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Is the "Leverage Effect" a Leverage Effect?

by

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Abstract

The "leverage effect" refers to the well-established relationship between stock returns and both implied and realized volatility: volatility increases when the stock price falls. A standard explanation ties the phenomenon to the effect a change in market valuation of a firm's equity has on the degree of leverage in its capital structure, with an increase in leverage producing an increase in stock volatility. We use both returns and directly measured leverage to examine this hypothetical explanation for the "leverage effect" as it applies to the individual stocks in the S&P100 (OEX) index, and to the index itself. We find a strong "leverage effect" associated with falling stock prices, but also numerous anomalies that call into question leverage changes as the explanation. These include the facts that the effect is much weaker or nonexistent when positive stock returns reduce leverage; it is too small with measured leverage for individual firms, but much too large for OEX implied volatilities; the volatility change associated with a given change in leverage seems to die out over a few months; and there is no apparent effect on volatility when leverage changes because of a change in outstanding debt or shares, only when stock prices change. In short, our evidence suggests that the "leverage effect" is really a "down market effect" that may have little direct connection to firm leverage.

Introduction

The Black-Scholes option pricing formula, and many subsequent models assume the volatility of the underlying asset is a constant parameter. But it has long been known that returns volatilities for many assets, especially stocks, appear to vary over time. Among many examples in the literature, Schwert[1989] gives an extensive analysis of the variability of equity volatility over time and its relation to other economic variables; Bollerslev, Chou and Kroner [1992] review the literature on using models of the ARCH family to model time-varying volatilities for financial variables.

In addition to time-variation in the level of volatility, equities, in particular, also exhibit an asymmetry that depends on whether returns are negative or positive. Volatility seems to rise when a stock's price drops, and fall when the stock goes up. An early reference to this phenomenon is Black[1976], and it has been found repeatedly since then by authors such as Christie[1982], Schwert[1989], Glosten, Jagannathan and Runkle [1992], Braun, Nelson and Sunier [1995], and many others. Recent work by Bekaert and Wu [2000] finds strong asymmetry in Japanese stock volatilities. The phenomenon shows up both in the measured volatility of realized stock returns and also in implied volatilities from stock options. Nelson [1991] introduces the EGARCH model in part in order to model the asymmetric behavior of volatility within a GARCH-family framework.

The most common explanation for asymmetry ties the behavior of a stock's volatility to the degree of leverage in the underlying firm's capital structure. In fact, in their original article, Black and Scholes [1973] (BS) discussed the impact of leverage on stock price behavior, and the argument was elaborated in articles by Merton[1974], Galai and Masulis [1976] and Geske[1979], among others. The reasoning stems from Modigliani and Miller's [1958] classic principle that the fundamental asset of a corporation is the whole firm, while the securities the firm issues--stock, bonds, and so on--are just different ways of splitting up the ownership of this asset. From that perspective, BS observed that the volatility of a stock's return should come entirely from the fluctuations in the total firm value. In a firm that has both equity and debt in its capital structure, the debtholders' claim on firm value is limited to the face value of the bonds, so (nearly) all variations in total firm value will be transmitted to the equity, except when the firm is close to insolvency.

Suppose there is an increase in overall firm value. Since equity is less than total firm value, the proportional return on the stock will exceed that of the whole firm. Therefore the stock in a levered firm should be more volatile than the whole firm, with the difference being a function of the relative amounts of debt and equity in the firm's capital structure. The connection to leverage will also cause stock volatility to vary systematically and asymmetrically with returns: When a negative stock return causes equity value to go down while debt is fixed, firm leverage is raised, which increases future equity volatility. The reverse effect should occur when stock returns are positive. Empirical evidence supporting this theoretical argument was presented by Christie

[1982], who found a positive correlation between the degree of leverage on a firm's balance sheet and the volatility of its stock.

