An Analysis of 1996 Equity Market Volatility
Executive Summary

The following summarizes our lengthier report on 1996 equity market volatility (copies available upon request). The primary conclusions are as follows, along with our outlook on volatility and our recommendations for the conduct of an appropriate option strategy:

CONCLUSION: **The bulk of the evidence points away from the hypothesis that equity market volatility has incurred a structural shift in 1996 to a higher equilibrium, or that it has begun a new trend higher.** The evidence leans to the argument that for a handful of identifiable yet transitory reasons, the equity market has developed a temporarily heightened sensitivity to certain events, namely the release of the nonfarm payroll report and earnings announcements for technology issues. History shows, however, that previous periods of similar heightened sensitivity did not last more than a few months, at most. Additionally, the market has a generalized level of sensitivity due to the current Presidential race, which clearly has a finite ending point in November.

The specific findings of our study include:

Finding 1: **Equity market volatility in 1996, while higher than that seen in recent years, has resulted more from a small handful of violent trading days than from a broad structural increase in market choppiness.** When *interday* volatility measures are examined, one only needs to drop the largest eight daily changes from the last eight months (184 trading days) to bring historical interday volatility down to under 10%. When *intraday* volatility is examined, one only needs to drop the largest five days in order to see historical intraday volatility fall to less than 10%. When we examine the frequency of violent trading days in 1996 rather than their singular intensity (by counting how many trading days had intraday ranges in the long-run upper quartile of all such daily ranges), we find that 1996 has experienced a "breadth" of volatility that has been slightly below average (fewer than 22% of the trading days in the last eight months fall in the highest quartile of all daily ranges, which is less than the 25% that would be expected on average).

Finding 2: **Virtually all the most volatile days in the last eight months were either in close proximity to the nonfarm payroll report or they were associated with tech stock news.** The days in 1996 that brought high volatility to the market have had two notable features: they have either been very closely clustered or they have been associated with clearly definable events. Of the 12 largest intraday swings in the last eight months, seven occurred in the one-month period from July 5 to August 2. This was a period that was rocked repeatedly by provocative news announcements about companies in the technology sector (HP, Intel, and Microsoft most notably). Additionally, seven of the most volatile days in the last eight months were within three days of a nonfarm payroll report's release.

Finding 3: **Sensitivity to the release of the nonfarm payroll report is clearly being driven by uncertainty that the Fed will clamp down on current economic strength. Sensitivity to the technology issues is exacerbated by the wide performance swings witnessed in that sector this year, but more broadly by the view that the equity market has reached a peak following 1995's strong gains.** We examined similar situations in the past to see what happened to equity market volatility under situations similar to these two scenarios. For the Fed we examined the 1994 tightening (due to its many unique features that surprised the market at that time). Our conclusion is that volatility only spiked two or three times during 1994 as a result, and for periods of less than a month each time, before returning to below-average levels. We also examined previous periods of market "toppishness," in order to examine whether higher volatility is persistent across the entire period that the market peaks. We identified five prior examples of a market peak over the last 14 years. In all cases higher volatility occurred only in response to a market correction (not just simply because the market had reached a peak), and then even at its worst the higher level of volatility did not persist for more than four months (typically only for a month or two). Finally, we examined whether the current Presidential race is having a unique influence on equity market volatility. We examined the last five Presidential election years and found that in all five previous Presidential elections volatility fell, and by a median of 180 bps, in the year following the election.

OUTLOOK: **It is our view that the current period of heightened volatility will likely reach a turning point by the fourth quarter of this year, and that actual volatility will fall by at least 100-150 bps in the 6-12 month period that follows.** Indeed, it appears that a period of quietude has already begun to settle in, although we would not rule out continued turbulence around the nonfarm payroll reports. Our historical analysis also suggests that as actual volatility falls off implied volatility lags its decline, offering improved potential for capturing the excess premium during that window of opportunity. In the long run our backtests suggest that a return of 25 bps per month, after transaction costs, is achievable within a volatility arbitrage strategy.

RECOMMENDATIONS: **Volatility trading and volatility arbitrage remain viable strategies, even during the current period of heightened market sensitivity.** In our view volatility continues to exhibit mean-reverting behavior, falling quickly back to a relatively low mean level shortly after any generating event. The real risk is that the occasional market moving event (mainly nonfarm payroll releases and key earnings announcements) has become more violently received due to such factors as the Presidential election cycle and nervousness over the Fed. This fact offers both risk management and arbitrage opportunities: properly timed, option overwrite programs and volatility trades can be initiated as soon as a nonfarm payroll related spike occurs, and removed during the following reversion to the mean.

