How to tell if options are cheap

The use of volatility cones to determine whether options are cheap or dear.

Galen Burghardt and Morton Lane

The single greatest challenge in trading options is determining whether options are cheap or expensive.

A trader who buys or sells an option takes a position on the volatility of whatever underlies the option. The price of the option is directly related to the market's perception of the underlying's volatility. If the market expects high volatility, option prices will be high. If the market expects low volatility, option prices will be low.

The buyer of an option can profit if either of two things happens:

1. The realized volatility of the underlying turns out to be greater than the volatility implied by the price paid for the option,[1] or
2. The market revises upward its perception of how volatile it believes the underlying is likely to be.

By the same token, an option seller can profit from realized volatility that is lower than implied volatility or from a decrease in the market's perception of volatility.

We propose to show how one can use information about the maturity structure of historical volatilities, which we represent with volatility cones, to determine whether options are cheap or dear.

VOLATILITY IS NOT CONSTANT

What makes option trading a challenging activity is that the world of options does not conform to the world described by Fischer Black and Myron Scholes in their seminal work on option pricing. In that world, volatility is both known and constant. Instead, what we find is that the observed or historical volatility of any traded commodity bounces around from period to period. Further, the market continuously revises its estimates of how volatile markets are likely to be.

Both of these volatility traits are illustrated in Figures 1 and 2. Figure 1, for example, shows a running history of two measures of Eurodollar futures volatility for the year from June 1987 to June 1988. The first is the thirty-day historical volatility of the June 1988 futures contract (dashed line). The second is the level of volatility implied by at-the-money options on the June 1988 futures contract (solid line). Figure 2 provides a similar comparison for September

FIGURE 1

EURODOLLAR JUNE 1988 IMPLIED VERSUS HISTORICAL (30 TRADING DAYS) VOLATILITIES
(Period: June 1, 1987 to June 13, 1988)

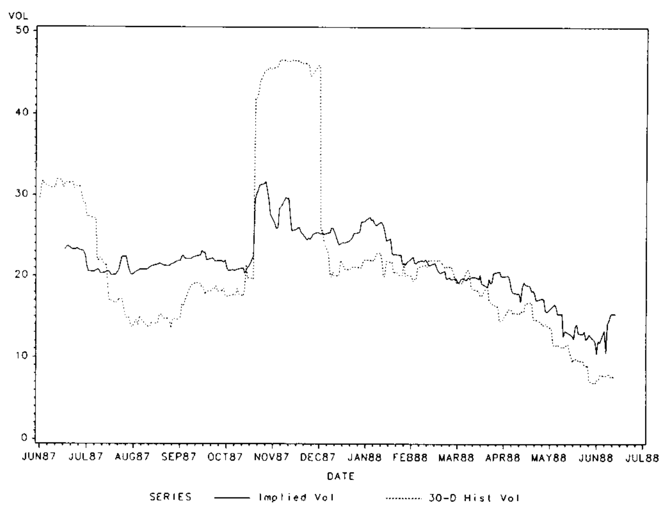

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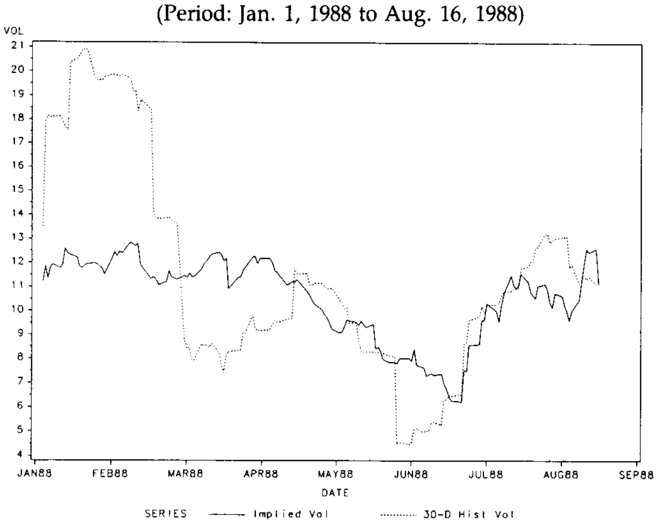
FIGURE 2

JAPANESE YEN SEPTEMBER 1988
IMPLIED VERSUS HISTORICAL
(30 TRADING DAYS) VOLATILITIES
(Period: Jan. 1, 1988 to Aug. 16, 1988)



Japanese yen futures and options from January 1988 to August 16, 1988.