With traded stock options, another measure of expected volatility is available. The implied volatility (IV) derived from market option prices is commonly thought of as "the market's" volatility forecast. If so, one may see directly what impact investors anticipate that a given event will have on future stock volatility under Black-Scholes assumptions. If stock volatility were actually expected to be a constant parameter unrelated to returns, the IV should be equal for every option of a given maturity on the same underlying stock. A plot of IV versus strike price would be a flat line at the expected volatility.

IVs for options on individual stocks and on stock indexes, however, tend to exhibit quite a different pattern. Options for most underlying assets show a volatility "smile," with higher IVs for out of the money (OTM) and in the money (ITM) contracts than for options that are just at the money (ATM). Equity IVs tend to display a more asymmetrical smile, often called a "skew" or "smirk." A volatility skew refers to a monotonic decreasing pattern of IV for higher strike prices.

Because of the "leverage effect," the market price of an out of the money put option, for example, will be higher than the Black-Scholes value for that option, so its IV will also be relatively high. If the stock does go down, toward the level at which the put will be in the money, stock volatility will also increase, adding to the option value. Similarly, an up move in the stock will decrease volatility, leaving option prices lower relative to at the money options than the constant volatility BS model would predict.

Attributing an empirically observed skew pattern in IV for stock options to financial leverage has become embedded in the conventional wisdom, to the point that it is not uncommon to call any asymmetric response between asset returns and volatility a "leverage effect," even when the underlying is something like an exchange rate, for which the concept of leverage can not apply. Obviously, a "leverage effect" in foreign currency options can not really be due to leverage; there must be some other explanation for asymmetric volatility behavior. But in the stock market, negative correlation between returns and subsequent volatility is taken as empirical evidence that financial leverage determines stock volatility in the way that the theoretical model predicts.

Yet, a skeptic may wonder how aware investors really are of the degree to which fluctuations in firm leverage caused by day to day stock price movements ought, in theory, to impact future volatility. For example, historical volatility estimates that are widely disseminated and used in the market are computed just from past stock returns, with no attempt to adjust for the impact those returns have on the capital structure of the underlying firms. Even when a stochastic volatility GARCH-family model is adopted, the "leverage" parameter is simply treated as a coefficient to be estimated from the returns data, not as a structural parameter that should be related to the firm's capital structure.

The question we will address in this paper is how much of the "leverage effect" in stock returns and option implied volatilities can really be tied to leverage, and how much will need to be explained by other causes. The next section presents a simple version of the theory of the leverage effect and derives an empirically testable relationship. Section 3 describes the data. We focus on large stocks with active options trading: the stocks contained in the Standard and Poors 100 stock index (OEX). We also examine the OEX index itself and the options written on it, that are typically found to exhibit a stronger leverage effect than do individual stocks (see, for example, Braun, Nelson and Sunier [1995]).

Section 4 presents preliminary empirical evidence for the existence of an asymmetric relationship between returns and volatility. With the most basic formulation, measured volatilities and also implied volatilities exhibit a strong "leverage effect" relative to returns both for the OEX index and for individual stocks. The size of the effect is distinctly greater for the index than for single stocks. Thus the initial evidence is consistent with the existence of a significant leverage effect in these stocks.

Yet, inconsistencies arise quickly as we delve deeper into the data. The logic of the theoretical argument suggests that the size of the leverage effect should not depend on whether the underlying stock return is positive or negative: a positive return should decrease leverage and volatility by about the same amount as a negative return of the same size increases it. But the results in Section 4 indicate a significant asymmetry in the leverage effect, such that there is a strong impact on volatility when stock prices fall and a much weaker effect, or none at all, when they rise. Also, a firm's leverage is a "level" variable rather than a "change." This means that a stock price move that alters the leverage of the underlying firm should produce a permanent shift in volatility. By contrast, we find that volatility changes associated with stock returns appear to die out quickly.

One problem with these tests of the "leverage effect" is that they are based on stock returns, not on the actual leverage in the firm's capital structure. In Section 5, we use data from the Compustat data base to relate the "leverage effect" to the actual change in underlying firm leverage. Overall, the results indicate a significantly positive relationship between changes in measured leverage and both realized and implied volatility, as well as significant differences between leverage increases and leverage decreases. However, the size of the effect of a change in measured leverage is too small. The elasticity of stock volatility with respect to leverage should be about 1.0, but the coefficient estimates indicate an elasticity that is less than half of that. There is less evidence with measured leverage than with returns that the effect dies out over time.