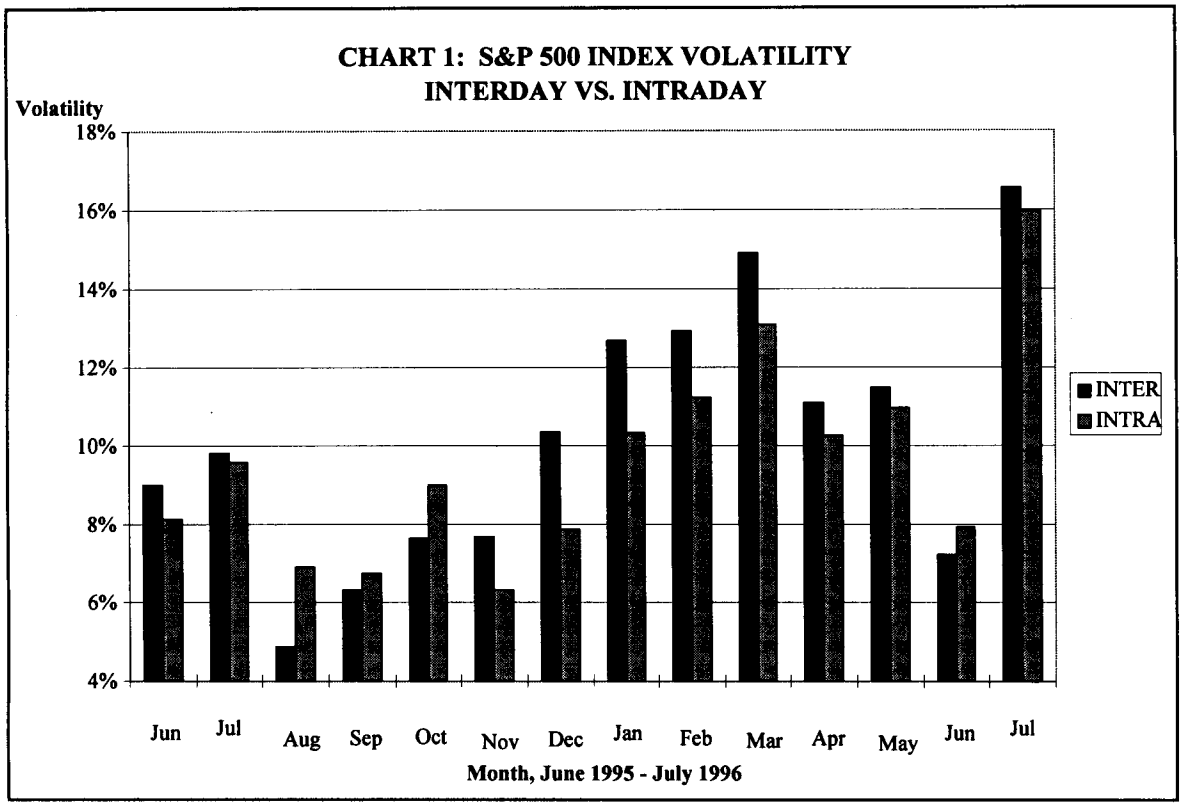
Bob Bannon
Director of Research

An Analysis of 1996 Equity Market Volatility

As part of its ongoing effort to identify anomalies in the behavior of volatility, Analytic•TSA has conducted a review of 1996 US equity market volatility. We have examined the nature of recent levels of intraday and interday actual equity market volatility,[1] with particular emphasis on the period from December 1995 to present. Our intention is to investigate whether, as some analysts have suggested, a structural shift to a higher volatility level may have occurred.

1.0 On the Nature of the Recent Behavior in Equity Market Volatility

It has been argued that equity market variability has increased in the last few months, owing to a wide variety of factors. Generally this pickup is dated back to December 1995, or January 1996. Chart 1 illustrates the pickup in interday as well as intraday volatility that has occurred in 1996 relative to what was seen in 1995, on a monthly average basis:

