Predicting Stock-Market Volatility

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On October 19, 1987, the stock market posted its largest one-day decline ever when the Dow Jones Industrial Average fell 508 points, a drop of over 22 percent in a single day. Prior to the crash of 1987, the largest single-day drop in the stock market occurred on October 29, 1929, when the market fell by about 13 percent. While drops of this magnitude are rare, it is not uncommon for stock prices to rise or fall by 3 percent or more in a single month. Stock prices seem to be very unpredictable. In addition, economists have long recognized that stock prices go through turbulent and tranquil periods. Turbulent periods are times of high uncertainty when stock prices move sharply from month to month; tranquil periods are times when stock price movements are much more subdued.[1] However, only recently have economists begun modeling how stock-market volatility (or stock-price turbulence) changes through time.

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[1]This recognition of the changing variability of stock prices goes back to the early 1960s. An early, comprehensive study of the behavior of stock-market prices is that of Fama (1965).

Why does stock-market volatility vary through time? Is stock-market volatility predictable? To address these questions we will need to examine theories about how stock prices are determined. Then we can see whether the behavior of U.S. stock prices over the last 30 years is consistent with the implications of these theories. But first, we would like to know how stock-market volatility affects the economy.

HOW DOES STOCK-MARKET VOLATILITY AFFECT THE ECONOMY?

Economists argue that stock-market volatility can affect the economy in several ways: (1) it influences how much people spend and save; (2) it influences the prices of stocks; and (3) it influences the prices of financial options and thus affects how investors might hedge investment risk.

The Effect on Spending and Saving. How might an increase in stock-market volatility affect people's spending and saving decisions?[2] Consider the case of a hypothetical person named Walter Wealthy who has an uncertain future income because of his investments in the stock market.[3]

Walter's decision about how much to spend today depends on how much income he expects his stocks to produce. If he expects a high return from his investment in stocks, he may want to spend less (and save more) today.[4] Doing this allows Walter to spend more in the future (if the high expected return comes about). This incentive to save more today is called the substitution effect, since future spending is substituted for current spending.

Offsetting this substitution effect is an income effect, which leads Walter to want to spend *more* today. If the expected stock return is high, he feels richer today because he expects to have higher wealth in the future. Feeling richer, Walter may increase current spending. Thus, the income effect works to offset the substitution effect. However, empirical evidence suggests that usually the substitution effect dominates the income effect, so that saving increases with an increase in expected returns.[5]

We have seen that the expected return on stocks affects Walter's spending and saving decisions. His decisions also depend on the degree of uncertainty about the return on stocks. An increase in the degree of uncertainty means that a stock's expected return is unchanged, but there is an increased chance that the actual return will be farther away from the expected return. For example, suppose you buy a stock today for $100 that pays off $105 with a 10 percent chance, pays $110 with an 80 percent chance, and pays $115 with a 10 percent chance. The expected payoff on this asset is then (.10 x $105)+(.80 x $110)+(.10 x $115) = $110. An increase in uncertainty can come about either by an increase in the likelihood of getting a high

[2]In the following discussion of the effects of stock-return uncertainty on people's spending and saving decisions, we get the sharpest predictions by assuming that stocks are the only risky assets in which people can invest. Alternatively, we can assume that there are other risky assets but that an increase in stock-return uncertainty reflects an increase in return uncertainty of all risky assets. If the increase in stock-return uncertainty is specific to the stock market, then the primary consequence of the increase may be a portfolio shift away from stocks and into other assets. The overall effect on spending and saving is then more difficult to pin down. For details see the 1989 article by Robert Barsky listed in the References.

[3]In general, part of the income uncertainty that people face is due to their future labor income being uncertain. In the case of Walter Wealthy we will ignore labor income uncertainty in order to focus on the uncertainty associated with holding risky assets such as stocks.

[4]The return from holding stocks includes both the dividends paid to the stockholder plus capital gains that accrue when the price of the stock increases.

[5]For a fuller discussion of the income and substitution effects associated with changes in uncertainty, see the articles by Barsky (1989) and Abel (1988).

or low payoff, for example, a 20 percent chance of $105, a 60 percent chance of $110, and a 20 percent chance of $115 (note that the expected return remains $110); or by a change in the value of the high and low payoffs, for example, a 10 percent chance of $100, an 80 percent chance of $110, and a 10 percent chance of $120. Again, the expected return is $110.

In the case of an increase in uncertainty, as in the case of an increase in the expected return, there are offsetting effects. A precautionary-saving effect induces Walter to cut back on current spending and increase current saving.[6] He increases current saving to guard against the increased likelihood of a bad outcome, which is a low return. On the other hand, a substitution effect leads Walter to spend more today. He spends more today in an effort to sidestep the increase in risk because current spending looks more attractive in the face of increased uncertainty about the future.