Next, we consider whether leverage changes that result from issuance or retirement of bonds or shares generate the same sized impact on the volatility of the stock, as do leverage changes resulting from stock price movements. We find that a leverage change arising from a change in the amount of debt in the firm's capital structure appears to have little or no impact on stock volatility. Similarly, there is no evidence of a "leverage effect" when an increase in leverage is caused by a change in the amount of stock outstanding, as opposed to a price change. In most cases the regression coefficients have the wrong sign, so if anything, there is a reverse effect.

Section 6 then goes on to look more closely at the options market. For IVs, a leverage effect should be the same size across all options with the same maturity. We find little difference in the behavior of IVs for calls versus puts, although, surprisingly, calls on individual stocks appear to exhibit a somewhat stronger effect than puts do. There is also little difference between options with high and low strike prices. However, index options show an extremely strong effect, but only in down markets. There is no significant "leverage effect" in IVswhen stock returns are positive.

So, is the "leverage effect" really a leverage effect? To anticipate our conclusions in Section 7, the results of our tests suggest that the answer is: Maybe a little, but leverage is far from a complete explanation for the volatility shifts associated with positive and negative stock returns.

II. Volatility and Leverage

Consider a firm with equity and debt in its capital structure, under the simplifying assumption that the debt is risk free, so that changes in firm value are entirely borne by the stock.[1] Let $V \equiv E + D$, represent total firm value. $E \equiv N\,S$ denotes the total current market value of the firm's N outstanding shares of stock with current market price S, and D is the value of the debt. Suppose there is a random change in overall firm value, ΔV. As a percent of firm value, this is $\Delta V / V$.

All of the change in firm value will flow through to the stock, so $\Delta E = \Delta V$, producing a percentage change in the stock price as follows:

(1) $$\frac{\Delta S}{S} = \frac{\Delta E}{E} = \frac{\Delta V}{V}\,\frac{V}{E} = \frac{\Delta V}{V}\left(\frac{E+D}{E}\right) = \frac{\Delta V}{V}\left(1+\frac{D}{E}\right)$$

The percentage change in the stock price is equal to the percentage change in total equity (given N fixed). This equals the percentage change in firm value times one plus the debt / equity ratio. The more levered the firm is (high D/E), the more volatile the stock will be relative to the total firm. That is expressed in equation (2).

(2) $$\sigma_S = \sigma_E = \sigma_V\, L$$

where σ_S is the volatility of the return on the stock, which equals the volatility of total equity, σ_E; σ_V is the volatility of the firm; and $L \equiv (1 + D/E)$ is the measure of leverage.

[1] This assumption is reasonable for the large firms we will be examining below.

If σ_V is constant, then the stock volatility, σ_S, will rise when the stock price goes down and fall when it goes up.[2] Hence, the empirically observed connection between stock returns and volatility changes is understandable and consistent with the established principles of modern finance. The "leverage effect" has become one of the stylized facts that it is felt need to be incorporated into models of time-varying volatility.

From equation (2), we can obtain θ_E and θ_D, the elasticities of stock volatility with respect to changes in the values of firm equity and debt, respectively. For example, $\theta_E = (d\, \sigma_V L / dE) \times (E / \sigma_V L)$, where we have substituted for σ_E from eq. (2). With a constant number of shares, the elasticity of stock volatility with respect to the stock price equals the elasticity of equity volatility with respect to total equity: $\theta_S = \theta_E$. We have,

$$\theta_S = \theta_E = -\frac{D}{D+E} \tag{3}$$

$$\theta_D = \frac{D}{D+E} \tag{4}$$

It is easily seen that $-1 \le \theta_S \le 0$ and $0 \le \theta_D \le 1$.