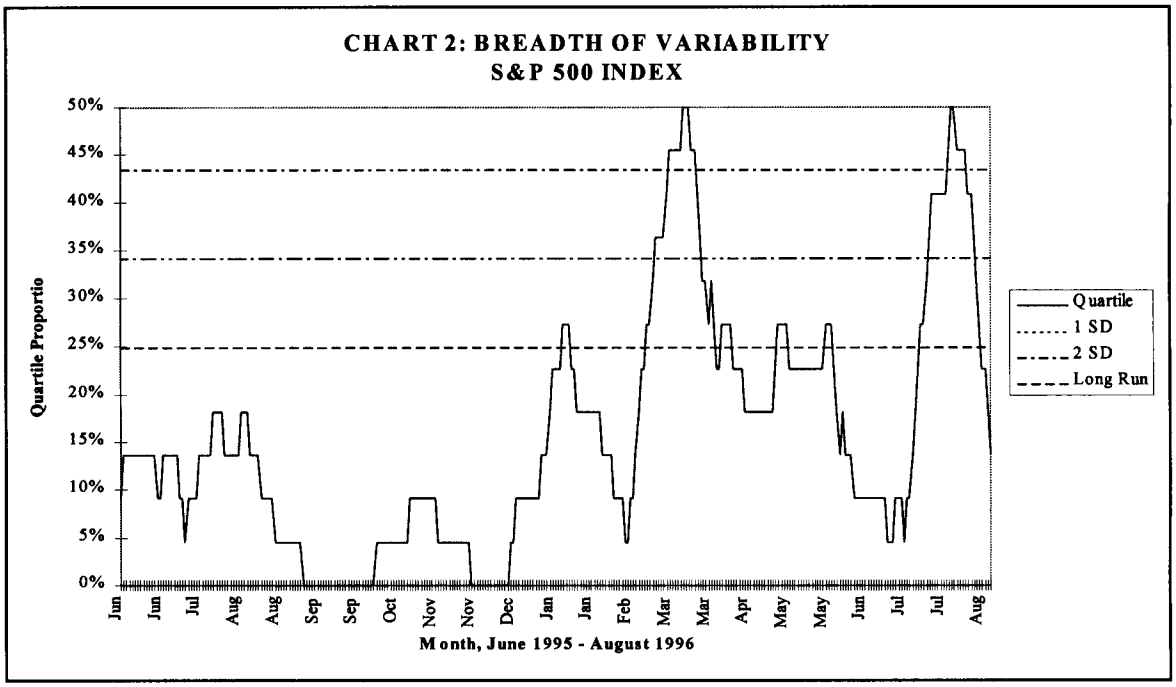


[1] In order to appreciate the nuances of the formulas we have used to define interday and intraday volatility, we recommend a quick review of the Appendix, beginning on page 12.

Chart 1 confirms that there was a pickup in equity market volatility at some point around the turn of last year. This pickup was manifested in both intraday and interday measures of volatility. Increases and decreases in both interday and intraday volatility are seen to be closely aligned over this period, although interday volatility has run a bit higher, on average. The uptick in volatility peaked in March, falling back by June to levels of volatility comparable to those seen through most of 1995. The recent volatility shock in July stands as a significant outlier to the post-March calming in volatility, although preliminary estimates of August volatility are again running at a much quieter level.

The impression given by Chart 1 is that of a sustained increase in volatility since December 1995. Examined in the aggregate, the annualized *interday* volatility in the S&P index over the period 12/1/95 to 8/22/96 (184 trading days) was 12.2%, compared to 7.7% over the six month period prior. However, one need only exclude the largest eight interday moves from this 184 trading day period to drop this volatility measure under 10%. When *intraday* volatility is measured, one need only exclude the largest five intraday ranges to push volatility under 10%. Virtually all of the trading days with the greatest volatility over the last eight months were either in close proximity to the release of a nonfarm payroll report (± 3 days), or were associated with an earnings announcement for a technology stock issue (HP, Intel, and Microsoft, most notably). In fact, 7 of the 12 largest intraday swings (generated either by a nonfarm payroll report or a technology earnings announcement) occurred in a single 4 week period, from July 5 to August 2.

If we examine the quartile proportion data for the last year, we see the same message. Chart 2 below shows the quartile proportion on each day since 6/1/95, along with lines marking the expected value (25%), 1 SD above the expected value (34%), and 2 SD above the expected value (43%).



As can be seen in Chart 2, the frequency of volatile days in the US equity market has been running below average for most of the period from 12/1/95 to present (although not as quiet as in 1995), with concentrations of volatility only once during March and once during July. This lends credence to the idea that volatility, while occasionally strong in 1996, has not been widespread.

2.0 An Event Analysis of Heightened Equity Market Volatility

The analysis above suggests very strongly that the market has become highly sensitized to the release of the nonfarm payroll report ever since last December, although the impact appears to be relatively short-lived each time. Since the equity market absorbed virtually every nonfarm payroll report in 1995 with barely a ripple (indeed, actual volatility never exceeded 12% at any time in 1995, measured on a 22/252 basis), the answer to why volatility is higher in 1996 cannot simply end with the phrase "because nonfarm payrolls have generated volatility."

The notion that volatility has seen a structural shift to a higher level (and is currently transitioning to that higher level) also seems incorrect. If this were the case there would not have been such a concentrated effect of the nonfarm payroll period on volatility (it would have been more evenly spread throughout the months), and the quartile proportion measure would not have spent so much of 1996 running at or below average Indeed there have been times in the past when the quartile proportion measure has run significantly above average for weeks or even months at a time - these periods, such as the post-87 crash and the post-Kuwait invasion, probably represent much truer instances of structural shifts. Interestingly, however, even past periods of clear structural shifts in volatility have had a relatively limited duration, and volatility eventually and always reverts back to its mean.

In our view the answer to the question of 1996's heightened equity market volatility lies not in a search for a structural shift, but instead can be found in an investigation of those factors that have heightened the market's otherwise only moderate long run sensitivity to the release of the nonfarm payroll report. We believe there are three possible factors that have contributed to the heightened sensitivity of the equity market: the forthcoming Presidential election, which may be decided on the strength of the economy and thus may have widely differing implications for the markets; the fear that the Fed may overreact to the strength of the economic data; and the perception that the equity market is far overvalued following last year's spectacular bull market. While nothing about these factors is in any way mutually exclusive as a contributor to volatility sensitivity to the nonfarm payroll report, we examined each similar situation in the past to see how long and how strong volatility stayed high.

2.1 An Event Analysis of Historical Periods Similar to 1996

Based on the data set available of S&P daily changes and ranges from 1982 to present (and interday data back even further), periods of similarity to 1996 were collected and examined. Each is reviewed in turn to assess the depth and length of any uptick in interday or intraday actual volatility.

