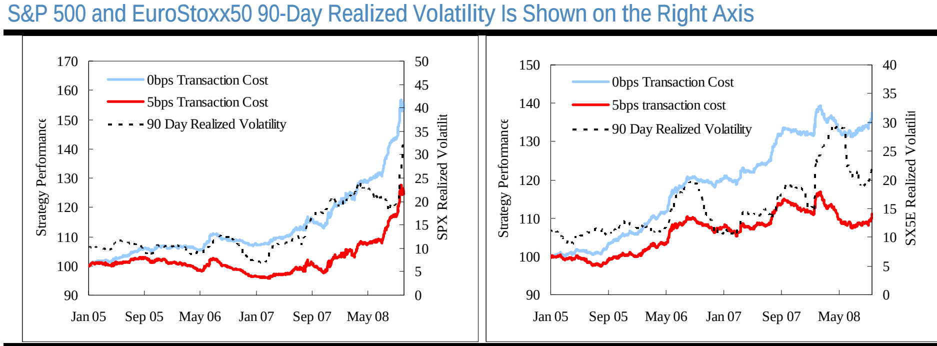
While the effect in the EuroStoxx 50 index was not as pronounced as in the S&P 500 index this year (a 7% amplification, as compared to 16% for the S&P 500), it has been more consistent over the past four years. For the 2005-2008 time period, the t-statistic (the measure of statistical significant) for the EuroStoxx 50 was ~11, or about twice as high as the t-statistic for the S&P 500. This is mainly due to the year 2006, in which we did not observe a significant impact of gamma hedging in the S&P 500 index (note that in 2006 the S&P 500 volatility was 10%, and the EuroStoxx 50 volatility was 15%, while in 2007 both indices had the same volatility of ~16%).

The observed inefficiency related to hedging flows can be used to construct a trading strategy. This strategy would call for buying the market if it is up on the day (prior to the hedging cutoff time, e.g., 3:30PM for the S&P 500 index) and selling it if it is down on the day. The position would then be exited at the market close (4:00PM for the S&P 500). By doing so, an investor is providing liquidity in anticipation of hedging flows, and can profit by absorbing the impact of hedging transactions.

Because the size of the hedging impact is proportional to the size of the market move prior to the hedging cutoff time, we expect the performance of this strategy to be positively correlated to the market realized volatility and therefore negatively correlated to the market itself. This is an interesting feature as a strategy with this property can be used to both generate alpha and diversify an equity portfolio.

The performance of such a strategy for the S&P 500 (left) and the EuroStoxx50 (right) indices since 2005 is depicted in Figure 9. We show the results for the 3:30PM-close (and 4:00PM-close for the EuroStoxx 50) trading strategy with zero transaction cost, and 5bps transaction cost, and overlay the market realized volatility. Assuming a 5bps transaction cost, the S&P 500 strategy had an information ratio of 1.3 and the EuroStoxx50 strategy had information ratio of 1. Note that in volatile market conditions, the transaction costs for an average investor would likely be higher, further reducing the information ratio.

Fig. 9: Strategy for the S&P500 (Left) and the EuroStoxx50 (Right) Since 2005; We Show the Performance with a 5bps Transaction Cost, as well as the Performance with a Zero Transaction Cost; S&P 500 and EuroStoxx50 90-Day Realized Volatility Is Shown on the Right Axis



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

The S&P 500 strategy had a positive correlation (~22%) to the daily changes in market volatility (a -6% correlation to the market, and a 73% correlation to volatility levels). The EuroStoxx50 strategy had a 37% correlation to the daily changes in market volatility (a -5% correlation to the market, and a 75% correlation to volatility levels). Due to the 100% daily turnover, the performance of the strategy is very sensitive to transaction costs. For instance, paying 10bps on each transaction since 2005 would have diminished

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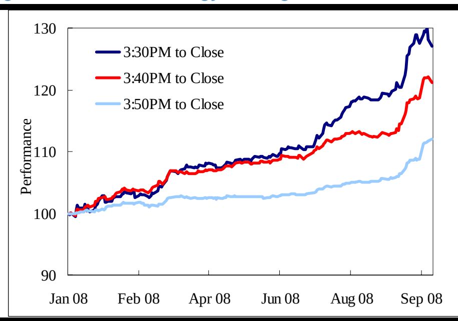
the returns to zero. Therefore the strategy is only suitable for investors with low or no transaction costs and should be implemented only in a high market volatility regime (which is usually a regime of low market efficiency). It could also be implemented opportunistically to reduce transaction costs when trading futures, or hedging index options.

Over the course of this year, the strategy performed well due to increased market friction caused by hedging flows in volatile conditions. The chart and table below (Figure 10) show the performance of the strategy implemented on the S&P 500 with the 3:30PM, 3:40PM, and 3:50PM cutoff times (a 5bps transaction cost is taken into account). With transaction costs at ~10bps, the information ratio was above 3 (e.g., at 8bps per transaction, the 3:40PM cutoff time strategy had an annualized return of 34% and an information ratio of 4.8).

Fig. 10: S&P 500 Strategy During 2008: Performance Chart (Left), Summary Statistics (Right)



T-cost	Perf.	3:30PM	3:40PM	3:50PM
4bps	Ret.	42%	32%	18%
	Risk	7%	5%	3%
	Inf. Ratio	**6.1**	**6.2**	**5.2**
8bps	Ret.	34%	24%	12%
	Risk	7%	5%	4%
	Inf. Ratio	**5.0**	**4.8**	**3.4**
12bps	Ret.	26%	17%	6%
	Risk	7%	5%	4%
	Inf. Ratio	**3.8**	**3.4**	**1.6**
16bps	Ret.	19%	11%	0%
	Risk	7%	5%	4%
	Inf. Ratio	**2.8**	**2.1**	**0.0**

Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

The main risk to the strategy is the change in transaction costs. For instance, for the 3:50PM cutoff strategy, an increase in transaction costs from 8bps to 16bps would have reduced the annualized return from 12% to zero.

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North America Equity
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05 February 2009

Price Patterns and Chaos Theory in Volatile Markets

How the Performance of Leveraged ETFs Uncovered New Investment Opportunities and Limitations of Efficient Markets

Summary

- The financial hypothesis of efficient markets states that market returns are random and can not be predicted by studying the patterns of past returns. On the other hand, proponents of technical analysis and "Chaos Theory in finance" argue that the market can exhibit trending or reverting patterns, and hence one can profit from these predictable price patterns.
- We analyze how high market volatility and price patterns of momentum and mean reversion have influenced the performance of leveraged ETFs. Last year levered ETFs were particularly hit hard, as their performance is governed by the amount of volatility and mean reversion in the market. In addition to theoretical estimates of the performance of levered ETFs, we analyze forward prices that are relevant for pricing options on these instruments.
- While market volatility and reversion patterns of daily returns may appear unrelated, there are theoretical and structural reasons that relate the two. The impact of derivatives gamma hedges that leads to intraday momentum patterns appears to have a significant effect on the reversion of daily returns. In addition, there may be behavioral effects that lead to market reversion as we find evidence of a relationship between reversion and volatility long before the introduction of derivatives in the marketplace.
- A systematic trading strategy can be designed to capture the reversal of market returns. This strategy can be implemented by investors with low transaction costs. Reversion patterns are observed both in the US and European markets and are related to gamma hedging intraday momentum patterns. In summary, our conclusion is that the current extreme volatility levels have reduced market efficiency and uncovered predictable trends of intraday price momentum and daily price reversion. Volatility and derivatives provide a link between efficient markets and price patterns of "chaos theory."
- An extensive Appendix details the math behind our results.