Which effect dominates depends on Walter's attitude toward risk. If he has a strong-enough dislike for risk, the precautionary-saving effect dominates, so his current spending will fall, and his saving will rise in response to an increase in the uncertainty of returns.[7] Empirical studies of household preferences toward risk suggest that most people fall into this category.

We can also consider how an increase in uncertainty affects the current prices of stocks. If Walter dislikes risk, an increase in the uncertainty of returns on stocks can lead him to sell some of his stocks and buy other, less risky assets, such as bonds. Since other holders of stock will also behave like Walter, the current prices of the stocks will fall as people sell their shares. Therefore, an increase in the uncertainty of returns can lead to a fall in the current price of stocks.

So, if Walter has a strong-enough dislike for risk, an increase in uncertainty about stock returns may cause him to increase current saving to guard against the possibility of a very low return next period. Thus, increased stock-market volatility can affect how much people spend and save. In addition, increased uncertainty can lead to a fall in the current prices of stocks.

The Effect on Stock Options Prices. An increase in stock-market volatility also affects another variable of economic interest: the price of stock options. A stock option is merely a contract that gives its owner the right to buy or sell a specified number of shares of an underlying stock at a specified price, called the exercise (or strike) price, within a specified period. For example, on July 3, 1992, as reported in the *Wall Street Journal*, one could have purchased a call option on Intel stock that would give the owner the right to buy 100 shares of Intel at a price of $55 per share on or before the third Friday in August 1992. The price to purchase the contract was $350, and Intel stock was selling on the National Association of Securities Dealers Automated Quotation (NASDAQ) system for $55-7/8 per share.

Stock options are like insurance contracts: the owner of a stock option has paid a "premium" to acquire "insurance" that eliminates some of the downside risk associated with holding a share of stock (the chance that the price of the stock will fall dramatically). The writer of the option contract acts like an underwriter, agreeing to "insure" the buyer of the contract against a bad outcome. Options are used by investors, consumers, and producers to hedge against uncertainty.

Investors and producers who use options as part of their financial strategy are of course interested in whether particular options are priced appropriately. In a 1973 article, Fisher Black and Myron Scholes developed a popular and widely used model of option pricing that

[6]For more on precautionary savings, see Barsky (1989) and Blanchard and Fisher (1987).

[7]This increased savings will flow partly into assets that are less risky than stocks.

shows how the price of an option can be determined from certain characteristics of the underlying stock. One of these characteristics is the volatility of the stock price. In the Black-Scholes model, the higher the volatility of the stock price, the higher is the price of the option.[8] The intuition behind this result can be understood without going into the complexities of the model. With higher volatility of stock prices, there is a greater chance of receiving both a good outcome (high stock price) and a bad outcome (low stock price). However, the option bears no downside risk. The worst that can happen is that the option will expire worthless at maturity. Referring to our Intel example, suppose that the share price of Intel stock fell to $52 in August. Then the call option would expire worthless, since no one would want to exercise the option and purchase the stock for $55 when it could be bought on the stock market for $52. In that case, the option buyer would lose the $350 spent to purchase the option. However, even if Intel fell to $1 per share, the most that the option owner could lose would be $350, the price of the option contract. Note that the owner of 100 Intel shares would lose over $5400 dollars if the share price fell to $1. On the other hand, if Intel's price rises to $155 in August, the option owner would exercise the contract and buy 100 shares for $55 per share. She could then sell those shares for $155 per share and receive a profit of ($155 - $55)x(100 shares) = $10,000.

Because the downside risk on a call option is limited and the potential gains on the upside are not, the price of an option should be higher when the volatility of the stock price is high. The higher the volatility, the greater the chance that at the option's expiration date the underlying stock price will exceed the option's exercise price.

There is also an indirect path by which a change in uncertainty might affect the price of a stock option. Recall that an increase in uncertainty can lead to a fall in the price of a share of stock. A fall in the share price will in turn lead to a decrease in the price of a call option written on that stock. Suppose that a stock is trading at a price that is below the exercise price of the call option on that stock. If the share price falls, the option would be less valuable, since the stock price will have to increase by a larger amount in order that, at the expiration date, the selling price of the stock exceeds the exercise price of the option. Thus, a fall in the current price of a share leads to a fall in the price of a call option written on that stock.

We see then that there are offsetting effects on options prices due to a change in the uncertainty of a stock. For a call option, the direct effect of an increase in volatility is to raise the price of the option. The indirect effect is to lower the price of the option through a change in the current price of the share. For a put option, which gives the owner the right to sell shares of the underlying stock at a fixed price, direct and indirect effects of an increase in volatility work in the *same* direction.