We may also compute the elasticity of stock volatility with respect to a change in L. Using (2), this gives

$$\theta_L = \frac{\partial\, \sigma_S}{\partial\, L} \frac{L}{\sigma_S} = \frac{\sigma_V L}{\sigma_S} = 1 \tag{5}$$

Equation (5) provides a theoretical value for the size of the leverage effect in our empirical tests presented below.

The above equations have been derived assuming firm volatility is constant. If this were weakened to allow firm volatility to change when firm value changes--a "leverage effect" at the firm level that is not due to its leverage--there will be second influence on equity volatility that will alter its measured elasticity with respect to leverage changes.

Taking the total derivative in (2) gives

$$d\sigma_S = \sigma_V \frac{dL}{dV} dV + L \frac{d\sigma_V}{dV} dV$$

[2] In practice, the relationship is expected to be somewhat more complicated. If the firm volatility is not constant, there will be a secondary effect. One might anticipate that rising firm volatility would be negatively correlated with movements in firm value (e.g., an increase in volatility leads to a drop in firm value), making the impact on stock volatility greater.

We also have

$$\frac{dL}{dV}\,dV \quad = \quad \frac{dL}{dE}\,\frac{dE}{dV}\,dV \quad = \quad -\frac{D}{E^2}\,dV$$

Substituting into the elasticity formula gives

$$\theta_L = \frac{d\sigma_S}{dL}\,\frac{L}{\sigma_S} = \left(\sigma_V - \frac{L}{D/E^2}\,\frac{\partial\sigma_V}{\partial V}\right)\frac{L}{\sigma_S} = 1 - \frac{E^2\,L^2}{D\,\sigma_S}\,\frac{\partial\sigma_V}{\partial V}$$

The coefficient on the second term in the final expression is non-positive, so if a drop in firm value is correlated with an increase in firm volatility (i.e., $\partial\sigma_V/\partial V < 0$), the measured elasticity of the stock volatility with respect to leverage will be greater than 1.

The empirical tests presented below are set up as regressions of the following form.

(6) $$\Delta \ln \sigma_S = c + a\,\Delta \ln L + \text{dummies}$$

The coefficient **a** is the estimate for elasticity θ_L. By the above analysis, **a** should be 1 if the market fully incorporates the change in leverage into stock volatility and firm volatility is constant. If firm volatility also increases when firm value falls, **a** should be greater than 1. An **a** value less than 1 suggests that leverage changes are not fully impounded in stock volatility. The dummy variables allow us to examine the relative importance of leverage for different subsets of the data.

Here, we are treating the value of the firm's debt as being unaffected by changes in firm value. In other words, debt is riskless in terms of default. If, on the other hand, we allowed the value of debt to change in the same direction as firm value, it could somewhat mitigate the impact of leverage on stock volatility. There are both theoretical and practical reasons for this assumption. On theoretical grounds, while risky debt would reduce the elasticity of volatility with respect to stock price movements, the magnitude of the effect is a decreasing function of how far the firm is above the point of insolvency. Our data sample consists of large and well-established firms, whose debt can be safely treated as having very low risk of default. A practical reason not to try to take account of equity price changes on debt values is that, as is customary for measuring debt / equity ratios, in our analysis, we will be using the reported book value of firm debt from Compustat as the measure for D.

III. Data

We wish to examine stocks of major firms, for which we expect market pricing to be the most efficient. To look at both realized returns volatility and implied volatility, we want stocks that also have active trading in options. We have therefore selected for analysis the stocks contained in the S&P 100 index as of December 1992. All stocks in the S&P 100 have options traded actively at the Chicago Board Options Exchange (CBOE). Definitional problems with bond data for two firms reduces the total number to 98. The sample firms are listed in the Appendix.

There are two different data samples. One spans the 20-year period 1977-1996 and is used for tests that just involve realized volatility. The other covers the shorter period 1991- 1996, for which we have options data and can compute implied volatilities. Although Compustat data for the book value of debt are only available quarterly, we create monthly data series by assuming any changes in the book value of the debt over a quarter are spread equally over the three months.