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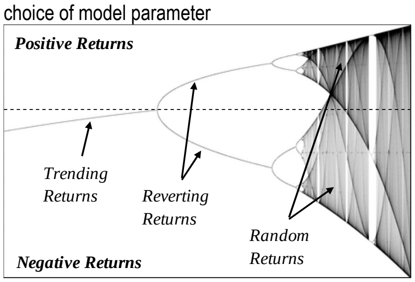
Efficient Market Hypothesis and Chaos Theory

The efficient market hypothesis (EMH) states that market returns are the result of new information coming into the marketplace and therefore past price patterns are not relevant for future performance[1]. The EMH basically invalidates the efforts of technical analysis that aim at predicting prices by solely looking at historical price patterns. In addition, the EMH implies that market returns are random. Both theoretically and empirically, the EMH holds very well. Empirically there has not been much evidence that market returns can be predicted by only studying observed price patterns. On the theoretical front, laws of statistics imply random returns – if there are a large number of independent events that drive the market, returns would be random.[2]

The existence of predictable momentum and reversion patterns of market prices would contradict the EMH and require additional models to explain them. This has led to the creation of various new and often controversial hypotheses trying to argue that market returns show persistent patterns. One of these hypotheses is "Chaos Theory" – a term borrowed from physical sciences and often misused in the context of finance. In physical sciences, Chaos Theory describes a group of systems (such as the growth of crystals, the evolution of storms, fluids in motion, etc.) that have a complex and apparently random behavior but are predictable and governed by simple principles[3]. To illustrate an example of chaos theory and how it could naively be applied to financial markets, one could model market returns by assuming they are exclusively driven by momentum and reversal investors. If one models today's returns to be proportional to yesterday's returns (momentum) and introduces a reversion term for large daily moves (reversion) – stock market returns would follow the simple chaos theory system of a "logistic map."[4] Market returns in this model are predictable but depending on the choice of the model parameter they can be trending, mean reverting, or be in a chaotic regime where returns appear completely random (see Figure 1 to the left for the distribution of returns as modeled by the logistic map). While the idea of market returns that appear random but are predictable as determined by a simple formula sounds appealing, it is in our view an oversimplification of reality and a futile effort for market practitioners.

Figure 1: A Logistic Map Is a Naïve Chaos Theory Model of Market Returns – Depending on the Model Parameters, Returns Can Be Trending, Reverting, or Exhibit Random Behavior

Vertical axis – market returns; Horizontal axis, choice of model parameter



Source: J.P. Morgan Derivatives and Delta One Strategy.

A more legitimate idea, in our view, is to apply the methods of chaos theory to financial time series in order to rigorously identify temporary trending or reverting price patterns. If a trend can be identified based on past price returns, one could then design profitable trading strategies. Systems that are described by chaos theory are usually characterized by so-called "fractional dimensions." Below we illustrate how determining the "fractional dimension" of a time series is closely related to

[1] This is the weak form of the efficient market hypothesis. It states that excess market returns can not be produced by studying past asset prices. The semi-strong form of the market efficiency hypothesis suggests that the market is instantly discounting all public information and that excess market returns can not be predicted by using any publicly available data (including price histories).
[2] This is a consequence of the central limit theorem which is the cornerstone of statistical theory. Independent events that drive the market could be economic, geopolitical news, the action of different market participants such as hedge funds, mutual funds, individual investors, etc.
[3] Their future evolution can be predicted theoretically or calculated with the help of computers.
[4] Trend is modeled by a linear term, and reversion by a quadratic term of the same strength. Market return today is solely determined by the market return yesterday by the following formula

$$r_n = \alpha \cdot r_{n-1} - \alpha \cdot r_{n-1}^2$$

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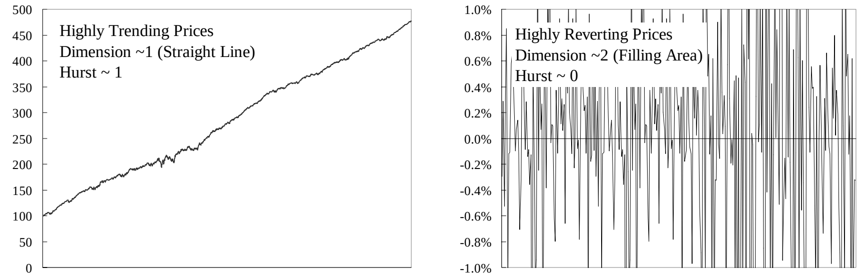
determining whether the time series is trending or reverting. A trending time series will have a "fractional dimension" close to 1 (a straight line has a dimension of one) and a highly reverting time series will have a dimension close to 2 (e.g., prices moving rapidly up and down and covering the area of the chart – hence the dimension is 2). In order to identify trending or reversion, technical analysts usually look at the "Hurst Exponent" of a price time series which is defined as 2 minus the dimension (e.g., perfectly trending series will have a dimension equal to 1 and a Hurst Exponent of 1, and perfectly reverting time series will have a dimension of 2 and a Hurst Exponent equal to 0). Completely random time series (i.e., one consistent with the efficient market hypothesis will have a dimension of 1.5 and a Hurst of 0.5 – see Figure 2 below).

Figure 2: Perfectly Trending Time Series (Dimension 1), Perfectly Reverting Time Series (Dimension 2)



Source: J.P. Morgan Derivatives and Delta One Strategy.

In this report we will show that markets are not always efficient and that in the current high volatility environment behavioral and structural effects (e.g., gamma hedging of derivatives exposure, and overreaction to insignificant news) **can lead to persistent patterns of momentum and reversion.** In that respect "Chaos Theory" plays a useful role in the process of identifying regimes of momentum and reversal. However, we believe that identifying patterns without understanding the "economics" behind the trends is not enough to formulate a sustainable trading strategy[5]. Persistent patterns tend to eventually disappear and it is critical to understand the evolution of the underlying "economics" of a pattern. Finally, we do not think that a naïve or literal implementation of chaos theory such as the one illustrated in the logistic map example can yield useful predictions for market practitioners.

Underperformance of Leveraged ETFs Caused by Market Volatility and Reversion Pattern of Returns

Levered ETFs aim to provide leveraged long or short exposure to the daily returns of equity indices. This suite of products was introduced in 2006, and there are currently more than 100 levered ETFs with ~$20 billion of assets under management in the US. In addition, there are more than 1.5 million option contracts on levered ETFs. As we will show in this section, the performance of these ETFs is determined by market volatility and predictable price patterns of momentum and reversion.

[5] By "economics" we mean for instance, supply/demand issues, behavior of dominant market participants, etc.

Levered long (short) ETFs replicate daily returns by acquiring a long (short) exposure to the underlying index, and re-adjusting that exposure every day. For instance twice-leveraged long ETF providers will borrow and invest double the notional amount in order to deliver double the market daily return. The exposure to the underlying index has to be adjusted near or at the market close every day. This will require providers (hedgers) of levered ETFs to buy more of the underlying index as the market rises, and sell more as the market drops. This hedging process of levered ETFs is explained and analyzed in detail in Appendix I. We show the number of shares that need to be traded to rebalance a levered ETF hedge for long and short levered ETFs and any type of leverage (i.e., twice, three times levered, etc.). The hedging of levered ETFs has contributed to the intraday momentum pattern in the market. Intraday momentum has caused the market to continue to trend in the last half hour of a trading day. This intraday momentum effect has largely been caused by the hedging of index options, variance swaps as constant proportion portfolio insurance programs (CPPI), and the hedging of levered ETFs which further enhanced the effect. We extensively analyzed intraday momentum patterns in our previous publication[6], and in this report we will largely focus on reversion price patterns (the underperformance of levered ETFs has been caused by market volatility as well as the reversal of daily returns).