We have seen two examples of how stock-market volatility affects behavior. Increased stock-market volatility causes people to spend less and save more, and for a given spread between a stock price and option strike price, it raises the price of the option.

HOW DOES STOCK-MARKET VOLATILITY CHANGE OVER TIME?

We have seen how changes in stock-market

[8]We should note that in the Black-Scholes derivation of option prices, it is assumed that the volatility of the stock price is constant. Thus, when we compare the effects of higher variance on option prices we are really comparing options written on two different stocks. The arbitrage argument used in the valuation procedure is not sufficient to determine the price of the option when the option depends on variables that are not traded or that cannot be hedged by an existing security, as is the case with stock price volatility. When stock prices have a time-varying variance, more restrictive equilibrium asset-pricing models can be used to derive option prices.

volatility can affect the economy. How has this volatility changed over time? To answer this question, we must first construct a measure of the volatility of the stock market.

A graph (Figure 1) called a histogram illustrates the idea behind volatility. Panel A shows annual returns on common stocks as measured by the Standard & Poor's 500 index (S&P 500), and Panel B shows annual returns on long-term government bonds. The height of the bars in each panel represents the number of times (frequency) a particular return was observed on a yearly basis from 1959 to 1991. A tall bar means that a particular return was observed relatively more often. The horizontal axis measures annual return in percent.

In Figure 1, the three tallest bars in the bond-return distribution account for more than 65 percent of the observations. In the common stock-return distribution, the three tallest bars account for only slightly more than 45 percent of the observations. The distribution of returns for common stocks is more spread out than is the return distribution for long-term bonds, which means that there is a higher likelihood of receiving either a high or a low return when investing in stocks versus investing in long-term bonds. This suggests that common stocks are riskier investments than government bonds, that is, stock returns are more volatile.[9]

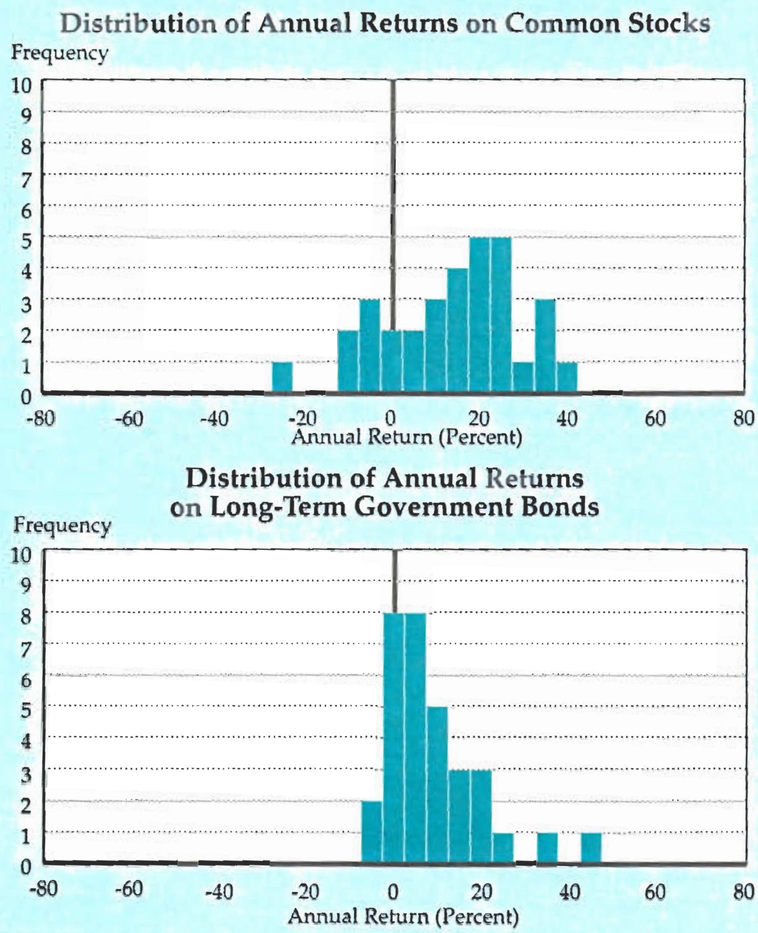
One useful way to measure the volatility of an asset is to look at its *variance*. Variance is a measure of dispersion—the larger the variance, the more spread out a distribution is. Another useful concept for measuring volatility is the *standard*

[9]Note, however, that an investor is rewarded for taking on the extra risk associated with holding common stocks. The average return on common stocks over this period is about 11 percent per year. The average return on long-term government bonds is 6.6 percent per year.