2.1.1 Prior Presidential Elections

More data are available for the calculation of historical interday volatility than for historical intraday volatility. Thus Table 1 calculates monthly actual volatilities from non-overlapping interday data for the last five Presidential elections. Data subsets were created around each of these elections, starting in January of the election year and ending in December of the following year.

TABLE 1: INTERDAY S&P VOLATILITY BEFORE AND AFTER PRESIDENTIAL ELECTIONS

Month	1976	1980	1984	1988	1992
JAN	13.09%	13.97%	9.95%	35.20%	10.11%
FEB	13.03%	15.54%	16.08%	15.72%	11.26%
MAR	11.83%	22.80%	12.70%	13.67%	7.35%
APR	11.22%	18.18%	11.70%	21.58%	14.31%
MAY	11.11%	13.32%	9.61%	17.84%	9.55%
JUN	10.34%	12.96%	14.43%	16.48%	9.43%
JUL	7.81%	11.84%	10.38%	15.88%	9.95%
AUG	9.45%	14.66%	17.32%	12.35%	6.57%
SEP	10.41%	18.21%	11.46%	13.24%	10.86%
OCT	12.52%	15.79%	12.09%	14.14%	10.65%
ELECTION	12.18%	16.63%	11.27%	13.02%	7.82%
DEC	7.38%	18.74%	12.33%	8.80%	7.46%
JAN	8.49%	13.81%	12.87%	9.60%	6.77%
FEB	6.59%	14.63%	10.15%	12.64%	12.69%
MAR	8.77%	15.48%	10.04%	12.37%	10.60%
APR	11.44%	10.09%	7.61%	10.47%	11.10%
MAY	8.78%	11.09%	9.18%	11.00%	10.23%
JUN	7.53%	10.91%	9.85%	13.22%	8.30%
JUL	9.05%	9.30%	9.30%	9.54%	8.74%
AUG	8.04%	8.66%	8.66%	12.49%	5.23%
SEP	7.65%	10.33%	10.33%	8.53%	7.66%
OCT	9.06%	9.74%	9.74%	26.40%	6.09%
NOV	13.04%	9.86%	9.86%	10.25%	8.48%
DEC	8.80%	11.93%	11.93%	10.99%	5.64%
Pre-Election	**11.22%**	**15.54%**	**11.70%**	**15.72%**	**9.95%**
Post-Election	**8.77%**	**10.91%**	**9.86%**	**10.99%**	**8.30%**
Vol. Decline	**-2.45%**	**-4.63%**	**-1.84%**	**-4.73%**	**-1.65%**

The message to be taken from Table 1 becomes clearer when the summary statistics are examined, rather than when the individual months or elections are reviewed. Based on the median volatility pre-election (January - November of the election year) vs. post-election (December of the election year to December of the following year), we see that interday volatility drops off, sometimes sharply, in the year following an election. The two largest post-election declines (the 80 and 88 elections) may have had other factors at work: pre-election 1980 saw financial markets settling in to an understanding of Paul Volcker's late 1979 change to monetarism (and associated increase in interest rate volatility), while pre-election 1988 saw the markets re-adjusting following the late 1987 market crash (and the ensuing months of record high volatility, from which a return to normality was eventually inevitable). Nevertheless the pattern seems to hold true: although perhaps a 500 bp volatility decline is a bit much to expect this year, a drop in the range of the median decline across the five elections (-184 bps) would be plausible.

As can be seen below in Table 2, the same message is true for the breadth of volatility around elections, as measured by the quartile proportion:

TABLE 2: QUARTILE PROPORTIONS BEFORE AND AFTER ELECTIONS			
MONTH	1984	1988	1992
JAN	19%	80%	27%
FEB	40%	45%	21%
MAR	27%	35%	0%
APR	15%	40%	29%
MAY	18%	33%	10%
JUN	19%	41%	9%
JUL	14%	40%	18%
AUG	39%	30%	5%
SEP	11%	24%	14%
OCT	17%	24%	14%
NOV	10%	14%	0%
DEC	10%	10%	5%
JAN	18%	33%	5%
FEB	16%	21%	16%
MAR	10%	14%	13%
APR	0%	10%	24%
MAY	14%	9%	10%
JUN	10%	23%	0%
JUL	7%	25%	5%
AUG	5%	26%	0%
SEP	10%	10%	5%
OCT	4%	41%	0%
NOV	5%	10%	10%
DEC	14%	15%	0%
Pre-Election	**18%**	**35%**	**14%**
Post-Election	**10%**	**15%**	**5%**

Intraday volatility measures for these same three elections also validate the post-election calming phenomenon.

2.1.2 Anticipations of an Aggressive Fed Tightening

There can be little doubt that the financial markets have been exceptionally sensitive this year to the possibility of an aggressive Fed tightening. A review of the volatility reports from several of the top brokerage firms on Wall Street confirms that most Street analysts attribute the pickup in volatility in 1996 to heightened fears of the Fed, and the possibility that the Fed might overreact to signs of growing economic strength.