While a leveraged ETF seeks to match daily returns and not returns over longer time periods, it is reasonable to expect that their performance will be in line with the levered index returns. For instance if the underlying index is up it would be reasonable to expect a levered long ETF to be up more, or if the market is down, one would expect a levered short ETF to be up. However, levered ETFs have surprised and often stunned investors with the rapid deterioration of their performance over longer time periods. For instance, over the course of last year, a double short Dow Jones US Real Estate ETF was down 50% at a point in time while the index was down 42%. A double short FTSE China 25 ETF was down 56% while the underlying index was down 34%.

In order to understand the drivers of such large underperformance, we investigate how the performance of a levered ETF depends on volatility and market price patterns. We start by illustrating how the return of levered ETFs starts diverging from the levered total return over a 2-day time period (Figure 3, below). As this divergence is more pronounced for large daily returns, we consider two consecutive 10% moves. First, we assume that the market moves up 10%, followed by a 10% down move. Starting at $100, the market would perform as follows: $100 – $110 – $99. On the other hand, a 2x-levered ETF would move as follows: $100 – $120 – $96. We find that while the ETF matched twice the daily market return on day one, the effect of compounding caused it to underperform two times the 2-day return by 2%. This is the type of discrepancy that caused the underperformance of levered ETFs over the past year. Next we consider a market that moves up 10%, followed by another 10% up move. The market would perform as follows: $100 – $110 – $121, while the value of a 2x-levered ETF would move as follows: $100 – $120 – $144. In this case, the 2x-levered ETF outperformed twice the 2-day market return by 2%.

[6] Please see our publication “Market Impact of Derivatives Hedging” from October 22, 2008.

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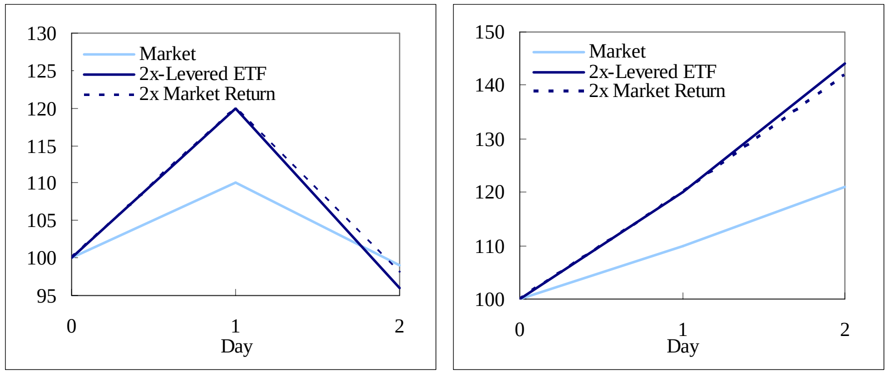
Figure 3: Divergence of ETF Performance and Levered Market Return Over a Two-Day Time Period



Source: J.P. Morgan Derivatives and Delta One Strategy.

This shows that over a 2-day time period, a 2x-levered ETF may outperform or underperform twice the 2-day return of the underlying index. This discrepancy will depend on the market reverting direction (levered ETF underperforms) or the market trending (levered ETF outperforms). For any long or short levered ETF we show in Appendix II that for two-day returns, the divergence between the levered ETF and the naively expected return – calculated by levering the 2-day market return with the leverage denoted with *p* (e.g., *p = 2* for double long, 3 for triple long, -2 for double short, etc.) – is:

$$2 - Day\ \ Divergence: \quad (p^2 - p) \cdot r_1 \cdot r_2$$

The divergence between a levered ETF and the levered 2-day return is proportional to the product of consecutive market moves. For this reason the **divergence will be significant when the market is volatile, i.e., when market moves are large**. Also for a double long levered ETF (p = 2) it will be twice the product of consecutive returns, and for double short (p = -2) it will be three times as large. Another important feature is that this analysis reveals that a **levered ETF will underperform in a reverting market** and will outperform in trending markets (when the market changes direction day to day, the product of consecutive returns and hence performance is negative, and when the market maintains the same direction day to day, the product of consecutive returns and hence performance is positive). Thus, the deviation of the performance of levered ETFs over the past year was expected on account of high market volatility. Yet **their underperformance suggests that the market returns were more likely to revert than trend**. In the following sections, we will establish a link between volatility and market reversion and propose investment strategies that may be profitable.

Having shown how the discrepancy between the levered ETF return and the levered market return appears over two consecutive days, we now want to quantify this performance divergence over any time period. This is a more difficult problem as the divergence will be dependent on a particular path taken by the underlying index. However, by carefully analyzing the compounding effect (see Appending III for details), we find that the total divergence (under- or outperformance) of a "*p*-times" levered ETF over a time period *T*, during which the market-realized volatility was σ and had a cumulative price return *r* is:

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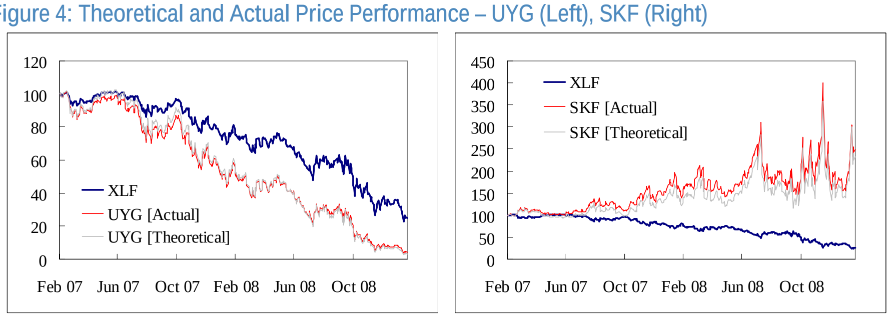
$$Divergence:\quad \frac{1}{2}\cdot(p^2-p)\cdot\left(r^2-\sigma^2\cdot T\right)$$

This indicates that the divergence will increase with the level of ETF leverage, and will be higher for short ETFs than for long ETFs.[7] For instance, the amount of divergence for a 2x-levered short ETF (p = -2) will be three times higher than for a 2x-long ETF. Also, a 3x-long ETF will have the same divergence as a 2x-short.

More importantly, the divergence is given by the difference between the market volatility and the total market return over the observed time period. **We find this finding remarkable in many ways. It tells us that the performance of levered ETFs depends on the balance between mean reversion and trending of market prices. This indicates that if the market is highly trending, levered ETFs will outperform, and if the market is mean reverting, levered ETFs will underperform.** In a perfectly efficient market, returns are random and the market-expected trend equals the volatility. Hence, **in efficient markets, one would expect levered ETFs to perform in line with a multiple of the market return**. Therefore, the outperformance and underperformance of levered ETFs appears to be a gauge of market inefficiency. **As most levered ETFs underperformed this year, it implies that market returns were highly mean reverting.** In the next section we investigate the link between market volatility and mean reversion of daily returns and show that there are both theoretical and structural reasons that relate the two.