FIGURE 1

Asset Return Distribution

(1959 - 1990)



Source: Ibbotson Associates and author's calculations *deviation*, which is defined as the square root of the variance (see *Calculating Variances and Standard Deviations* for technical details on variances and standard deviations).[10] In Figure 1 we saw that common stocks are more volatile than long-term government bonds. This is reflected in the statistic for the standard deviation: annual stock returns have a standard deviation of 15.6 percent, which is larger than the standard deviation of annual government bond returns of 10.8 percent.

Forecasting Stock-Market Volatility. People need to forecast how volatile the stock market is so that they can make better decisions about spending and saving and about pricing options. You might think that the best forecast of the volatility of the stock market is simply to calculate the variance of stock returns from a distribution like that shown in Figure 1. That calculation shows that the long-run standard deviation of annual stock returns is 15.6 percent. But this is not the best forecast of the variance at any particular date. Forecasts that use recent information are more efficient than forecasts that do not use recent information. If stock-market volatility is high this month, that may indicate an increased chance that volatility will be high next month. If this is the case, we want to use this information in making forecasts of stock-market volatility.

One method of forecasting the variance of the stock market is to use *time-series models*.[11] A

[10]A helpful rule of thumb is that 67 percent of the observations tend to fall within one standard deviation of the mean, and 95 percent of the observations tend to fall within two standard deviations of the mean. This rule of thumb is for symmetric distributions, which means that the tails of the distribution are mirror images of each other.

[11]Alternative methods of deriving and forecasting stock-return volatility are used as well. An estimate of the return variance can be derived using option-pricing theory. In the Black-Scholes model of option pricing, the variables that determine the current price of the option are the current stock price, the time to maturity of the option, the strike

Calculating Variances and Standard Deviations

Variance is a quantitative measure of how spread out a distribution of variables is. The variance is defined as the average value of squared deviations of a variable from its mean. If we have a sample of n observations on a variable x, the general formula for variance is given by:

$$\sigma^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2$$

where $\overline{x}$ is the sample mean:

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n}x_i$$

We can clarify this formula with a simple example. Suppose a stock yielded 3 percent one month, -2 percent the next month, and 1 percent and 6 percent in the following months. The average return on the stock is, in units of percent:

$$\frac{3 + (-2) + 1 + 6}{4} = 2$$

The variance is given by:

$$\frac{(3-2)^2 + (-2-2)^2 + (1-2)^2 + (6-2)^2}{4} = 8.5$$

The standard deviation of returns is given by the square root of the variance, or 2.92 percent. The standard deviations reported in Figure 1 were calculated this way, using 32 observations on annual returns.

The standard deviation of stock returns exceeds the standard deviation of bond returns in Figure 1 because actual individual stock returns are often quite different from the average value of stock returns. Individual government bond returns are usually much closer to their average value.

time-series model is simply a way to look at the relationship between current and past values of data. In the case of stock-return variance, a time-series model would show how this month's variance is related to the variance of the stock market over the past few months.[12] The best long-run forecast of monthly stock-market variance is the variance calculated from a distribution like that in Figure 1.[13] But the best short-run forecast of variance may be much lower or higher, depending on what the variance has been in recent months.

Economic theory suggests a method for forecasting stock-return variance: calculate the size of past errors in forecasting stock returns,[14] then use the squared values of these forecast errors to estimate the stock-return variance.[15]

price, the risk-free interest rate, and the variance of the stock price. Since the current price of the option is observed, the Black-Scholes formula can be inverted to solve for the variance. This method of calculating stock price variance is referred to as the "implied-volatility" method. See, for example, the 1991 book *Option Valuation: Analyzing and Pricing Standardized Option Contracts*, by Rajna Gibson. For a comparison of how well time-series methods and implied-volatility methods characterize stock-return volatility, see Day and Lewis (1992).

[12]Time-series modeling of variances is a very active area of research for economists. See the April/May (1992) issue of the *Journal of Econometrics*, which is devoted entirely to ARCH (autoregressive conditional heteroskedasticity) models of financial market data. In their simplest form, ARCH models assume that the current value of the conditional variance is a linear function of past squared deviations.

[13]We would need to calculate a distribution for monthly stock returns. The distribution in Figure 1 is for annual stock returns.

[14]This method of calculating the variance and standard deviation of stock returns follows Schwert (1989) and Salinger (1989). An alternative method is to calculate the variance of daily stock returns and then use these daily variance observations to calculate a monthly variance. Schwert presents graphical evidence indicating that the two measures are similar.