HOW CAN YOU TELL IF AN OPTION IS CHEAP?

In the face of such variability, how can the option trader decide if an option is cheap or expensive?

Our own experience indicates that traders place considerable weight on a comparison of implied volatility with a fixed-horizon historical volatility. For example, historical volatilities frequently are estimated over ten-, twenty-, and thirty-trading day periods. Such periods are short enough for the observed volatility information to be fairly current and long enough for the standard deviation estimates to be free of really wild errors.

Do such comparisons provide a reliable guide to whether an option is cheap or expensive? We think not.

To see why, consider this problem. An option has several key characteristics, including its exercise price and its time to expiration. Thus, any reading on implied volatility taken from an option is a reading on option traders' forecasts of the volatility of the underlying over the remaining life of the option. Implied volatility taken from an option with two weeks to expiration is a two-week forecast of the underlying's volatility. Implied volatility taken from an option with two months to expiration is a two-month forecast of volatility.

On any given day, one can find options on essentially the same underlying but with expirations that are anywhere from one to three months apart. In stock options and in most futures options, expirations are spaced three months apart. In currency options, both cash and futures, options are spaced one month apart, at least for the first three months. Thus, one can find implied volatilities that provide volatility forecasts over substantially different horizons.

Further, these horizons grow smaller by one day with each day that passes. For example, bond futures options that trade today might have expirations of three weeks, three months and three weeks, and six months and three weeks. Tomorrow, each of these options will be one day closer to expiration, and the corresponding volatility forecast from each of the options will cover a horizon that is one day smaller.

FINDING THE APPROPRIATE HISTORICAL HORIZON

Because an option has a specific time horizon — its time to expiration — any comparison of its implied volatility with a fixed-period historical volatility is inappropriate. What we need is a tool for comparing an option's volatility forecast with historical volatility experience over the same or similar horizons. That is, implied volatilities from four-month options should be compared with four-month historical volatilities, while implied volatilities from one-month options should be compared with one-month historical volatilities. Put differently, the only option for which a thirty-trading-day historical volatility is an appropriate standard is an option with thirty trading days remaining to expiration.

VOLATILITY CONES

Our answer to this need is the volatility cone. Examples are shown in Figures 3 and 4 for Eurodollar and Japanese yen futures and options.

The purpose of a volatility cone is to illustrate the ranges of volatility experience for different trading horizons. For example, a one-year span can be broken up into one-day, one-week, and one-month periods. This would give us roughly 250 one-day volatility estimates, fifty-two one-week volatility estimates, and twelve one-month volatility estimates.

For the cones shown in Figures 3 and 4, we started with two years of trading data and estimated historical volatilities over periods of one month, three months, six months, and a year. Because we moved forward in one-month increments, this procedure produced twenty-four one-month historical volatilities, twenty-two three-month historicals, nineteen six-month historicals, and thirteen one-year historicals. We could have used daily rather than one-month increments, of course, but the value of the additional information would have been small.

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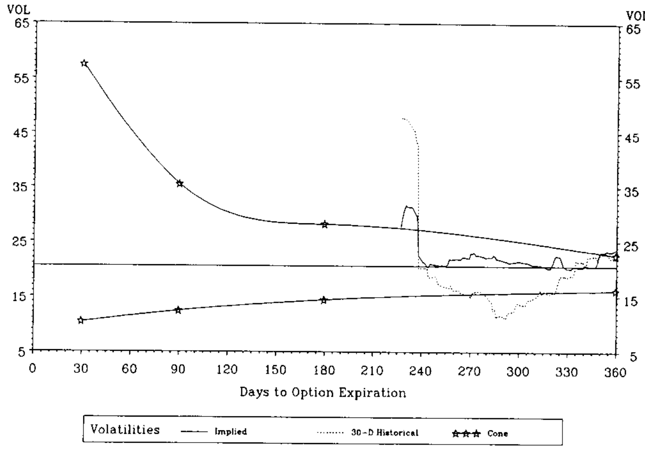
FIGURE 3