Before looking into the link between volatility and price reversion, we compare our theoretical results for performance divergence to the actual prices of levered ETFs. Figure 4 below depicts the performance of UYG (double long XLF) and SKF (double short XLF) ETFs, as well as our theoretical estimate based on realized volatility and mean reversion of the underlying index. One can see that the theoretical performance very well matches the observed performance. The slight underperformance of actual ETFs may be attributed to the cost of leverage and transaction costs.

Figure 4: Theoretical and Actual Price Performance – UYG (Left), SKF (Right)



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

Further, we illustrate the divergence of the performance of SRS (2x-levered short IYR) and the double negative rolling return of IYR. We show both the theoretical underperformance as well as the underperformance of the actual ETF (Figure 6, left). As discussed above the theoretical divergence has two components – a volatility

[7] This is the exactly same as we found is needed to hedge these ETFs in Appendix I.

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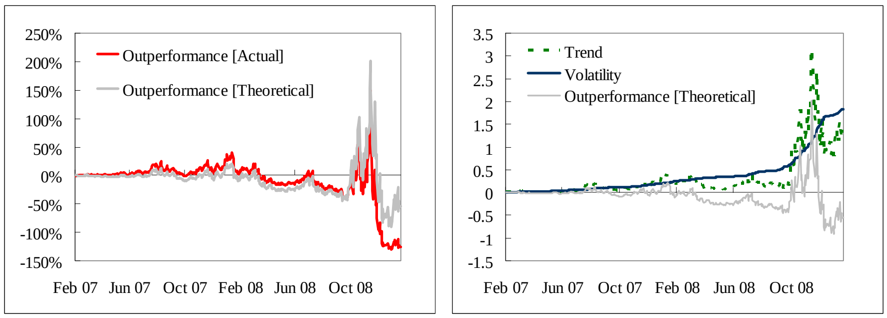
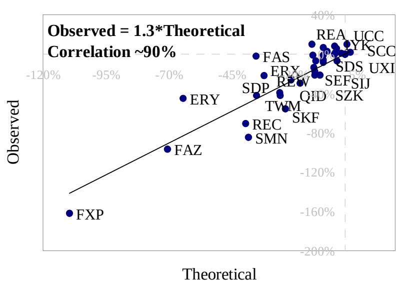
component that causes the ETF to underperform and a trending component (total return) that causes the ETF to outperform. The breakdown of the divergence into a trending (outperforming) and a volatility (underperforming) component is represented in the chart below (Figure 6, right). One can notice that while volatility continuously dragged the performance down, occasional spikes in the market trend "lifted" the ETF performance. Over the observed time period, the levered ETF underperformed even more than our theoretical prediction, probably on account of high borrow cost for the underlying index of IYR.

Figure 6: SRS Example – Performance Divergence: Theoretical and Observed (Left), Contribution of Volatility and Trending Component to Divergence (Right)



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

Figure 5: Observed Versus Theoretical Divergence for 37 US Levered ETFs



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

Figure 5 (at left) shows the observed divergence of levered ETFs versus our theoretical estimates of the divergence for long and short levered US ETFs. The agreement between observed and theoretical divergence is good across all products (correlation of 90%, slope is 1.3 which means that actual ETFs underperformed our theoretical estimates on account of borrow/leverage cost, and transaction cost). Our theoretical results also worked better for short products than for long products.[8]

Another important consideration about levered ETFs is their expected future price (or their forward value). The forward value is an important ingredient in the pricing of equity options. Currently there are ~1.5 million option contracts outstanding on levered ETFs, the most popular being levered and short levered financial, S&P 500, Nasdaq 100, and DJUS Real Estate ETFs. In Appendix IV we show that the forward value of a levered ETF is given by:

$$ETF_T^{Forward} = ETF_0 \cdot \left(1 + \frac{p^2}{2}\left(E\left[r_T^2\right] - \sigma_T{}^2\right)\right)$$

Here σ_T is the expected future volatility of the underlying index that can be estimated from the implied volatility of maturity *T*, and $E\left[r_T^2\right]$ is the expected move of the market over the same time period. This correction of the forward value has the same form as the performance divergence of levered ETFs. It tells us that in a

[8] We also excluded twice-levered Financials and Real Estate ETFs from Figure 5, as their "expected performance" would have been below zero.

trending or reverting volatile market, the ETF forward value will differ significantly from the forward value under the efficient market assumption (random returns)[9].

If persistent price patterns of reversion develop, the forward values and performance will start deteriorating (similarly, if the market starts trending, forward values will increase). By mathematical manipulation (see Appendix V), we can show that level of mean reversion (or trending) can be expressed in terms of autocorrelation of market returns. Autocorrelation gives us the likelihood that market will continue following a trend (positive autocorrelations) or revert (negative autocorrelation). Autocorrelations can be calculated for different time lags (e.g., influence of today's return on return tomorrow, day after tomorrow, in three days, etc.). The expected amount of market mean reversion can be written as:

$$E\left[r_T^2\right]-{\sigma_T}^2 = 2\cdot\sum_{k=1}^{T-1}\left(\frac{T-k}{T}\right)\rho_k\sigma_k^2$$

Positive autocorrelations signal trending in prices (e.g., if the market is up one day it will more likely be up the next day – in other words positive autocorrelation indicates market momentum) and negative autocorrelation signals reversion in prices (e.g., if the market is up one day, it will more likely be down the next day – in other words negative autocorrelation indicates market reversion).

This measure of reversion determines the performance of levered ETFs and levered ETF forward prices. It is expressed as a sum of correlations of market returns today and tomorrow, market returns today and day after tomorrow, etc. (sum of autocorrelations). It is also multiplied with realized variance (square of volatility). **Therefore, any outperformance or underperformance of levered ETFs due to reversion or trading patterns will be largely magnified in a high volatility environment such as the one we had during 2008.**

[9] For simplicity, we are assuming zero dividends and zero interest rates.

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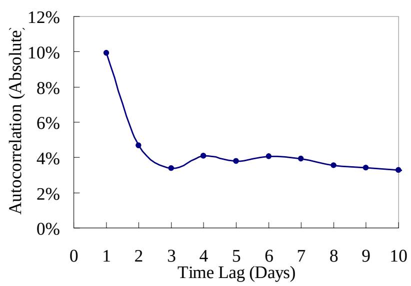
Volatility and Mean Reversion of Daily Returns

In the previous section, we showed how the existence of a reversion pattern in market returns (negative autocorrelation) would eat up the performance of levered ETFs. **The actual poor performance of levered ETFs during the recent increase in market volatility points to a high level of mean reversion. Over the course of 2008, daily returns were not random but on average reverted more often than they trended. In this section, we investigate this reversion effect in further detail and establish the link between market volatility and the patterns of market reversion.** The market mean reversion can be quantified using autocorrelations (correlation of returns today and tomorrow, today and day after tomorrow, etc.). The correlation of consecutive market returns is called the one-day lagged correlation, and similarly one can look at the correlation of the two-day lagged returns, etc. A negative one-day lag correlation would mean that the market tends to reverse direction every day, and a negative two-day lag correlation would suggest that large market moves tend to revert after two days, and so on (similarly, a one-day lag positive correlation would mean that large market returns tend to extend into the following day, etc.). Any momentum or reversion trends are expected to wash out over longer periods of time as the market does not retain a long memory of past return patterns.[10] For this reason, one would expect that if there are any price momentum or reversal trends, they would appear in the correlation of consecutive returns (one-day lag returns).