This method of forecasting stock-return variance makes intuitive sense as well. In calm times, our forecasting model for stock returns should predict relatively well, and so our forecast error should be relatively small and the predicted variance will be small. In a particularly volatile time, our model will not fit quite as well, so that the forecast error is large and the predicted variance will be large.

We have plotted a measure of stock-market volatility using forecast errors from a time-series model of stock returns (Figure 2). The figure shows the forecast errors from a forecasting model of monthly returns to the S&P 500 stock index from 1959 to 1992.[16] Note that the stock-market volatility measure shows a great deal of variation. Volatility does not appear to be constant. The highest spike corresponds to the month of October 1987. Recall that on October 19, 1987, the stock market experienced its sharpest one-day drop ever. This figure also suggests a correlation through time in return volatility. Visual evidence suggests that sharp upward spikes are bunched together. This pattern indicates that volatility may in part be predictable based on its own past values.

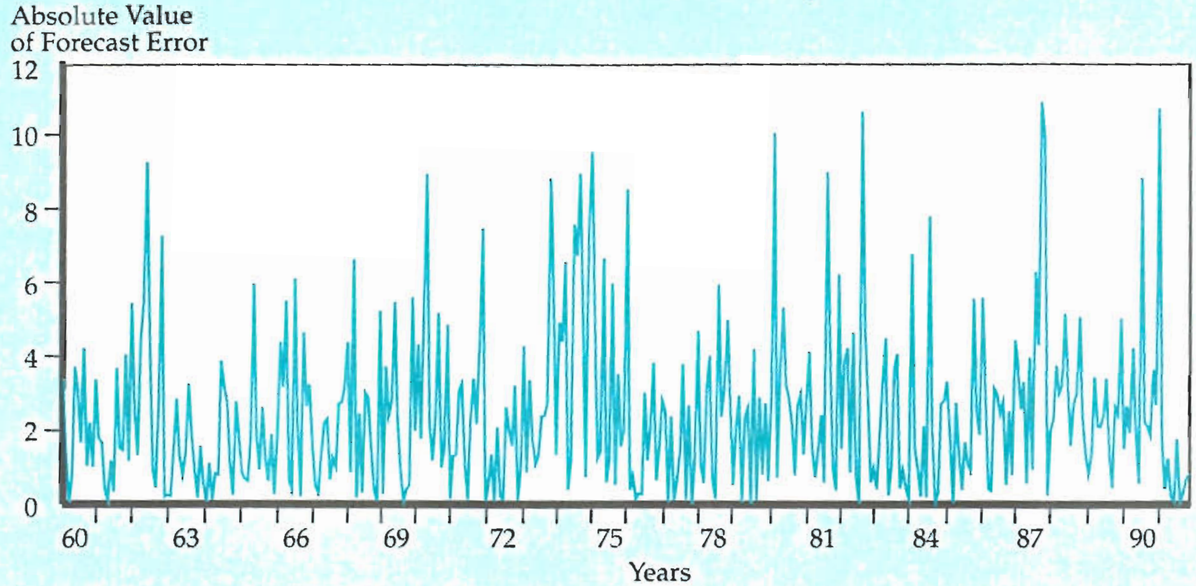
PREDICTING STOCK-MARKET VOLATILITY

Why is it that stock-market volatility changes over time? Are there regular patterns in the time-series behavior of volatility? To help us address these questions it is useful to have an economic model of how stock prices are determined.

[15]The forecast errors are the in-sample residuals from the estimated model for returns. The variance that is estimated from these forecast errors is called the conditional variance of returns.

[16]The absolute value of each monthly forecast error is plotted in Figure 2.

FIGURE 2
Stock-Market Volatility



Suppose we take a simple model that expresses the current price of the stock as a positive multiple of current dividend payments.[17] This is certainly an oversimplification, but it will keep the discussion uncomplicated. For a stock portfolio as diversified as the S&P 500, current dividend payments might be proxied by current, economywide output. If the stock price is then represented as a positive fraction of current output, the expected variance of stock returns will be positively related to the expected variance of output *growth*.

In this model, the fundamental factor that drives stock prices is the level of output. We can think of output as indicating the state of the economy. When output growth is high, the state of the economy is good (expansions). When output growth is low, the state of the economy is bad (recessions). Any patterns over time in the volatility of output growth will be reflected in the volatility of stock returns. When we examine output growth (as measured by monthly industrial production), we find that output-growth volatility is correlated over time and that output-growth volatility is higher in recessions than it is in expansions. Our simple model suggests that we should see similar behavior in the time path of stock-market volatility.

