Fischer Black
on
OPTIONS

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ONE WAY TO ESTIMATE VOLATILITY

The volatility of a stock I define as the standard deviation of the return on the stock. The return on a stock is the change in the stock price over some interval, plus any dividends or other distributions, expressed as a fraction of the stock price at the start of the interval. For example, an annual volatility of 20% can be thought of as follows: the typical move in the stock over the next year, if the volatility doesn't change, will be 20%. More precisely, there is about a 2/3 chance that the stock will end up the next year between 20% above its expected value and 20% below its expected value, including dividends.

Research on how volatilities change over time is moving ahead, partly because the Center for Research in Securities Prices (sponsored by Merrill Lynch, Pierce, Fenner and Smith, Inc.) at the University of Chicago now has tapes available of daily stock prices and returns since 1962. The data on these tapes is far more accurate than data from any other source that I know of.

Since volatilities do change over time, daily data lets us make much better estimates of volatility than weekly or monthly data. We can use lots of data points without going too far back in time. In 4 months, we can have about 84 data points. With monthly data, it would take 7 years to get 84 data points. Data from seven years ago just isn't very relevant in estimating current volatility.

For recent daily stock prices (and also for option prices and dividends), I have been using the Interactive Data Corporation system. The IDC main office is in Waltham, Massachusetts. I use their data in making my estimates of future volatility for the stocks underlying listed options. The CRSP data from the University of Chicago is also based on IDC prices and dividends.

One thing that the research done to date has shown is that the volatilities on different stocks tend to move together. When some stocks get more volatile, the other stocks tend to get more volatile at the same time. In other words, when the market in general is more volatile, most stocks tend to be more volatile.

This should not be too surprising, because large moves in the market tend to be accompanied not only by large moves in individual stocks, but by large moves in the same direction in individual stocks. If stocks tend to move together in direction as well as in magnitude, then we'd expect that their volatilities would tend to move together. The underlying reason for this is that when significant information comes in that affects business generally, it will affect most individual stocks. When the rate of arrival of such information is high, the volatilities of most individual stocks will be high.

Another thing that the research done to date has shown is that most (but not all) changes in volatility are temporary. When a stock's volatility (or the market's volatility) was much lower in the most recent month than in earlier months, it is very likely that its volatility will jump back up again. It may not jump all the way back up in the next month, though, so we may want to forecast a substantial increase in the next month followed by smaller increases in later months. Similarly, if the volatility was much higher in the most recent month, we will forecast a more or less rapid decline in volatility in future months.

This means that when we forecast the volatility of a stock because we want to estimate the value of an option, we will use a forecast that depends on the maturity of the option. The volatility of the stock changes, and what we want is an estimate of something like the average volatility of the stock over the life of the option. If we're not forecasting any changes in volatility for the stock, then we'll use the same volatility estimate for all option maturities. But if we're forecasting an increase in the stock's volatility, we'll use higher volatility estimates for longer maturity options. And if we're forecasting a decrease in the stock's volatility, we'll use lower volatility estimates for longer maturity options.

My research has shown also that there is a striking tie between changes in a stock's price and changes in its volatility; and between changes in the level of stock prices generally and changes in the volatility of stocks generally. When the price goes down, the volatility goes up, and when the price goes up, the volatility goes down.

Or perhaps I should say that when the volatility goes up, the price goes down, and when the volatility goes down, the price goes up. Because we don't know the direction of causation. The changes in price may cause the changes in volatility, or the changes in volatility may cause the changes in price. Or the causation may run in both directions at once. Or, more likely, there may be common factors causing both changes in price and changes in volatility. No matter which way the causation goes, though, we can use changes in price to forecast changes in volatility.

What's most striking about this tie is its strength. It seems to be so strong that when a stock goes up, its dollar volatility goes down along with its percentage volatility. If this were true, it might mean something like this: suppose that a $20 stock has a typical daily move of 1/2; then it doubles to $40, and its typical move goes down to 3/8. If this happened, the percentage volatility of the stock would decline by more than 60%. I can't bring myself to believe that the effect is really that strong, though, so I use a much more modest adjustment based on stock price moves when estimating volatility.

What I'm talking about here is changes in volatility and changes in stock prices. I'm not talking about the dollar stock price. It does seem to be true that the kinds of companies that have low price stocks also tend to have volatile stocks, but that's not what I'm talking about here. That would not in itself imply that a change in price would cause a change in volatility.

I'm also not talking about changes in price caused by splits or stock dividends. None of the reasons for a tie between stock price and volatility or between change in stock price and change in volatility would imply that a split should have any effect on a stock's volatility.

Finally, I believe that option prices have some information about the future volatility of a stock over and above any information in the past behavior of that stock or of other stocks. There are many possible future events affecting a stock's volatility that the market might know about before I do. If the market knows, then that information will normally be reflected in the option prices. So I give some weight to the option prices in estimating the future volatility of a stock.

The steps that I go through to estimate stock volatilities each month are given below. These are the steps that I am using to make estimates for June, 1976. The steps have been different in the past and they will be different again in the future.

I could make new estimates more often than once a month. Perhaps some day I will. With the method I use now, the volatility estimates change abruptly once a month, and so do my estimated option values. These abrupt changes do have one virtue, though: they should remind the user that my estimates are only estimates. They are far from being perfectly accurate. The changes that occur once a month are a reminder of the uncertainty that always surrounds the estimates.