There have been numerous occasions in the past when the Fed has switched policy that could be examined for an impact on volatility, and then compared to the current market environment. Greenspan's tightening move in September 1987, which many have offered as a contributing factor to the market crash one month later, is one example. However, we will deal with the aftermath of the October 1987 crash later. A more recent (and possibly better) example would be

the market's reaction to Greenspan's tightening of monetary policy in February 1994. For several reasons this tightening stands out as a prime example of the impact the Fed can have on the market. The unique aspects of this particular tightening episode include:

(1) It was the first tightening following a 17 month period of absolutely no Fed policy changes. Prior to that, the Fed had been in an extended easing mode. There have been few periods of unchanged policy by the Fed that were as long, thus making the tightening in February 1994 quite a change.

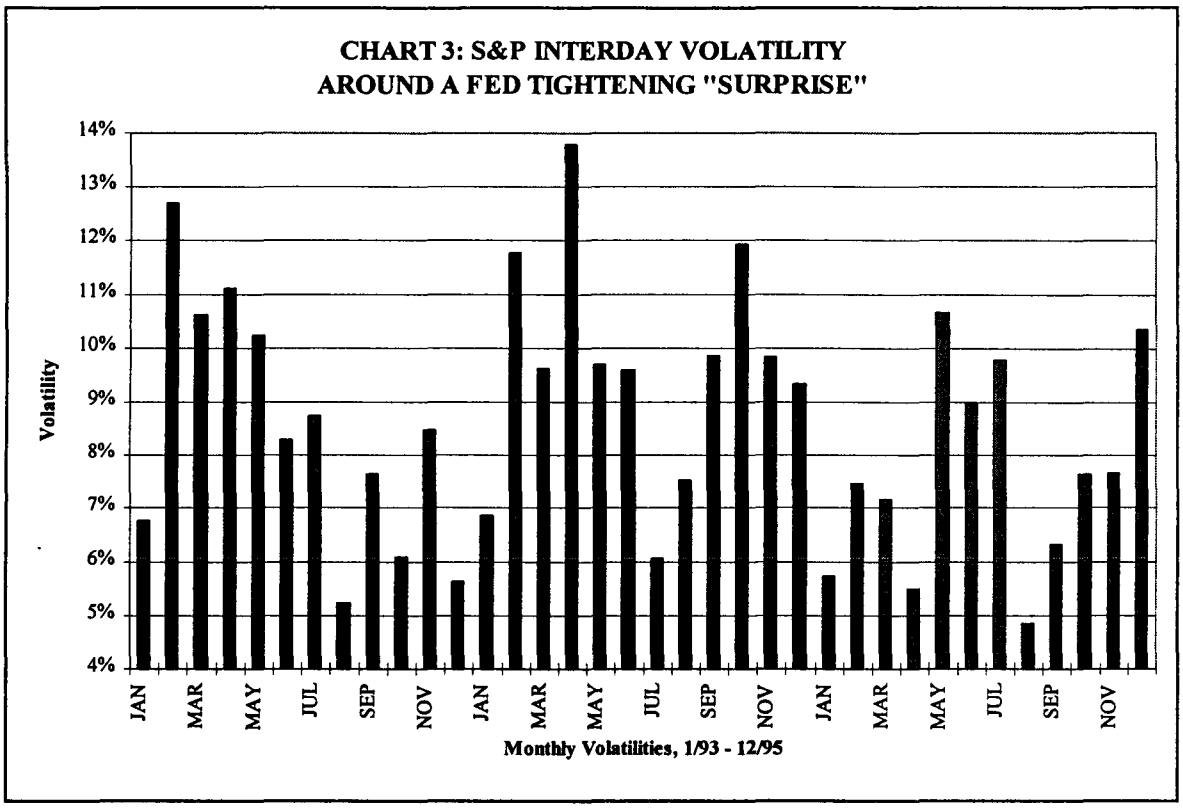
(2) The tightening was the first in the Fed's 70 year history to be formally announced immediately following the conclusion of an FOMC meeting, a practice the Fed continued from that point forward (definitely a paradigm shift in monetary policy implementation).

(3) The follow-on Fed tightening was aggressive: the Fed tightened repeatedly in 1994, and moved short-term real interest rates up by more than 250 bps.

(4) The Fed repeatedly used the nonfarm payroll reports to justify their decision to tighten, setting a tone of apprehension around the release of those numbers that continues to today.

(5) The bond market's reaction to the Fed's 1994 move was excessive: for every tightening the Fed did over the initial six month period following the February 1994 move, the long end of the curve tightened twice as much.