Let us first examine whether stock-market volatility is correlated through time. One way to do this is by checking whether past volatility is useful in predicting current volatility. If we take monthly data on the S&P 500 from 1959 to 1992, we find that past volatility does help predict future volatility. However, the model's ability to predict future volatility is rather poor. Only a little over 1 percent of the total variation

[17]This result can be derived from an intertemporal model of asset pricing where investors face an uncertain future and have utility that is a logarithmic function of consumption. More general models of stock pricing suggest that the current price of a share of stock is related to the entire future stream of dividends that investors expect to receive. See Sargent (1987) for a technical discussion of these models.

in return volatility is explained by its own past values; over 98 percent of the movement over time in volatility evident in Figure 2 remains unexplained.

To test whether stock-market volatility is higher in recessions than it is in expansions we forecast volatility using data on its own past values and a variable that captures whether the economy is in a recession or an expansion. As suggested by our model, we find that the recession variable does help to explain volatility. Volatility is *higher* in recessions than in expansions. Based on our volatility measure we would forecast that the standard deviation of monthly returns would rise by about 2 percentage points in recessions.[18] By including the recession variable in the volatility forecast equation we can account for about 6 percent of the movement in stock-market volatility over time.

What other things might help us to improve our predictions of volatility? What about the seasons of the year? Is volatility predictably higher in one month than in another? A simple way to test for the presence of seasonal movement in volatility is to form a forecast of volatility using data on its own past values and a set of variables that account for the different months, or seasons, of the year. We can then test whether these seasonal indicators improve the forecast. Some evidence indicates that stock-market volatility is predictably lower in June, but in general, the evidence for a seasonal pattern in stock-market volatility is weak.

What have we learned so far about patterns in the behavior of stock-market volatility? First, stock-market volatility is not constant. It can be predicted, though rather imprecisely, using its own past values. Second, volatility tends to be higher in recessions than in expansions. Third, there is weak evidence of a seasonal movement in volatility.

Prediction Using Macroeconomic Variables. We have seen that there are identifiable patterns in stock-market volatility over time. The observation that stock-market volatility is higher in recessions than in expansions suggests that we might improve forecasts of volatility by using variables that predict recessions. If we can predict recessions, perhaps we can predict stock-market volatility. However, our test will be a little more demanding. Stock-market volatility itself predicts industrial-production volatility and so might predict recessions. Therefore, we will look at how well macroeconomic variables forecast stock-market volatility over and above the forecasting power of past stock-market volatility itself.

I examined a battery of macroeconomic variables to see if they predict future stock-market variability. These variables included inflation, various measures of money-supply growth, industrial production and consumer spending growth, and oil price shocks. Somewhat surprisingly, these macroeconomic variables did not improve forecasts of stock-market volatility over and above forecasts made using past levels of stock-market volatility. However, interest-rate variables did help to improve predictions of volatility because interest rates convey information about the risk of bankruptcy and about the stance of monetary policy.

When a firm borrows money, it might go bankrupt before paying off the loan. Lenders realize this and charge an interest rate on loans that reflects the firm's default risk, which is the likelihood that the firm will not pay off the loan. Strong firms, which are unlikely to go bankrupt, pay low interest rates, while weak firms pay higher interest rates. However, the whole schedule of interest rates changes as the economy changes. During recessions, all firms face an increased risk of bankruptcy, so all firms must pay higher interest rates on loans. Since the chance of bankruptcy is higher in recessions, expected dividend payments are

[18]The long-run standard deviation of monthly stock returns, measured by the S&P 500 index, is about 3.1 percent.

lower, and stock prices fall. Thus, there is a correlation between the default risk on corporate borrowing and stock prices.

How can we measure default risk? One way is to look at the interest rates on corporate bonds and compare them with the interest rates on default-free bonds, such as U.S. government bonds. The difference between these two interest rates, called an interest-rate spread, acts as a measure of default risk.

A different interest-rate spread may provide useful information about stock-market volatility in another way: the spread can indicate not just default risk but also changes in monetary policy. We have seen that stock-market volatility is higher in recessions than in expansions. If tighter monetary policy predicts future recessions, it will predict stock-market volatility. If monetary policy tightens, the cost of funds to banks increases. Banks will then have to increase the interest rates they pay on certificates of deposit (CDs). Since CDs and commercial paper are near-perfect substitutes, their interest rates will rise together; but Treasury bills are imperfect substitutes for CDs, so their interest rates won't rise as much. The overall effect is that the spread between interest rates on commercial paper and Treasury bills will increase. Another possibility is that banks may cut back on loans to customers, but again, the spread between commercial-paper interest rates and Treasury-bill interest rates could rise. In this case, firms issue commercial paper rather than borrowing from banks, causing interest rates on commercial paper to rise.[19] If the spread between the commercial-paper rate and the Treasury-bill rate is a measure of the stance of monetary policy, this spread could predict stock-market volatility because it predicts future recessions.