The raw data come from three sources:

- Stock prices, the number of outstanding shares, dividends, monthly and daily stock returns (without dividends), and the 3 month Treasury bill rate all come from the Center for Study of Security Prices (CRSP) database, 1998 edition.

- The face value of firm debt comes from the Compustat Quarterly Industrial File, 1997 Edition. We sum the values shown for short and long term debt.

- Options price data, along with contemporaneous intraday prices for the underlying stocks and the OEX index, is obtained from the Berkeley Option Database for years 1991 to 1995.

One firm (American International Group) is excluded completely from the sample because the reported face value of short term debt in the Compustat database also includes a portion of its long term debt, so that the total value of the debt can not be reliably determined. Three other firms (Baker Hughes, Massmutual and Unisys) are not present in the Berkeley options database, so they are eliminated from analysis with implied volatility but leverage data is available for BHI and UIS, so they are included in the historical volatility analysis. Individual observations may be excluded for a valid firm when there are not enough data points to compute the historical volatilities or implied volatilities from both puts and calls needed for that date.

The raw data are used to construct the data samples analyzed below, according to the following procedures.

Historical (i.e., realized) volatility is computed by calendar month from the CRSP daily returns series, as the square root of the sample variance of the daily returns without dividends for that month. An observation is excluded if the stock has more than two missing values in that month. Volatilities are annualized by multiplying the daily figure by the square root of 252.

Leverage, L, is computed as 1 plus the face value of the debt for the quarter (long term + short term) divided by the period ending market value of equity. Market value of equity is the period ending closing price times the total shares outstanding. In the regression specifications below, the log change in this directly measured leverage variable will be denoted LEV.

Implied volatility is computed by averaging over five consecutive trading days. We compute one IV from the first 5 days in a month and another from the last 5 days. We will refer to these as $IV_{Beg\,t}$ and $IV_{End\,t}$. For every stock, on each day we extract from the Berkeley Options database the last trade prices at or before the 4 P.M. close of the stock market for the three closest to the money calls and the three closest to the money puts that mature in the next month, along with the matching contemporaneous stock price for each option. In this way, we obtain IVs from options with a comparable degree of moneyness each day as the stock price moves.

The sample and subsample IVs are computed as averages of the IVs from the individual call and put IVs for those options that are in the sample over the five-day period. For example, the call IV will be computed as the average of up to 15 individual option IVs, depending on the availability of option prices. In cases where there were fewer than 3 good option quotes over 5 days due to missing data, the observation was dropped from the sample.

Options traded at the Chicago Board Options Exchange (CBOE) have American exercise, so implied volatility is computed for each option using the binomial model. Adjustment for discrete dividend payout is done using a tree-building technique that allows a discrete jump in the tree when the stock goes ex-dividend, but lets it recombine rather than splintering in the next period. The procedure is based on building a recombining binomial tree for the stock price minus the present value of the dividend, then adding back the PV of the dividend to the nodes prior to ex-dividend date. It is explained in more detail in Hull [1997], example 15.5. To reduce the impact of non-monotonic convergence caused by discreteness in the binomial lattice, we price each option with a 60-step tree and also a 61-step tree and average the results.

The dividend input is the actual payout over the option's lifetime and the current 3-month Treasury bill rate, converted to a continuously compounded rate is used as the riskless interest rate.

To understand the dating of the leverage and volatility change variables it is useful to refer to Figure 1. Construction of the leverage variable uses the quarterly Compustat database. Assume that the firm in question has a normal fiscal year and we are looking at the quarter ending in June. Call June month t. The log change in leverage for that observation is simply $\log L_{June} - \log L_{March}$, i.e., $LEV = \log L_t - \log L_{t-3}$.

To measure the change in volatility that might result from this quarterly change in leverage, without overlapping the period during which leverage is changing, we compute the difference between volatility in the first period after the end of the quarter and volatility in the last period prior to the beginning of the quarter. We use a full month of prices to compute historical volatility, so in this case, we subtract the log of measured volatility for the month of March from that for July, i.e., log σ_{t+1} - log σ_{t-3} .