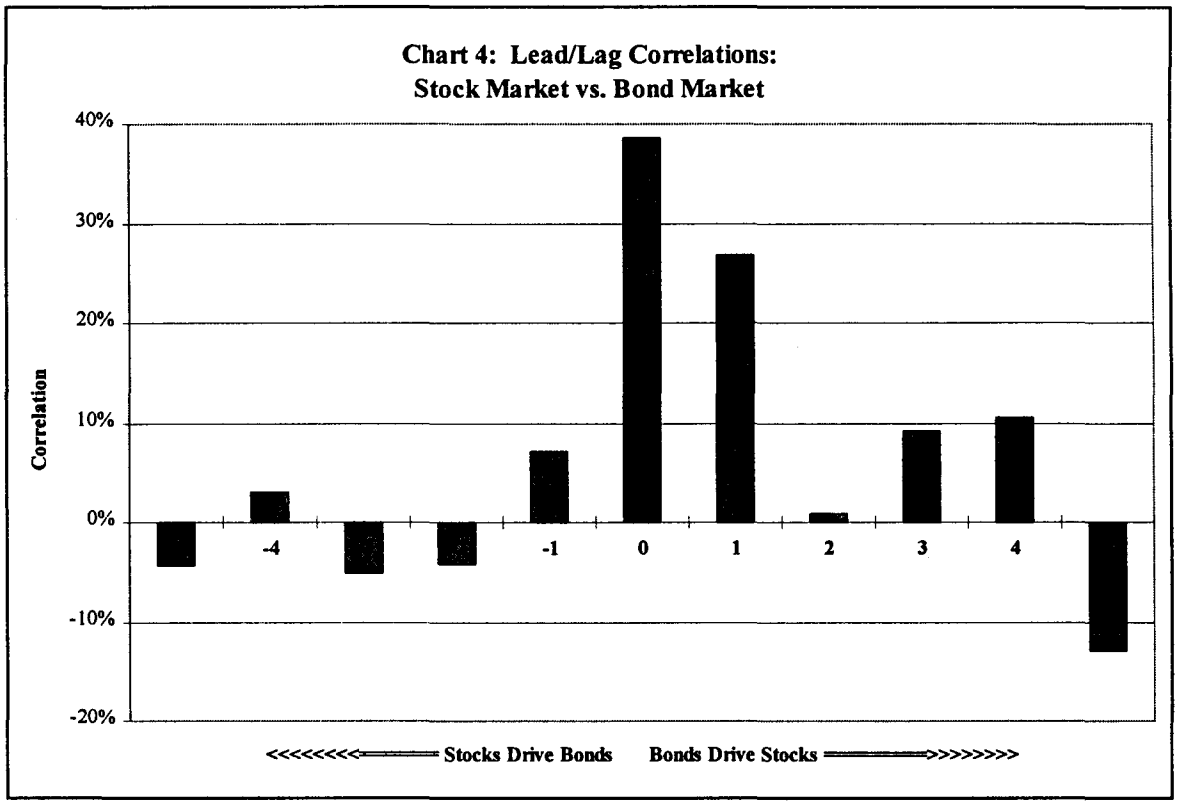
Given these reasons, the period around the February 1994 Fed tightening provides an excellent forum for an event analysis and a comparison to current apprehensions. In Chart 3 below we see the period before, during, and after the Fed's tightening. As can be seen, the equity market was lulled by the Fed's 17 month period of inaction, and the associated bond market inactivity. Starting in February 1994, though, equity market volatility popped higher. Except for February, April, and October of that year, however, equity market volatility repeatedly returned to normal (indeed, subnormal) levels. In fact, April was the only month in which equity volatility even exceeded 12%.



A similar story can be seen in the quartile proportion measure over the same period. While the graph is not presented here, suffice it to say that over this same period the rolling quartile proportion measure rarely exceeded its long-run norm of 25%, and then mainly in April 1994. The breadth of the equity market's reaction to the Fed tightening in 1994 was never that strong, and actually fell back repeatedly and very quickly to low levels. Our intraday volatility measure also tells the same story. Actually, once the overreaction in April had passed, intraday volatility also fell sharply. For the remainder of 1994, fewer than 5% of the trading days saw a one-month intraday volatility reading in double digits.

There is another way to analyze whether anticipation of a Fed move is impacting the stock market: if it is, then it stands to reason that the bond market would react first to any indication that an event would influence the Fed's decision-making (given the bond market's greater sensitivity to issues concerning Fed policy changes), and the stock market would take its cue from the bond market. Thus we would expect to see any large moves in the bond market precede (or at least occur on the same day) as large moves in the stock market. Conversely, we would not expect to see too many large moves in the stock market preceding large moves in the bond market.

Chart 4 provides an interesting test as to whether the bond market has been leading or lagging the stock market. Chart 4 looks at the leading and lagging correlations (leads and lags ranging from 0 to 5 days) of the intraday ranges of the S&P 500 vs. the US long bond futures contract. The period of analysis is again from 12/1/95 to present. As can be seen, the strongest correlation (38.6%) is contemporaneous: that is, when bonds have a wild day, stocks have a wild day. However, the correlation of today's bond market range to tomorrow's stock market range is almost as high (26.8%). On the contrary, the correlation of today's stock market range to tomorrow's bond market range is relatively low (7.1%). In general, the chart shows that the 5 positive lead correlations (when the bond market would be driving the stock market) are, taken as a group, generally larger than the 5 negative lag correlations. [2]



The lesson to be learned from this analysis is clear: equity markets have dealt with Fed policy changes many times in the past, and even moves by the Fed that are a surprise, that are aggressive, and that are conducted uniquely do not affect equity market volatility for more than two or three months. Indeed, the correlation analysis suggests bond market shocks do not have a lasting impact on the stock market of more than a few days.