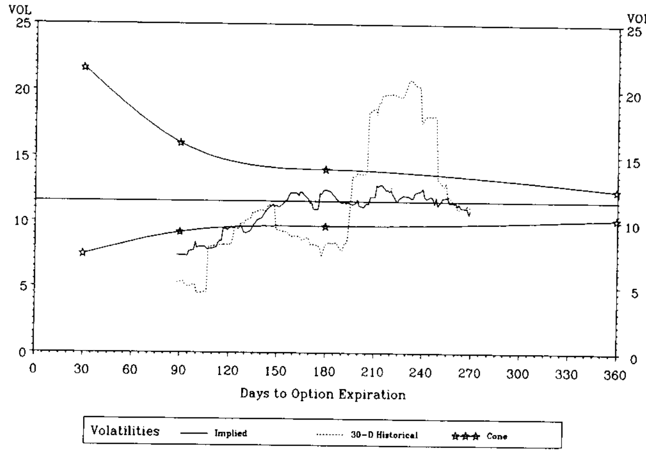
MATURITY STRUCTURE OF JUNE 1988
EURODOLLAR VOLATILITY:
IMPLIED VOLATILITY VERSUS 30-DAY
HISTORICAL VOLATILITY



Time Period for Historical Cones: Nov-85 through Oct-87
Source : DCNYF Research Group.

FIGURE 4

MATURITY STRUCTURE OF SEPTEMBER 1988
JAPANESE YEN VOLATILITY:
IMPLIED VOLATILITY VERSUS 30-DAY
HISTORICAL VOLATILITY



Time Period for Historical Cones: May-86 through Apr-88
Source : DCNYF Research Group.

The historical volatility estimates used to construct the cones are shown in Table 1 (for Eurodollars) and Table 2 (for Japanese yen). In the first data column of Table 1, we find that the highest one-month historical volatility was 57% during — not surprisingly — October 1987. The quietest month was November 1985, when historical volatility was only 10%.

What Can Be Learned From Volatility Cones?

One of the most important lessons to be learned from volatility cones is that short-term historical volatilities are far more variable than long-term volatilities. For example, while one-month Eurodollar historicals ranged from 10% to 57%, three-month historicals ranged from 12% to 35%. That is, the range of volatilities was a full twenty-four percentage points narrower. Note, too, that the range of six-month historicals was smaller still.

From a trader's perspective, however, the most important use of the volatility cone is in deciding whether an option is cheap or expensive. To show how this can be done, we have overlaid two volatility series on each of the cones. For Eurodollars, the dashed line in Figure 3 represents the thirty-trading-day historical volatility shown in Table 1, and the solid line represents the implied volatility taken from at-the-money June 1988 Eurodollar options. For yen, the solid line in Figure 4 represents the implied volatility taken from at-the-money September 1988 options.

The chief difference here, however, is that time runs from right to left. For example, in September 1987, the June Eurodollar option had ten months remaining to expiration, and its implied volatility is recorded in the cone chart at 300 days. In the middle of December, the June Eurodollar option had six months left to expiration, and its implied volatility is recorded at 180 days.

TABLE 1

Eurodollar Lead Contract Historical Volatilities

Period Ending*	1-Month	3-Month	6-Month	1-Year	2-Year
1985					
November	10.338				
December	16.248				
1986					
January	18.067	15.921			
February	13.416	15.998			
March	13.957	15.286			
April	24.683	18.114	16.741		
May	18.872	18.796	17.657		
June	22.809	22.469	19.063		
July	17.923	19.965	19.034		
August	17.132	19.015	19.284		
September	23.444	19.660	20.810		
October	14.146	20.050	19.656	18.343	
November	12.047	18.203	18.671	18.363	
December	11.351	12.767	16.984	17.669	
1987					
January	12.402	12.335	16.355	17.707	
February	16.320	13.677	16.112	17.694	
March	14.417	14.392	14.349	17.727	
April	20.313	17.390	14.783	17.391	
May	19.113	18.035	15.902	17.296	
June	19.957	20.899	17.797	17.417	
July	13.456	19.176	18.151	17.266	
August	11.476	15.408	17.537	16.679	
September	19.014	15.281	18.269	16.107	
October	57.415	35.415	28.098	22.528	20.536
Maximum	57.415	35.415	28.098	22.528	20.536
Minimum	10.338	12.335	14.349	16.107	20.536