Implied volatility is computed as an average over a five day period. The change in the log of implied volatility for this case would be the log of IV from the first five days of July less that from the last five days in March. This is indicated in Figure 1 by the subintervals shown in gray.

For the regressions involving only stock returns and volatility changes with no measured leverage variable, we are not restricted to quarterly observations. For the June observations, we would relate the change in volatility from May to July to the return over the month of June. For historical volatilities, this involves log σ_{t+1} - log σ_{t-1}; for IVs, it is log $IV_{Beg\,t+1}$ - log $IV_{End\,t-1}$.

Finally, since most of the variation in leverage is due to changes in the market price of the stock, rather than issuance or retirement of firm securities, we also construct pseudo-monthly leverage observations, using the market value of the stock for each month within a quarter and the book value of the debt from Compustat. If the latter changes during the quarter, the change is divided evenly across the three months in the quarter. The change in implied volatility used for one of these monthly observations is computed from $IV_{Beg\,t+1}$ and $IV_{End\,t-1}$.

Table 1 gives summary statistics for the variables for individual stocks and for the S&P 100 index that are used in the study. The longer sample covers 1977-1996, while the shorter one spans 1991-95, the 5-year period for which we have detailed options data.

The 1977-96 period contains about 21,500 valid observations for individual stocks, with a typical firm having about $8.9 billion of equity and $5.1 billion of debt. The leverage measure is about 1.77, and historical volatility averaged .273. The Standard Deviation, Min and Max columns show that there is considerable variation across firms. The maximum values suggest the presence of several significant outliers in the data. We experimented with trimming more extreme data points out of the sample, but found that it does not have a very large influence on our results. One reason for this is that the regressions are all run in log form, making outliers less extreme.

With five years of monthly observations and 98 firms with valid data, the 1991-1995 data sample contains potentially up to 5880 observations. For the variables covered in the longer sample, we have about 5714 observations in this period. The number of observations on implied volatility was somewhat smaller. As expected, the average firm was larger in the later sample, with equity of $13.2 billion and debt of $8.8 billion. Interestingly, the leverage and historical volatility values were virtually identical for the two periods. Implied volatilities from calls averaged 0.254, very close to average historical volatility of 0.260. Put IVs averaged about 4 percentage points higher than IVs from calls. Both samples show a Max value of 4.219 for historical volatility. This is due to an outlier, rather than indicating a very noisy variable; the 99th percentile for historical volatility is 0.70.

The data for the OEX index are consistent with a rising stock market over the years, whose average return increased during the later period, at the same time average volatility was falling from 0.136 to 0.101. Unlike options on individual stocks, implied volatilities for index options averaged well above the level of realized volatility. Puts had slightly higher mean IV than calls.

For some of our analysis, we look at both monthly and quarterly data. Leverage variables are only available from Compustat quarterly, so we are somewhat more confident in the accuracy of the data at that interval. It will be seen, however, that the results are quite similar with quarterly and monthly data. The summary statistics for the quarterly interval would be very similar to what is shown in Table 1, so we do not report them here.

IV. The Leverage Effect with Returns

In this section, we will take a first broad look at the "leverage effect," as the term is normally used to describe the relationship between the return on an underlying asset and its subsequent volatility. Volatility can mean the standard deviation of realized returns, which we will call historical volatility, or it can mean implied volatility in option prices. Leverage effects are commonly found in both.

We will examine the behavior of both historical volatility and IV. Historical volatility can be analyzed over the 20-year period, while IV is only available for the shorter 5-year period. To facilitate comparisons, we also present results with historical volatility over the 1991-95 period.

We run the following simple regression in logs:

(7) $$\Delta\sigma = a_0 + a_1 R$$

where $\Delta\sigma$ is the change in the natural log of the volatility variable and R is the logarithmic return on the underlying stock or index over the period (excluding dividends).