Examining the data, we find that the interest-rate spreads and their volatility help forecast stock-market volatility. In both cases, the default-premium variables have significant explanatory power for stock-market volatility. In fact, including the recession index and the interest-rate spreads, we can account for about 10 percent of the variation in stock-market volatility.

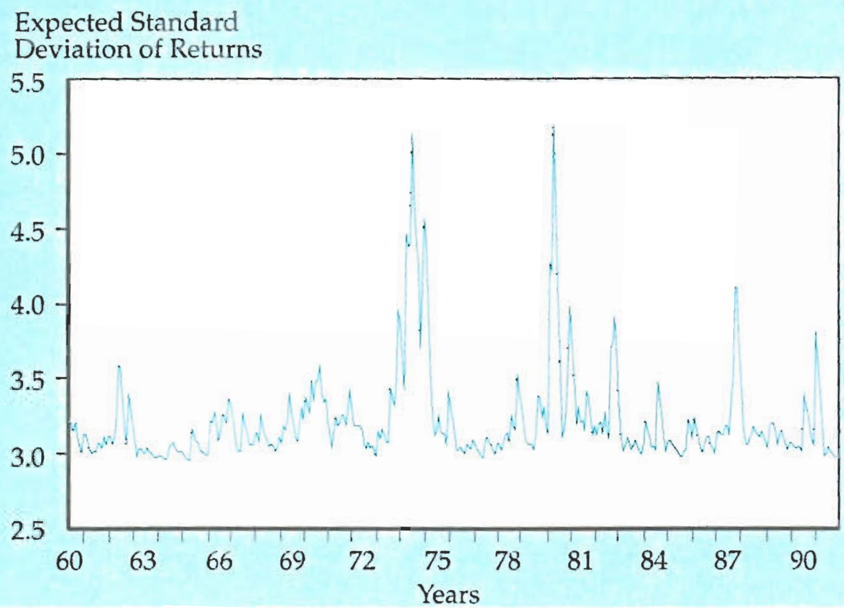
The Time-Series Behavior of Expected Volatility. The data show that stock-market volatility is difficult to predict. However, even though forecasts of volatility might be poor, the economic significance of these forecasts can be large. Forecasts of stock-market volatility are a measure of what people expect future stock-market volatility to be. After all, a forecast is just a best guess of what will happen in the future. Recall from our discussion of people's spending and saving decisions and the discussion of options prices that expected stock-market volatility affects behavior and prices. People act today based in part on their expectation of future events. Therefore, we would like to know if there are large changes over time in expectations of future stock-market volatility.

We have plotted the forecasted, or expected, stock-market volatility (Figure 3), constructed using past values of stock-market volatility and past values of the volatility of the interest-rate-spread variable.[20] Expected stock-market volatility clearly changes through time, though the movement is not as pronounced as the movement in the volatility displayed in Figure 2. (Recall that Figure 2 shows realized values of the forecast errors.) The sharpest upward movement in expected volatility occurs over the period 1973 to 1975, which coincides with

[19]See Bernanke (1990) for an in-depth discussion of the predictive power of interest rates and interest-rate spreads for future economic activity.

[20]This measure of expected volatility was constructed by using a bivariate ARCH model for stock returns and the T-bill/commercial paper spread. For details on how the measure of expected stock-market volatility was constructed, see my working paper listed in the References.

FIGURE 3
Expected Volatility of Stock Returns



the first OPEC oil price shocks and a recession. The next sharpest upward movement in expected volatility occurs in 1980, which also coincides with a recession. In fact, expected stock-market volatility in Figure 3 rises in each of the six recessions since 1959.[21]

How economically significant are these movements in expected volatility? Consider the case of option prices. The Chicago Board Options Exchange trades in call and put options on the S&P 500 index. Suppose that the current level of the S&P 500 index is 426.65, the call option contract has 30 days until maturity, and the strike price of the option is $425. Suppose further that the expected volatility of the index return is 3.1 percent. Under these conditions, the Black-Scholes option pricing formula predicts that the price of the call option is $6.87.[22] Suppose that we keep all parameters the same except for the volatility of returns, which increases by 2 percentage points, the amount that monthly volatility is predicted to increase during recessions. In this case, the Black-Scholes model predicts the call option price will be $10.19. Thus, the option price is quite sensitive to changes in expected volatility. Economic theory suggests that changes in expected volatility can also influence other economic variables such as consumption and investment. Measuring the effects of these changes in volatility is an active area of research for economists.[23]

VOLATILITY IN THE 1980s

The data on stock-market volatility have suggested that: (1) past levels of volatility predict future levels of volatility; (2) interest-rate spreads help to predict volatility; and (3) volatility is higher in recessions than expansions. However, if we test propositions (1) and (2) using data from 1980 through 1991, we find little evidence to support them. That is, in the

[21]The recessions occurred April 1960 to February 1961, December 1969 to November 1970, November 1973 to March 1975, January 1980 to July 1980, July 1981 to November 1982, and, most recently, the recession that began in July 1990.