*Period ending on last trading day of each month

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TABLE 2

Japanese Yen Lead Contract Historical Volatilities

Period Ending	1-Month	3-Month	6-Month	1-Year	2-Year
1986					
May	17.193				
June	12.600				
July	12.842	13.430			
August	10.676	11.353			
September	9.914	10.870			
October	11.587	10.501	11.950		
November	10.258	10.227	10.806		
December	7.438	9.495	10.097		
1987					
January	12.768	9.982	10.230		
February	7.928	9.693	9.822		
March	8.458	9.880	9.608		
April	11.447	9.430	9.613	10.845	
May	10.393	10.276	9.818	10.305	
June	9.879	11.120	10.436	10.252	
July	11.894	11.062	10.231	10.182	
August	12.778	11.372	11.068	10.447	
September	9.104	11.188	11.117	10.400	
October	13.926	12.075	11.439	10.627	
November	10.134	11.129	11.169	10.706	
December	13.968	12.974	11.909	11.240	
1988					
January	21.603	15.952	13.987	12.274	
February	8.159	15.582	13.423	12.302	
March	10.050	11.474	13.564	12.400	
April	9.781	9.139	12.971	12.229	11.539
Maximum	21.603	15.952	13.987	12.400	11.539
Minimum	7.438	9.139	9.608	10.182	11.539

*Period ending on last trading day of each month

Where Do the Cone Charts Make a Difference?

To see how the cone charts put a different slant on the question of whether options are cheap or dear, consider two different situations:

- Eurodollar options in late October and early November of 1987
- Japanese yen options in late May and early June of 1988

Following the market explosion surrounding the stock market crash on October 19, interest rates (for a fairly brief period, as it happened) became considerably more volatile. The effect on Eurodollar volatility is apparent in Figure 3. Option traders responded with substantial increases in the prices they were willing to pay for options.

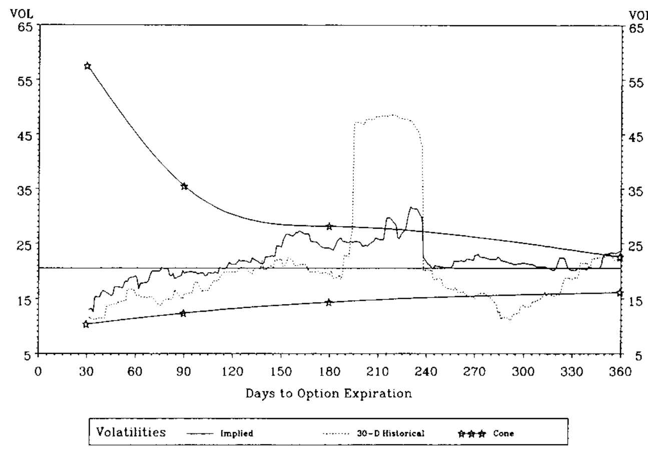
The big question is this. During the weeks following October 19, were Eurodollar options cheap or dear? The standard comparison would have suggested that they were cheap. Even at 30% volatility, options were trading at levels well below the thirty-trading day historical volatilities that were observed at the time.

Note, however, that the implied volatility path lies outside the volatility cone. What does this mean? The June 1988 Eurodollar options had anywhere from eight to nine months remaining to expiration during this time. During the two years leading up to the episode, the highest level of volatility recorded for a nine-month period was somewhere between 24% and 29%. At 30% and above, June Eurodollar options were trading at volatilities higher than the highest nine-month historical volatility recorded any time during the two years up to and including October 1987.

Thus, we would count the June 1988 Eurodollar options as expensive, even though implied volatilities from these options were well below thirty-day historical volatilities. The correctness of this view is borne out in Figure 5, which shows how both implied

FIGURE 5

MATURITY STRUCTURE OF JUNE 1988
EURODOLLAR VOLATILITY:
IMPLIED VOLATILITY VERSUS 30-DAY
HISTORICAL VOLATILITY



Time Period for Historical Cones: Nov-85 through Oct-87
Source : DCNYF Research Group.

and historical Eurodollar volatility played out during the months following the Crash. Selling Eurodollar options after the Crash would have been highly profitable. Buying Eurodollar options would have been an extraordinarily costly mistake.