[2] A more sophisticated test, known as a Granger Causality test, also strongly suggests that bond market variability tended to precede stock market variability during this period. This test does not validate, however, that the bond market variability came from fears of the Fed, nor does it exclude the possibility that other factors influence stock market variability (although it does suggest that any independent factor which influences stock market variability generally does not tend to spill back over to bond market variability).

2.1.3 Fears that the Equity Market has Peaked

The final event that appears to be aggravating equity market volatility this year is the view that the overall equity market has reached a top: consequently, every market reaction to any event (particularly a bearish event) is overblown, since every event is perceived as possibly being the one that will send the market spiraling lower. Since no such event has yet spiraled the market too sharply this year, every overreaction rebounds back to equilibrium, thus adding to the market's choppiness.

In order to study how long markets remain volatile due to "toppishness," we examined volatility during previous periods of toppishness. As a criterion for reaching a top we identified each time that the S&P 500 first reached a point 15% above where it had been six months before and defined that as the start of a period of toppishness. Prior to the current peaking period in 1996, we have identified five periods since 1982 during which a perception of a peaking equity market might have developed. These periods were the following (expanded three months on either side to allow for broader analysis):

Table 3: Periods of Equity Market Plateaus

Staring Point	Ending Point
July 1982	October 1983
December 1985	November 1986
January 1987	May 1988
January 1989	April 1990
January 1991	November 1991

Of the three factors in 1996 that we are examining (elections, Fed policy changes, market peaks), the sensitivity of the market to a peak has the greatest potential for inducing both large volatility and extended volatility. Each of the periods listed above experienced a surge at some point of significant volatility across all the measures we used (interday, intraday, quartile proportion), although the starting point and length of the shift varied substantially from period to period. One fact about the behavior of volatility in each of these plateau periods is universal, however; the upward shifts in volatility seem to have less to do with the fact that the market has achieved a level not seen before as it has to do with the recency of a market correction. Whether the correction is just temporary or *ex post* turns out to be the end of the bull market run, volatility does not increase during market plateaus until after the correction has occurred. For example, in the 82-83 peak, volatility increased twice to nearly 30%, requiring nearly 3 months to wind down to equilibrium levels. Both of these volatility jumps were associated with only modest corrections, however, and the equity market continued to break through to new peaks later (and with relatively low volatility, due to the absence of any further corrections). During the 85-86 peak volatility jumped three times, and again only following moderate corrections: in each case only 1 or 2 months was required for a return to equilibrium volatility levels.

The 1987 peak is a story all its own. After an initial worry that the market had reached a peak in April 87 (a reaction that affected volatility for only 1 month), the market again became worried in September and early October. Once the October 1987 crash occurred, all major volatility measures stayed well above equilibrium for the next 4-5 months. As for the remaining two equity market peaks (89 and 91), both witnessed relatively low volatility over most of their plateau period, with one or two post-correction bounces in volatility that generally lasted only about a month.

Two important conclusions can be drawn from the study of volatility around perceived market peaks. First, it is much more likely that an actual correction from the peak, rather than the perception that the market is experiencing a peak, generates the volatility. Volatility patterns so far this year show a similar pattern of behavior. During March and July of this year (when we saw sharp equity market corrections on March 8 and July 16) volatility spiked only in response to the corrections. Second, while the bounce in volatility following a correction to a peak can be severe, it is not of an extended duration. The worst case scenario was the four month period following October 87. Other examples lasted only 1-3 months.[3] It does not appear that market peaks, or even corrections from those peaks, induce any type of a permanent upward shift in actual volatility. It is doubtful that the current view of toppishness is generating a structurally higher level of volatility.

3.0 Conclusions and Recommendations for the Volatility-Based Options Strategies

Based on the work we have done, we feel comfortable with the following findings:

Finding 1: Equity market volatility in 1996, while higher than that seen in recent years, has resulted more from a small handful of violent trading days than from a broad increase in market choppiness. Indeed, measures that respond to the breadth of market variability rather than its occasional intensity suggest that 1996 has experienced a breadth of market variability consistent with the long run average (higher than that seen in 1995, but not high for the long run).

Finding 2: The concentration of days in 1996 that have generated high volatility have had a clear fundamental driving factor. When the ten largest daily moves are dropped from a volatility measure (either interday or intraday) covering the last eight months, actual equity market volatility drops to single digits. When these ten largest days are examined closely, it is found that seven of the ten are in very close proximity to the release of a nonfarm payroll report.

Finding 3: When the factors that are driving the market's heightened sensitivity to the nonfarm payroll report are examined historically, it is seen that past sensitivity typically is not sustained. We examined such factors as the uniqueness of being in a Presidential election year, the fear that the Fed will clamp down due to strong economic data, and the potential sensitivity to the equity market being perceived as "overvalued" or near a peak. After reviewing several similar situations over the last 14 years, it seems clear that the market does not sustain its heightened sensitivity for long, a return to equilibrium in equity market volatility typically takes between 1 to 4 months.

CONCLUSION: The bulk of the evidence points away from the hypothesis that equity market volatility has incurred a structural shift to a higher equilibrium, or that it has begun a new trend higher. The evidence leans to the argument that for a handful of identifiable and temporary reasons, the equity market has developed heightened sensitivity to certain events, namely the release of important economic data. History shows, however, that previous periods of similar heightened sensitivity did not last more than a few months.