Figure 7: Lagged S&P 500 Autocorrelation (Absolute Value) – Average from 1928 to 2009

Shown are correlations of returns for lags from 1 to 10 days



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

This is indeed the case as can be noticed in Figure 7 (left). The figure shows the average (absolute) level of correlations of daily market returns lagged by 1, 2…10 days over the past 80 years. It appears that price trends of momentum or reversion are relevant only over one-day time periods (consecutive returns). For this reason, in the rest of this section we will focus only on one-day lag correlations and look at strategies that identify and profit from one-day patterns.[11]

Figure 8 below shows the one-day lag correlations over the past four years. One can see that over the past two years, these 1-day lag correlations were persistently negative.[12] This means that day to day, the market was more likely to revert than trend. While in 2006 autocorrelation was equal to zero (consistent with efficient markets), 2007 and 2008 had significant negative autocorrelations in a range of -10% to -20%. This explains why a large spike in realized volatility in 2008 combined with negative autocorrelation led to a significant deterioration of the performance of levered ETFs.

[10] This is also supported by statistics theory (central limit theorem) – as adding a large number of independent returns results in uncorrelated (normal distribution) returns.
[11] For longer-term patterns of technical analysis (such as double tops, head and shoulders, etc.), we can not precisely define significant tests and do not have enough data to draw rigorous conclusions. Our belief is that these longer-term patterns in isolation can not be used to define a meaningful trading strategy.
[12] The t-statistics for the negative autocorrelation was 4.5.

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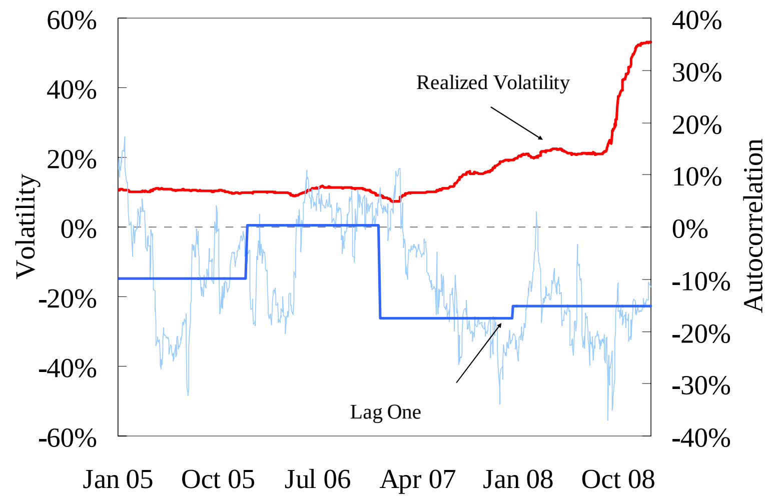
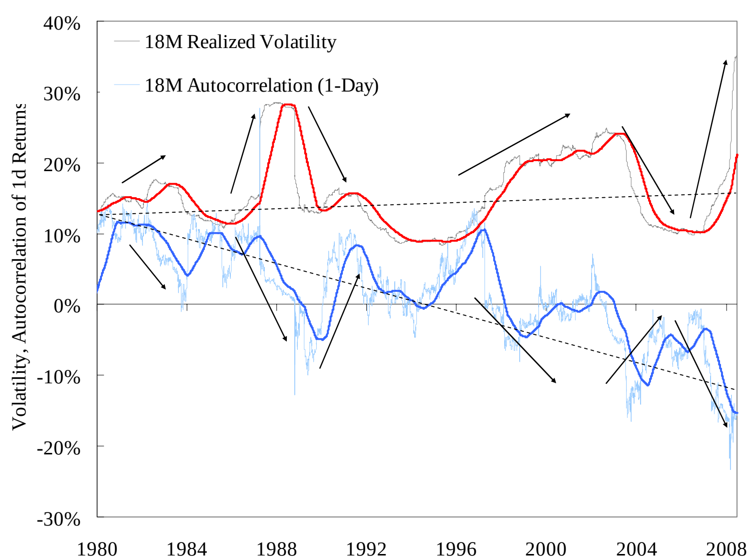
Figure 8: One-Day Lag Correlations and Volatility for the S&P 500 Over the Past Four Years



Source: J.P. Morgan Derivatives and Delta One Strategy.

Carefully looking at Figure 8 raises the following question: Is the simultaneous drop in autocorrelation and increase in volatility a coincidence or is there a relationship between the two quantities? Figure 9 below illustrates the volatility and one-day lag correlation over the past 30 years**. It is evident that the volatility and lag-1 correlation are inversely related. Also one can notice a gradual drop in absolute levels of autocorrelation over the past 10 years.**

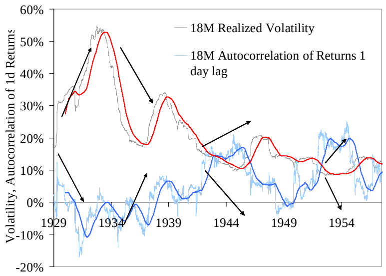
Figure 9: Market Volatility and Lag-1 Autocorrelations Over the Past 30 Years



Source: J.P. Morgan Derivatives and Delta One Strategy.

There are both structural and behavioral reasons that could explain the negative relationship between market volatility and 1-day lag correlations. We will first start by analyzing the structural reasons. In our previous publication on the impact of derivatives hedging, we demonstrated how the hedging of short gamma risk has resulted in intraday momentum and price trending in the last ~30 minutes of a trading day. The net short gamma imbalance comes from index option positions, variance swaps, dynamic delta hedging programs (constant proportion portfolio protection), and most recently from hedging of levered ETFs. As this hedging demand is liquidity-driven, its market impact is of temporary nature and reverts back over the course of the following day[13]. This has significantly contributed to the reversion of daily levels (in the next section when designing trading strategies we provide more evidence that the two effects are closely related). An additional contribution to the reversion may come from asset allocation rebalances. If the market drops, an investor will need to increase the allocation to equities and buy the market. Some of these allocation trades can be only done on the following day causing reversion of returns (e.g., allocations to mutual funds that can not be priced/traded intraday).

Figure 10: Same as Figure 9 for 1928-1958 Time Period



Source: J.P. Morgan Derivatives and Delta One Strategy.

In addition to the negative relation between volatility and 1-day lag correlation, Figure 9 shows a pronounced drop in 1-day lag correlation over the last 30 years. We believe that this drop is caused by an increased use of leverage, dynamic hedging programs, and derivatives that create a short gamma exposure. While gamma hedging programs have contributed to a current low (negative) level of autocorrelation, they are not responsible for the relationship between autocorrelation and volatility. By looking at the 30-year time period from 1928 to 1958 (Figure 10, left), we also found that as volatility rose autocorrelation fell, and vice versa[14]. In particular, following the crash of 1929, autocorrelation dropped to low levels similar to the current readings. Thus, we find that the negative relationship between volatility and 1-day lag correlation was present even before derivatives contracts were introduced to the market.

Furthermore, we suggest that the relationship between volatility and autocorrelation is also related to behavioral finance and market impact theory. A high volatility environment is usually an environment of high economic uncertainty. In turn, uncertainty can cause market participants to overreact on insignificant and often contradictory news. Low liquidity increases temporary market impact, and dissipation of this temporary impact further contributes to price reversion.