Option Price Adjustment

I start with last month's estimates of volatility: one for each expiration month for each stock. If the option prices are higher than the values using last month's estimates, I move the estimates up. If the option prices are lower than the values, I move the estimates down.

I could, of course, move the estimates so far that the option values would be roughly equal to the option prices (except that they wouldn't be equal for all the strike prices). But I don't. I move them about 15% of the way toward equality. (The 15% is a judgment figure. It wasn't arrived at by any sort of statistical analysis.)

I look at the options that are closest to being at the money, and estimate the ratio of price to value. Sometimes I use separate ratios for each maturity, but most often I use a single ratio for each stock. I take the ratio (minus 1.0) expressed as a percentage, multiply by .15, and increase the volatility estimates by the resulting percentage.

For example, suppose the option prices are 30% higher than the option values. Then I'll increase the volatility estimates by 4.5%. A volatility estimate of 22% will be changed to 23%, because 4.5% of 22% is 1%.

It happens that for maturities up to a year (and even longer maturities), an increase of 1% in the volatility estimate means an increase of about 1% in the value of an at-the-money option. So moving the volatility estimate the way I do, using a factor of 15%, means moving the option value about 15% of the way toward the option price.

Stock Price Adjustment

The stock price adjustment has two parts: one that depends on the change in each individual stock price, and one that depends on the average change in price across stocks. They both have the same form.

I start with the percentage change in each stock price over the last month, including dividends, and adjusted for splits and the like. I also average this figure across the option stocks to get a "market change" for the last month.

For each option maturity, I figure a divisor $4 + n/6$, where n is the number of months to maturity. If the option expires in the month in which the estimates will be used, n is 0. If the estimates will be used in June, and the maturity month is January, then n is 7. The exact form of the divisor is another judgmental factor.

I take the percentage change in the stock price for each stock, divide by $4 + n/6$, and make that an additional percentage change in the volatility estimate for each maturity. If the stock is up, the volatility estimate goes down; and if the stock is down, the volatility estimate goes up.

Then I take the percentage change in the market (for option stocks), divide by $4 + n/6$, and make that an additional percentage change in every volatility estimate for every stock.

If a stock and the market were both up 20%, then the volatility estimate for an expiration month would go down 10%, and the volatility estimate for a 6-month option would go down 8%.

New Data Adjustment

The new data is a set of volatility estimates on all the option stocks based on about one month of daily returns. One month of daily returns in a typical month is 21 data points. For each stock, I square the returns, take the average of the squares, and then take the square root. I don't subtract the average return before squaring, because a monthly average return isn't a good estimate of the long run average return. Zero is a better estimate.

The new data adjustment, like the stock price adjustment, is in two parts; but this time the parts are somewhat different in form. The adjustment based on the average of the new data across the option stocks does not depend on the maturity of the option, while the adjustment based on the new data for an individual stock does depend on the maturity of the option.

I start with the estimated volatilities after the option price and stock price adjustments have been made. I figure an average estimated volatility for each stock, using the estimates for maturities between 2 and 7 months.

Then I average the estimates across stocks.

I compare this average estimate with the average of the new data across stocks. I express the difference as a percentage of the average estimate. I multiply this percentage by 1/5, and make that the fractional change in each volatility estimate for each stock. For example, if the new data averages 25% lower than the estimates, the adjustment will be -5%.

Then I make an adjustment that is specific to each stock and each maturity. I form a weighted average of the estimated volatilities as they now stand and the new data, using weights that depend on the option maturity. As before, n is the number of months till the option expires. The weights on the estimated volatilities and the new data are:

$$1 - \frac{1}{4 + n/3} \qquad\qquad \frac{1}{4 + n/3}$$

Thus the weight on the new data is .25 for an option about to expire, and .20 for a 3-month option.

After I figure the adjustment factors for the option prices, the stock prices, and the new data, I look at them. In cases where they are all in the same direction, I may eliminate the smallest adjustment, to avoid too much double counting. For example, the option prices may be anticipating an increased volatility due to a fall in the stock price, and the increase may already have shown up in the new data. That would amount to triple counting. I won't cut the adjustment back too much, though, because the method allows for some double counting.

New Options

When new option maturities start trading on an old stock, I take the estimated volatility for the longest old options on that stock, after all the adjustments except the very last one have been made. Then I weight in the new data using weights that are right for the new expiration month according to the above formula.

When options start trading on a new stock, I look at data on the volatility of that stock for the last 12 months. I form a weighted average starting with weights of .8 on the first month and .2 on the second month, and then using .8 on the old estimate and .2 on the new data for the first 10 months. For months 11 and 12, I use the formal procedure explained above, except that the comparison of option prices with option values isn't used.

Smoothing

Finally, I look at the volatility estimates and do two smoothing operations. If the volatility estimates increase or decrease with maturity on any stock, I want them to do so gradually and smoothly. I'm not willing to forecast an increase in volatility followed by a decrease, or a decrease followed by an increase.

If the overall change in the volatility estimates for a stock is greater than 12%, I look at those estimates closely. In some cases, I cut the change back, often to the point where it is only a 12% change.

If you have any questions or comments, please call me at 617-253-6691, or write me at 50 Memorial Drive, Cambridge, MA 02139.