RECOMMENDATIONS: The issue of whether equity market volatility is currently transitioning to a higher level or whether it is just experiencing occasional temporary spikes is important to anyone engaged in volatility trading or option overwriting. In particular, it would be unwise to engage in short-term option overwriting during a period of rising volatility, since any directional bet taken (or any belief that the option was intrinsically overvalued) might be overwhelmed by a continuing move

[3] It should be pointed out that a one month period is generally the shortest time period over which a spike in volatility will need to be observed in order to see the volatility measure fall, if the volatility measure is itself a rolling one-month measure. In point of fact it may have taken even less time for the impact of the volatility spike to subside.

higher in equity market volatility. We believe, however, that this is not an uncontrollable risk. In our view volatility continues to exhibit mean-reverting behavior, falling quickly back to a relatively low mean level shortly after any generating event. The real risk is that the occasional event (mainly nonfarm payroll releases and certain earnings announcements) have become more violently received due to such factors as the Presidential election cycle and nervousness over the Fed. This fact offers both risk management and arbitrage opportunities. Properly timed, option overwrite programs or volatility trades can be initiated as soon as a nonfarm payroll related spike occurs, and taken off during the following reversion to the mean.

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Appendix

Data and Methodology

A.1 Data Sources

Daily high, low and closing index levels for the S&P 500 cash index were collected from Datastream and DRI for the entire period of the existence of S&P 500 futures trading (April 1982 to August 1996). Holiday closures were dropped from the sample, so that any close-to-close calculations are strictly from one trading day to the next.

A.2 Calculation of Ranges and Changes

For each trading day a daily range and a daily change were calculated using the natural logarithm of the appropriate ratio:

$$RNG_t = LN\left(\frac{HI_t}{LO_t}\right)$$

$$CHG_t = LN\left(\frac{CLOSE_t}{CLOSE_{t-1}}\right)$$

A.3 Calculation of Variability Measures

Three measures of the depth and breadth of the equity market's variability were used in this study: An interday actual volatility, an intraday actual volatility, and an intraday quartile proportion. They are defined as follows:

A.3.1 Interday Actual Volatility

This calculation is the standard 22 day/252 day standard deviation measure, calculated using the close-to-close change measure listed in A.2. This formula is expressed as:

$$INTER_t = \sqrt{\frac{\sum_{i=0}^{21}\left(CHG_{t-i} - \overline{CHG}\right)^2}{21}} \times \sqrt{252}$$

where:

$$\overline{CHG} = \frac{\sum_{i=0}^{21} CHG_{t-i}}{22}$$

A.3.2 Intraday Actual Volatility

This formula, taken from Brown [1990], is an attempt to model intraday actual volatility in a price series for which there is only high and low price information available. Other measures of intraday volatility that rely on numerous intraday readings are available, but there is wide disagreement as to the proper manner in which they should be calculated. The formula by Brown is expressed as:

$$\mathbf{INTRA}_t = \sqrt{\frac{.361}{22}\sum_{i=0}^{21}\left[\mathbf{LN}(\mathbf{HI}_{t-i}) - \mathbf{LN}(\mathbf{LO}_{t-1})\right]^2} \times \sqrt{252}$$

The logic behind this number is based on the relationship of the variance of a series that is drawn from a normal distribution to the variance of its order statistics (minima and maxima). They are related by a factor of proportionality, the inverse of four times the natural logarithm of two, or 0.361.

A.3.3 Intraday Quartile Proportion

This measure is one that I devised in order to show the breadth of the market's variability, rather than its depth. First I calculate the cutoff level for the upper quartile (top 25%) of all the daily intraday ranges across the entire sample. As a point of information, this cutoff value was 1.2672% across 3,618 trading days examined. At current levels of the S&P 500 index (665), this would translate into a daily range of 8.4 S&P points, which says that any current daily range that is observed to be larger than 8.4 S&P points would rank in the top 25% of all daily ranges observed for the S&P 500 cash index since futures trading began.

Once the quartile level cutoff is established, each trading day in the sample is flagged as to whether it falls in the upper quartile or not. By definition 25%, or 905 trading days, were flagged. I then calculated a running percentage of how many days within a moving 22 day window were in the top quartile. This measure can range between 0% and 100% (and has), and should be 25% in an otherwise typical 22 day period. In order to determine whether the quartile proportion observed is significantly different from what would be expected (i.e., 25% should be expected on average), we can use the formula for a 95% confidence interval around a sample proportion:

$$\Pi \in \mathbf{P} + 1.96\sqrt{\frac{\mathbf{P}\cdot(1-\mathbf{P})}{\mathbf{n}}}$$

where:

$\mathbf{P}$ = Observed Quartile Proportion

Π = True Proportion

n = Sample Size

This formula gives a 95% confidence interval around the sample quartile proportion. For example, if we observed a quartile proportion of 55% in a 22 day sample this would be significantly different from 25% at the 95% confidence level, since it exceeds the calculated interval cutoff of 45.8%. Of course larger sample sizes would make the confidence interval tighter.