The behavioral and structural reasons may be related to each other. As investors are driven by “fear and greed,” they usually want to participate in the market upside, but scramble for protection in a market downturn. This has caused investors to frequently overreact on insignificant news by selling on the downside and buying on the upside – effectively increasing the overall “short gamma” of the market. The overreaction is then followed by an adjusting phase leading to reversion. Similarly, the factor of “greed and fear” has led to demand for downside protection, leverage, and dynamic hedging programs that increase the overall market gamma. These programs are usually rebalanced and hedged once a day, usually near the market close. The hedging impact causes intraday market momentum and is particularly pronounced in volatile markets. The temporary nature of this market impact (hedging of any short gamma trade) contributes to the subsequent price reversion.

[13] Liquidity-driven market impact is usually temporary, and reverts quickly. Permanent market impact is usually a result of new fundamental information coming into the market.
[14] Regression of 18M volatility and 18M lag-1 autocorrelation from 1928 to 2008 has a negative slope of -0.8, with a significant t-stat of -12.

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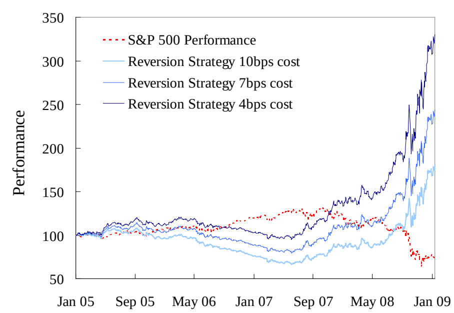
Investment Strategies that Capitalize on Inefficient Markets

In this section we analyze the performance of a trading strategy that aims to profit from the daily reversion of market returns and show how reversion strategies are closely related to intraday momentum strategies which we discussed in our previous publication.[15] The simplest way to implement the reversion strategy would be to buy the market at the close if it is down for the day, or sell it on the close if the market is up for the day. This simple prescription is then repeated every day. If the market is mean reverting, and the average amount of mean reversion exceeds the transaction costs, this strategy will be profitable. Volatility will also help the strategy as high volatility usually results in lower autocorrelations, and provides higher absolute daily returns. As the strategy has a large turnover, it can be implemented by investors with very low transaction costs. Figure 12 below shows the performance of the simple reversion strategy for the S&P 500 Index over the past four years. We show the performance with transaction costs in a 4-10bps range. **In 2008, the strategy would have had a 114% return and 40% volatility for an information ratio of ~2.8.**[16] **We estimate the performance in 2007 would have been strong as well.** Similar to the intraday momentum strategy that we discussed in our previous publication, the reversion strategy thrives in volatile market conditions.

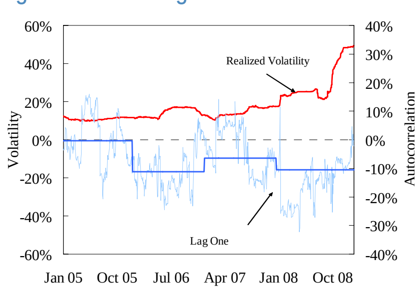
Figure 12: Simple Reversion Strategy for S&P 500 – Performance Chart (Left) and Performance Summary (7bps Transaction Cost, Right)



Year	Return	Vol.	IR
2005	4%	10%	0.3
2006	-15%	10%	-1.5
2007	25%	16%	1.6
2008	114%	41%	2.8

Source: J.P. Morgan Derivatives and Delta One Strategy.

Fig. 11: Same as Figure 8 for EuroStoxx 50



Source: J.P. Morgan Derivatives and Delta One Strategy.

We also investigated the performance patterns in European markets and found that the reversion trend for the EuroStoxx 50 (SX5E) was significant in 2006, 2007, and 2008. Figure 11 (left) shows the autocorrelation and volatility for SX5E over the past four years. The overall effect appears to be weaker in Europe as compared to the US. However, during 2006, when there was no reversion in the US market, the effect was the strongest in Europe. The figure below shows the performance of the simple reversion strategy for the EuroStoxx 50 (SX5E) with transaction costs in a 4-10bps range. **In 2008, the strategy would have returned 38% with a volatility of 39% for an information ratio of 1.** The 2007 performance would have been positive but weaker. The 2006 performance was strong, as opposed to the 2006 performance of S&P 500 strategy.

[15] For an analysis of intraday momentum patterns in the US and European markets, please see our previous publication "Market Impact of Derivatives Hedging."
[16] Transaction cost of 7bps.

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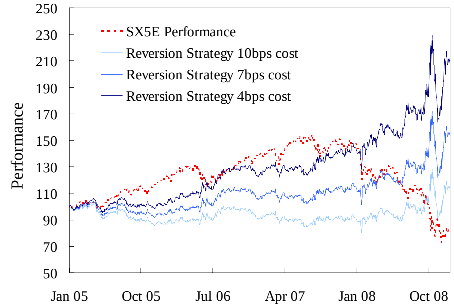
Figure 13: Simple Reversion Strategy for EuroStoxx 50 – Performance Chart (Left) and Performance Summary (7bps Transaction Cost, Right)



Year	Return	Vol.	IR
2005	-6%	11%	-0.6
2006	13%	14%	0.9
2007	7%	16%	0.4
2008	38%	39%	1.0

Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

Finally, we investigate the link between daily reversal patterns, and intraday momentum patterns both in the US and in Europe. Intraday momentum patterns result from the hedging of market short gamma exposure and cause the market to extend gains or losses in the last ~30 minutes of a trading day. We studied this effect and created a trading strategy that aims to take advantage of it in one of our past publications. Figure 14 (below) compares the returns of our close-to-close reversion strategy to the strength of the intraday momentum effect resulting from gamma hedging. In particular, we show the information ratio of the reversion strategy as well as the strength of the reversion (as measured by autocorrelation) and compare it to the strength of the intraday momentum trend (as measured by the correlation of 9:30AM-3:30PM returns to 3:30PM-4:00PM returns).

Figure 14: Strength of Daily Reversal and Intraday Momentum Effects Are Closely Related

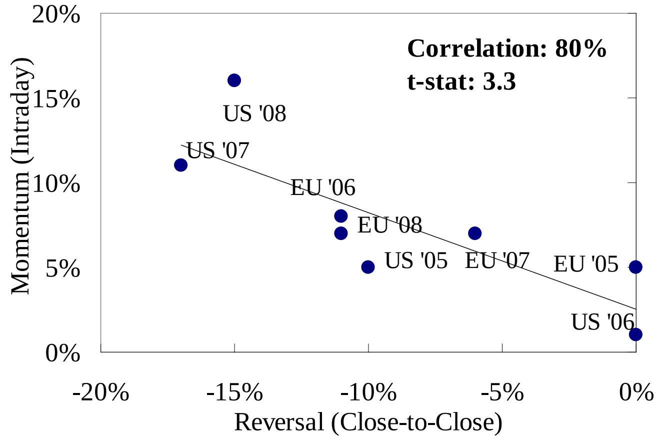
Year	SPX				SX5E			
	Rev. IR	Rev.	Mom.	Mkt. Vol	Rev. IR	Rev.	Mom.	Mkt. Vol
2005	0.3	-10%	5%	10%	-0.6	0%	5%	11%
2006	-1.5	0%	1%	10%	0.9	-11%	8%	15%
2007	1.6	-17%	11%	15%	0.4	-6%	7%	16%
2008	2.8	-15%	16%	41%	1.0	-11%	7%	40%

Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

There are several observations that directly link daily reversal patterns with intraday momentum patterns. In 2006 there was no reversal effect in the US, and during the same year there was no momentum effect either. In 2005, the reversal effect was absent in Europe, and that was the year when the momentum effect was the weakest as well. 2007 and 2008 in the US were the years with the strongest momentum and reversal effect. Similarly, in Europe 2006 and 2008 were the years with the strongest momentum and reversal effect. **It would be hard to imagine that the relationship between momentum and reversal effects is a coincidence. This is confirmed by a statistical test that points to a strong relationship between intraday momentum and the daily reversal effect,** as shown in Figure 15 below[17].