A second example is provided in Figure 4. In late May and early June, observed volatility in September 1988 Japanese yen futures was very low. Similarly, September options on those futures were trading at very low levels of implied volatility. What we can see, however, is that while short-term historical volatilities were very low during this time, September yen options — which had three months left to expiration — were trading at volatilities that were far lower than any three-month historical volatility observed during the two years leading up to this period.

Thus, we would count the September 1988 Jap-

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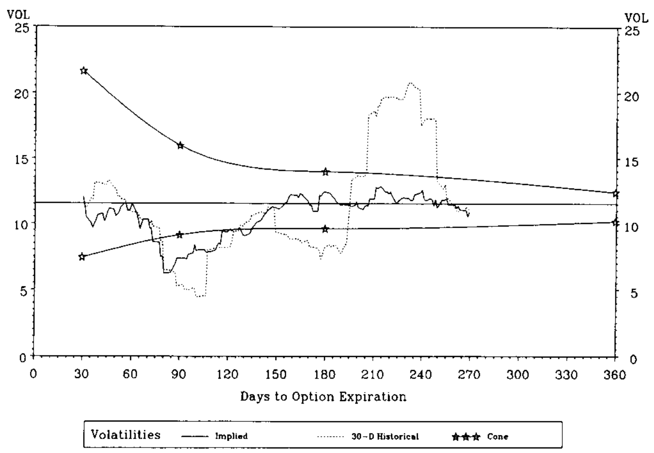
anese yen options as cheap even though they were trading at levels higher than thirty-trading day historical volatilities. Figure 6 shows that both implied

FIGURE 6

MATURITY STRUCTURE OF SEPTEMBER 1988 JAPANESE YEN VOLATILITY: IMPLIED VOLATILITY VERSUS 30-DAY HISTORICAL VOLATILITY



Time Period for Historical Cones: May-86 through Apr-88
Source: DCNYF Research Group

and historical yen volatilities came back inside the cone well before the September yen options expired. Those who bought yen options during late May and early June reaped handsome profits. Those who were selling yen options suffered substantial losses.

How Useful Are the Cones as a Guide to Cheapness?

For those who are steeped in the efficient market tradition, a natural question is whether the position of implied volatility relative to a volatility cone provides any useful information about whether options are cheap or dear. Our understanding of efficient markets is that prices embody all relevant information, including information about the history of prices. In the world of options, efficiency in this sense would mean that implied volatilities, which are derived from option prices, should reflect all relevant information.

If implied volatilities do contain all relevant information about the future course of volatility, there are two empirical consequences. First, implied volatilities should be unbiased forecasts of subsequently realized volatilities. Second, information about the distribution of historical volatilities, or, what is the same thing, information about the position of implied volatility relative to an historical volatility cone should provide no information about the subsequent distribution of realized volatilities.

What we have, then, are two competing hypotheses about the relationship between implied and realized volatilities. These are

- The efficient market (all relevant information) hypothesis, under which the conditional distribution of subsequently realized volatilities is centered around implied volatility
- The volatility cone hypothesis, under which the distribution of historical volatilities can be used to improve forecasts of subsequently realized volatilities

The efficient market hypothesis is illustrated by panels A and B of Figure 7. Panel A shows the distribution of N-day historical volatilities, where N is the number of days left in the option's life. Suppose, now, that the level of volatility implied by the prices of options with N days remaining to expiration is toward the upper end of the distribution, which puts it in the upper reaches of the volatility cone.

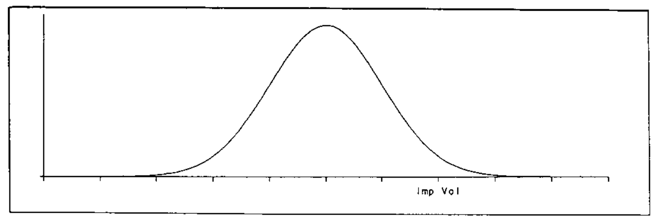
If the efficient market hypothesis is a reasonable characterization of the world, then the distribution of realized volatilities would look like the distribution drawn in Panel B. In an efficient market the probability of profiting from a delta-balanced sale of options would be roughly half, as shown by the shaded area in Panel B.