[22]The parameters of the Black-Scholes pricing model include the time to maturity of the contract, the current price of the stock, the strike price of the contract, the volatility of the stock return, and the value of the risk-free interest rate. In the example in the text, the risk-free interest rate was assumed to be 4 percent per year.

[23]For a comprehensive survey of recent empirical work on time-series modeling of expected volatility, see Bollerslev, Chou, and Kroner (1992).

1980s, the forecasting power of past levels of stock-market volatility and the interest-rate spread deteriorated significantly. Why was this the case?

One possibility, suggested by the simple model of stock pricing, is that the time-series behavior of the volatility of output growth changed in the 1980s. However, when the data are examined we find that past values of output-growth volatility still have predictive power for future output-growth volatility in the 1980s. According to the simple model, past levels of stock-market volatility should still have predictive power for future volatility.

The change in the behavior of stock-market volatility may be related to developments in financial markets that occurred over the course of the 1980s. For example, the transaction costs of buying and selling stocks were much lower in the 1980s than in the early 1970s. Institutions, which account for about 80 percent of the trading on the New York Stock Exchange (NYSE), now pay less than 5 cents per share in commissions versus 80 cents per share in the early 1970s. These lower commission charges are reflected in the increased volume of trading on the market. This higher trading volume serves to make the stock market more liquid, thus helping to further reduce the costs associated with executing a trade. With these lower costs of trading, investors are able to react more quickly and more frequently to new information. These developments may have altered the time-series behavior of volatility.

Another possibility is that the time-series behavior of stock-market volatility has been influenced by the trend toward increasing integration of world financial markets. In the 1960s, transactions by foreigners accounted for about 12 percent of the dollar volume of trade on the NYSE.[24] In the 1970s the average had risen to about 16 percent. In the 1980s, the average reached over 19 percent. With the increasing interdependence of world markets, U.S. stock prices are influenced more and more by developments in foreign countries. This could contribute to a change in the time-series behavior of stock-market volatility.[25]

Why did the interest-rate variables have lower forecasting power in the 1980s? In a 1990 article, Ben Bernanke offers two possibilities. First, in the decade of the 1980s there have been changes in the way the Federal Reserve implements its monetary policy. These changes allowed short-term interest rates, such as the federal funds rate, to become more variable, all else equal. As a result, short-term interest rates may have become less tightly linked to the monetary policy actions that ultimately affect the economy.

A second possibility is that financial deregulation and financial innovation in the 1980s may have increased the substitutability between Treasury bills, commercial paper, and CDs. If these assets are closer substitutes, the sensitivity of interest-rate spreads to changes in monetary policy may be reduced. The weaker link between interest-rate spreads and monetary policy might then be reflected in a weaker link between the interest-rate spreads and the economy.

CONCLUSION

The data on stock returns suggest that: (1) stock-market volatility can be predicted based on its own past values; (2) volatility is higher in recessions than in expansions; (3) some variables that theory suggests might help explain

[24]The percent of transactions accounted for by foreigners is measured as the sum of sales by foreigners to Americans and sales to foreigners by Americans divided by the dollar volume of trade on the NYSE. These data are taken from various issues of the *New York Stock Exchange Fact Book.*

[25]Another innovation to financial markets in the 1980s has been the introduction of futures and options trading on stock market indexes. These contracts allow investors to buy and sell large baskets of stocks at a fraction of the cost required to execute the same trade in the stock market.

stock-market volatility (such as money-supply variability, inflation variability, and industrial-production variability) are not helpful; and (4) the spread between commercial-paper rates and Treasury-bill rates has predictive power for stock-market volatility. However, the best we can do with these variables is to explain about 10 percent of the variation in stock-market volatility over time. In addition, it appears that volatility became more difficult to predict in the 1980s.

Even though it is difficult to accurately predict stock-market volatility, the forecasts that people make about volatility are important. Economic theory argues that it is these expectations about future volatility that can affect people's decisions to spend and save. Changes in expected volatility can also affect stock prices and investment and the prices of stock options. The evidence suggests that there are substantial movements in expected stock-market volatility relative to the average level of volatility.

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