[17] Momentum as measured by the correlation of 9:30AM-3:30PM returns to 3:30PM-4:00PM returns. Reversal as measured by one day log autocorrelation.

Figure 15: Reversal and Momentum Effect in US and Europe



Source: J.P. Morgan Derivatives and Delta One Strategy, Bloomberg.

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APPENDIX: Derivation of Formulas

Appendix I: Market Impact of Leveraged ETFs Hedging

Levered ETFs aim at providing daily returns that are equal to a fixed number of times the daily return of the underlying security. To deliver such returns, levered ETF providers need to adjust the number of contracts of the underlying security that they hold daily. Consider a p-levered ETF and let x_N be the number of shares of the underlying security that need to be held at time N. x_N must satisfy:

$$x_N \cdot S_N \cdot r_{N+1} = ETF_N \cdot p \cdot r_{N+1}$$

where S_N is the value of the underlying security at time N, ETF_N the value of the ETF at time N, and r_{N+1} the return from time N to $N+1$. Hence:

$$x_N = p \cdot \frac{ETF_N}{S_N}$$

The same calculation at step $N+1$ yields:

$$x_{N+1} = p \cdot \frac{ETF_{N+1}}{S_{N+1}}$$

Hence, the number of shares that need to be traded at step $N+1$ to acquire the appropriate exposure in the underlying security is:

$$x_{N+1} - x_N = p \cdot (p-1) \cdot \frac{ETF_N}{S_N} \cdot \frac{r_N}{1+r_N}$$

Appendix II: Discrepancy Between Levered ETF Performance and Levered Return for Two-Day Time Period

Over a two-day period of time, the performance of a p-levered ETF may differ from p times the return of the underlying security. Indeed, over a two-day time period the value of the p-levered ETF grows by:

$$R_{ETF} = \frac{ETF_2}{ETF_0} - 1 = (1+pr_1)\cdot(1+pr_2) - 1 = p\cdot(r_1+r_2) + p^2 r_1 r_2$$

and the value of the underlying security grows by:

$$R_S = (r_1 + r_2) + r_1 r_2$$

Therefore, the discrepancy over the two-day period can be written as:

$$Discrepancy : (p^2 - p) \cdot r_1 \cdot r_2$$

Appendix III: Discrepancy Between Levered ETF Performance and Levered Cumulative Return for Any Time Period

The formula of the two-day discrepancy can be generalized to any time period N. After N days, the values of the underlying security (S_N) as well as the p-levered ETF (ETF_N) can be expressed as:

$$S_N = (1+r_1)\cdot(1+r_2)\ldots(1+r_N)\cdot S_0$$

$$ETF_N = (1+pr_1)\cdot(1+pr_2)\ldots(1+pr_N)\cdot ETF_0$$

Expanding the value of the ETF at time N gives:

$$\frac{ETF_N}{ETF_0} - 1 \approx p\cdot\sum_{i=1}^{N} r_i - \frac{p^2}{2}\cdot\sum_{i=1}^{N} r_i^2 + \frac{p^2}{2}\left(\sum_{i=1}^{N} r_i\right)^2 = p\cdot\sum_{i=1}^{N} r_i + p^2\sum_{i<j} r_i\cdot r_j$$

The discrepancy between the return of the ETF up to time N and p times the return of the underlying security over the same time period can be expressed as:

$$Discrepancy \approx (p^2 - p)\cdot\sum_{i<j} r_i\cdot r_j = \frac{(p^2-p)}{2}\cdot\left(\left(\sum_{i=1}^{N} r_i\right)^2 - \sum_{i=1}^{N} r_i^2\right)$$

$$Divergence\text{:}\quad \frac{1}{2}\cdot(p^2-p)\cdot\left(r^2 - \sigma^2\cdot T\right)$$

Appendix IV: Forward ETF Price

The forward value of a levered ETF can be determined by calculating the expected value of the ETF at a future point in time. Using equation from Appendix III, we can write:

$$E[ETF_N] = ETF_0\cdot\left(1 + p\cdot\sum_{i=1}^{N} E(r_i) + p^2\cdot E\left(\sum_{i<j} r_i\cdot r_j\right)\right)$$

Assuming that the expected value of the returns is equal to 0, this expression can be rewritten as:

$$E[ETF_N] = ETF_0\cdot\left(1 + \frac{p^2}{2}\cdot\left(E[r_T^2] - \sigma_T^2\right)\right)$$

where $r_T = \sum_{i=1}^{N} r_i$ and $\sigma_T^2 = \sum_{i=1}^{N} r_i^2$

Appendix V: Relationship Between Volatility and Autocorrelations

Let Cov_k be the covariance of the returns with lag k. Cov_k can be written as:

$$Cov_k = \frac{1}{T-K} \cdot \sum_{i=1}^{T-K} r_i \cdot r_{i+k}$$

It is easy to show that the following relationship holds:

$$\sum_{i<j} r_i \cdot r_j = \sum_{k=1}^{T-1} (T-k) \cdot Cov_k$$

And hence:

$$E\left[r_T^2\right] - \sigma_T^2 = 2 \cdot E\left(\sum_{i<j} r_i \cdot r_j\right) = 2 \cdot \sum_{k=1}^{T-1} (T-k) \cdot Cov_k$$

$$E\left[r_T^2\right] - \sigma_T{}^2 = 2 \cdot \sum_{k=1}^{T-1} \left(\frac{T-k}{T}\right) \rho_k \sigma_k^2$$

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Predicting Market Patterns

Trading Daily Gamma Moves in Stocks and Sectors

- Over the past few years, we have written several times on how gamma hedging of derivative products (such as options and levered ETFs) and trading strategies such as stop-loss and dynamical hedging can cause predictable price patterns and present alpha opportunities for investors. In this report, we focus on a recent example of the gamma hedging impact on mining stocks and sector indices.
- We explain how gamma hedging of levered ETFs and options cause price distortions of mining sector stocks and indices and illustrate strategies that can take advantage of it. Patterns of momentum and reversion are also important to properly price and hedge options, as **volatility can be drastically different based on sampling frequency**.