In contrast, if the volatility cone hypothesis is a better representation of the world, then the distribution of realized volatilities should look like the distribution drawn in Panel C. In this case, the location

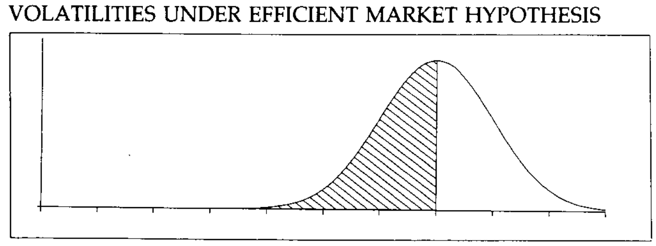
FIGURE 7

COMPETING VOLATILITY HYPOTHESES

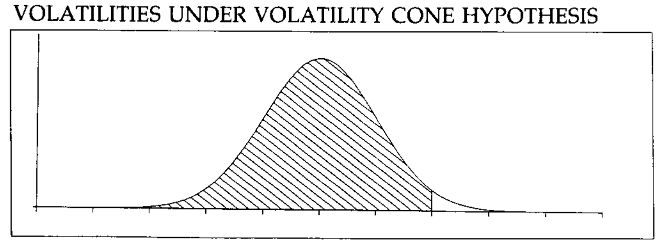
A. DISTRIBUTION OF HISTORICAL VOLATILITIES



B. CONDITIONAL DISTRIBUTION OF REALIZED VOLATILITIES UNDER EFFICIENT MARKET HYPOTHESIS



C. CONDITIONAL DISTRIBUTION OF REALIZED VOLATILITIES UNDER VOLATILITY CONE HYPOTHESIS



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of implied volatility in the cone is a predictor. Moreover, the probability of profiting from a delta-balanced sale of options would be substantially larger than under the efficient market hypothesis.

To test the efficient market hypothesis, we undertook the following exercise with Japanese yen for April 1986 through July 1988. First, we looked for days when implied volatilities in yen options were trading either in the top decile or bottom decile of implied volatilities over the period. Second, for options with three to six months to expiration (that is, comparatively long-dated options), we calculated realized volatilities over the actual days left in each option's life and took the difference between the resulting volatility and the option's implied volatility.

The results are shown in Table 3. For days when implied volatility was in the upper range of the volatility cone, we found that implied volatility forecasts of realized volatility were systematically too high. The largest difference between realized and implied volatilities was −4.39%. Had you sold those

TABLE 3

Difference Between Realized and Implied Volatility for Japanese Yen Options With More Than 3 Months Left To Expiration (April 1986 through July 1988)

Summary Statistic	Implied Volatility at High End of Volatility Cone*	Implied Volatility at Low End of Volatility Cone**
Maximum	−4.39	+4.83
Minimum	+0.82	−0.20
Mean	−2.93	+1.71
Standard Deviation of Mean	0.19	0.32
T-Value	−15.40	5.34
Number of Observations	46	20

*Implied Volatility in Top Decile
**Implied Volatility in Bottom Decile

options and delta-balanced the position to expiration, you would have made a profit consistent with selling volatility 4.39 percentage points higher than it proved to be. The worst case was an error on the high side of 0.82 percentage points. On average, you would have sold volatility 2.93 percentage points higher than realized volatilities. And, as shown in the bottom panel of the table, the average gain was not only large, but it was also different from zero at any reasonable level of statistical significance.

For days when implied volatility was in the lower range of the volatility cone, the results are just the opposite. Implied volatility forecasts proved to be biased downward, with a maximum error of 4.83 percentage points, and an average error of 1.71 percentage points. Had you bought options at these implied volatilities and delta-balanced them to expiration, your average volatility gain would have been 1.71 percentage points. Your worst loss would have been −0.2 percentage points. Again, the average gain is different from zero at any reasonable level of statistical significance.

What these results seem to show is that options markets are not yet entirely efficient, at least when implied volatilities are trading at very high or very low levels in markets for long-dated options. Put differently, the position of implied volatility relative to the volatility cone seems to provide useful and reliable information about whether the options are cheap or dear.

How Robust Are the Cones?

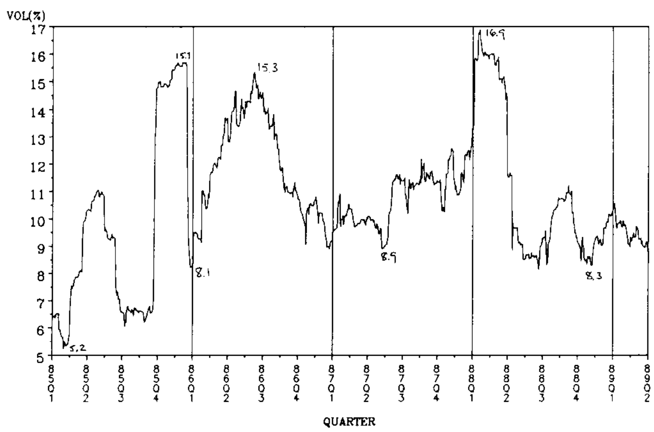
How much data does one need to construct a reliable volatility cone? The answer depends on the market you wish to examine, but two years or more of data would seem to be adequate, at least if there has been no fundamental change in the forces driving the market.

Figure 8 shows the history of three-month historical volatilities for Japanese yen futures. How well would a cone constructed on January 1, 1987, using data for 1985 and 1986, have held up in 1987? The highest three-month historical volatility over 1985 and 1986 was 15.7%; the lowest historical volatility was 5.2%. Thus, the upper and lower bounds of the volatility cone at three months to expiration would have been 15.7% and 5.2%, respectively.

How well did the cone hold up in 1987? Very well. There were no new highs and no new lows, and

FIGURE 8

LEAD JAPANESE YEN FUTURES 3-MONTH HISTORICAL VOLATILITY
(Period: January 1, 1985 to April 18, 1989)



Lead Series Switches on the first day of the expiring lead contract month
Source : DCNYF Research Group.

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the distribution of volatilities stayed near the middle of the range. Further, it is easy to see that a two-year cone constructed with data from 1986 and 1987 would have served quite well through 1988. To be sure, there were both a new high (16.9% versus 15.3%) and a new low (8.3% versus 8.9%), but the differences were comparatively small.

CAVEAT

We have shown that volatility cones can be useful in determining whether options are cheap or dear. Even so, whenever the cones suggest that options are unusually cheap or dear, there is merit in taking a hard look at the world to see whether anything fundamental has changed to affect the long-run outlook for volatility.

For example, when the Federal Reserve put a reserves targeting policy into place in the fall of 1979, there was a dramatic upward shift in the distribution of interest rate volatility. And, when the Fed abandoned that policy at the end of 1982, the distribution shifted downward again.

Thus, whenever the volatility cone standard suggests either a sale or purchase of volatility, it is certainly worth one's while to review changes in economic policy (or in the market for stock options, the capital structure of the firm) that would have a bearing on the volatility generating machine that drives the options market.

CONCLUSIONS

We have shown two things here. First, the appropriate standard of comparison for gauging whether implied volatilities are high or low is an historical volatility that corresponds to the time left in the option's life. One-month options should be judged using one-month historical volatilities. Three-month options should be judged using three-month historical volatilities. This differentiation is important, because the range of observed one-month historical volatilities is considerably larger than the range of observed three-month historical volatilities.

Second, the market for longer-dated options does not appear to be entirely efficient.[2] At least in those instances when implied volatilities are trading at extremely high or extremely low levels, we find that implied volatilities are biased forecasts of realized volatilities, and that there is valuable information contained in the distribution of historical volatilities. Another way of putting this is that longer-term volatility forecasts, as embedded in the prices of longer-dated options, appear to be overly sensitive to short-term volatility developments. Consequently, volatility cones provide a useful and potentially profitable guide as to whether options are cheap or dear.

[1] Realized volatility and historical volatility are both standard deviations of percentage changes in the price of the underlying security or futures price. Percentage changes most often are calculated using daily closing prices, although there are several variants and refinements that can be brought to bear on volatility estimation.

[2] We first introduced the concept of volatility cones in a May 4, 1988, memorandum, "Is Currency Volatility Low Enough to Buy?" and in an August 29, 1988, follow-up, "Results of Recommended May 4th Purchase of Currency Volatility." Since then, we have encountered an October 1988 piece by Steven Pomerantz, "An Information-Based Model of Volatility" (Morgan Stanley), which deals with what the author calls a volatility time curve.

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