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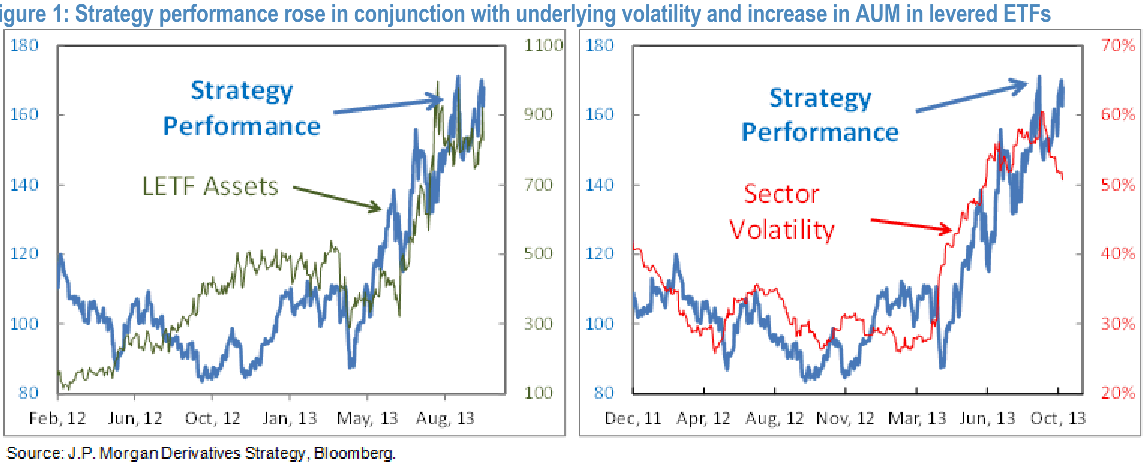
Over the past few years, we have written several times on how gamma hedging of derivative products (such as options and levered ETFs) and trading strategies such as stop-loss and dynamical hedging can cause predictable price patterns and present alpha opportunities for investors. While we largely focused on broad indices, these effects also occur at the sector and stock level. The key for predicting gamma-driven price patterns is to understand the nature of products and their rebalance method, as well as to understand the size of the rebalancing needs relative to liquidity in the cash market. As gamma rebalances are often proportional to daily moves in the underlying asset, the effects can show up dramatically during high-volatility regimes. This should make strategies based on the gamma impact a "holy grail" for asset managers as they perform well when most other strategies suffer.

A recent example we want to illustrate is related to mining sector stocks. Given the recent volatility of precious metals, many mining stocks exhibited high levels of realized volatility and poor performance. In addition to gamma content of downside put options, growth of assets in levered and inverse ETFs added significant short gamma exposure for this sector (e.g. ~$60M of gamma in 2 popular ETFs). Given that the mining sector regularly shows ~5% daily moves recently, and given relatively low stock liquidity, gamma hedging is causing significant price distortions for underlying stocks and sector products.

A rigorously tested strategy that takes advantage of daily reversion and momentum patterns due to gamma hedging in mining stocks would have returned ~100% in the past 6 months. The chart to the left below shows how performance of the strategy took off alongside volatility of underlying stocks. The chart to the right below also shows the close relationship between strategy performance and assets under management (AUM) in levered ETFs, suggesting that a product's gamma is a significant driver of the strategy's performance.

Figure 1: Strategy performance rose in conjunction with underlying volatility and increase in AUM in levered ETFs



Source: J.P. Morgan Equity Derivatives Strategy, Bloomberg.

In addition to the attractive feature of gamma-driven systematic strategies to perform well when volatility is high, investors can also estimate capacity of these strategies. By calculating the amount of dollar gamma in related derivative products, one can approximately calculate the size of rebalance trades (as % of ADV), their impact and hence estimate the capacity of a potential arbitrage strategy.

Price patterns caused by gamma hedging also manifest in various ways related to options prices and realized volatility effects. Many investors have noticed recently that implied volatility of mining stocks have been significantly lower than realized volatility since April. This is true for both single stock and sector options. Does this mean that options on mining stocks and sector are a good buy across the board? It depends on how an

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investor approaches hedging these options. For instance, while daily volatility of mining stocks was up to ~15 points higher than implied volatility, weekly realized volatility was in line with option volatility. The divergence between daily and weekly volatility (chart to the right below) was caused by patterns of momentum and reversion introduced by hedging of levered products.

Figure 2: Daily volatility of mining stocks was significantly higher on a daily basis but in-line on a weekly basis

Source: J.P. Morgan Derivatives Strategy, Bloomberg.

Source: J.P. Morgan Equity Derivatives Strategy, Bloomberg.

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Risks of Common Option Strategies

Risks to Strategies: Not all option strategies are suitable for investors; certain strategies may expose investors to significant potential losses. We have summarized the risks of selected derivative strategies. For additional risk information, please call your sales representative for a copy of "Characteristics and Risks of Standardized Options." We advise investors to consult their tax advisors and legal counsel about the tax implications of these strategies. Please also refer to option risk disclosure documents.

Put Sale. Investors who sell put options will own the underlying asset if the asset's price falls below the strike price of the put option. Investors, therefore, will be exposed to any decline in the underlying asset's price below the strike potentially to zero, and they will not participate in any price appreciation in the underlying asset if the option expires unexercised.

Call Sale. Investors who sell uncovered call options have exposure on the upside that is theoretically unlimited.

Call Overwrite or Buywrite. Investors who sell call options against a long position in the underlying asset give up any appreciation in the underlying asset's price above the strike price of the call option, and they remain exposed to the downside of the underlying asset in the return for the receipt of the option premium.

Booster. In a sell-off, the maximum realized downside potential of a double-up booster is the net premium paid. In a rally, option losses are potentially unlimited as the investor is net short a call. When overlaid onto a long position in the underlying asset, upside losses are capped (as for a covered call), but downside losses are not.

Collar. Locks in the amount that can be realized at maturity to a range defined by the put and call strike. If the collar is not costless, investors risk losing 100% of the premium paid. Since investors are selling a call option, they give up any price appreciation in the underlying asset above the strike price of the call option.

Call Purchase. Options are a decaying asset, and investors risk losing 100% of the premium paid if the underlying asset's price is below the strike price of the call option.

Put Purchase. Options are a decaying asset, and investors risk losing 100% of the premium paid if the underlying asset's price is above the strike price of the put option.

Straddle or Strangle. The seller of a straddle or strangle is exposed to increases in the underlying asset's price above the call strike and declines in the underlying asset's price below the put strike. Since exposure on the upside is theoretically unlimited, investors who also own the underlying asset would have limited losses should the underlying asset rally. Covered writers are exposed to declines in the underlying asset position as well as any additional exposure should the underlying asset decline below the strike price of the put option. Having sold a covered call option, the investor gives up all appreciation in the underlying asset above the strike price of the call option.

Put Spread. The buyer of a put spread risks losing 100% of the premium paid. The buyer of higher-ratio put spread has unlimited downside below the lower strike (down to zero), dependent on the number of lower-struck puts sold. The maximum gain is limited to the spread between the two put strikes, when the underlying is at the lower strike. Investors who own the underlying asset will have downside protection between the higher-strike put and the lower-strike put. However, should the underlying asset's price fall below the strike price of the lower-strike put, investors regain exposure to the underlying asset, and this exposure is multiplied by the number of puts sold.

Call Spread. The buyer risks losing 100% of the premium paid. The gain is limited to the spread between the two strike prices. The seller of a call spread risks losing an amount equal to the spread between the two call strikes less the net premium received. By selling a covered call spread, the investor remains exposed to the downside of the underlying asset and gives up the spread between the two call strikes should the underlying asset rally.

Butterfly Spread. A butterfly spread consists of two spreads established simultaneously – one a bull spread and the other a bear spread. The resulting position is neutral, that is, the investor will profit if the underlying is stable. Butterfly spreads are established at a net debit. The maximum profit will occur at the middle strike price; the maximum loss is the net debit.

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