It is important to get the timing right, so that the volatility change is measured from just before the beginning of the period spanned by the return variable to the period immediately following it, as described above. Historical volatilities are computed month by month, so the left hand variable is defined as $(\ln \sigma_{t+1} - \ln \sigma_{t-i})$ for i=1 (monthly) or i=3 (quarterly), where σ_t is the realized volatility for month t. IVs are measured over 5-day periods at the beginning and end of each month, so the change in implied volatility is measured from the end of month t-i to the beginning of month t+1. R is the log price change on the underlying stock or index over the period, defined as ($\ln S_t - \ln S_{t-i}$), for i=1 or 3, where S_t is the price at the end of month t.

The coefficient a_1 is the estimate of the elasticity of stock volatility with respect to the value of equity, θ_S from equation (3). It should be negative and smaller than 1 in absolute value, ranging from 0 for an all equity firm to -1.0 for an all debt firm.

In the theory sketched out above, a fall in the market price for the stock should increase its subsequent volatility, and a price rise of the same magnitude should reduce volatility by a comparable amount. However, the existence of a "leverage effect" is most commonly associated with falling, rather than rising, stock prices. This raises the question of whether it may be an asymmetrical phenomenon more closely related to negative returns than to leverage per se. To examine this possibility, we add a Down market dummy variable specification to equation (7):

$$(8) \qquad \Delta\sigma = a_0 + a_1 R + a_2 R \times \text{Down}$$

where Down = 1 if R is negative, and 0 otherwise. Now the "leverage effect" is measured by a_1 in an up market and $a_1 + a_2$ in a down market. A significantly negative value for a_2 will indicate that the effect is stronger when prices are falling.

Table 2 presents results for the S&P 100 index and Table 3 shows the same regressions on the individual stocks in the index. To facilitate comparisons with later results, and also to check that our procedure for constructing monthly variables does not introduce any major discrepancies, we run these regressions with both monthly and quarterly data.

Looking first at the estimates in Table 2 for the basic equation (7) regression with no dummy, we see that the "leverage effect" coefficient a_1 for the OEX index over the long sample period is estimated to be negative at both the monthly and quarterly interval, but not statistically significant. An estimate of -0.452 for a_1 in the monthly data regression means that if volatility starts at its sample average value of 0.136 (see Table 1) and the OEX index drops by 10 percent over a month, volatility can be expected to increase by about 4.52 percent, to 0.142. But the standard error on this coefficient is so large that the impact is far from being statistically significant.

For the shorter sample, historical volatility shows a negative coefficient on a_1 only at the quarterly interval, but neither estimate is close to being significant. The "leverage effect" in implied volatilities is substantially larger, however, and highly significant at the monthly interval. The same 10 percent drop in the OEX over a month should raise call IV more than 17%, from its average level of 0.133 to 0.159.

Note that from equation (3), the elasticity of stock volatility with respect to a change in the stock price should be - D / (D+E). Substituting from Table 1, we find that for the average firm in our sample, this is -0.365 and -0.399 for the longer and shorter period, respectively. We have not tried to determine the actual leverage of the OEX index, but we expect its theoretical elasticity to be close to these values.

When regression equation (8) is run, adding the Down market dummy to the specification, there is a striking change in the estimated "leverage effect." The theoretical relationship of volatility to financial leverage should be symmetrical to up and down moves in the market, but that is clearly contradicted here. Allowing differing "leverage effects" for up and down markets over the longer sample period, historical volatility exhibits a very strong effect when the market falls, but a reverse leverage effect when the market rises. A 10 percent market drop corresponds to an increase of (0.1079 - 0.3123) = 20.44 percent in measured (log) volatility, which would translate into a rise from the mean volatility value of 0.136 to 0.167. On the other hand, a 10 percent market rise would also increase volatility, by an estimated 10.79 percent, although this is not statistically significant at the 5 percent level. The t-statistic on a_2 indicates a statistically significant difference between the "leverage effect" on the OEX index in up and down markets.

Historical volatility in the shorter 1991-95 sample shows a similar pattern of an insignificant a_1 coefficient and a large negative value for a_2, although neither is significant. The asymmetry is greatest for implied volatilities. The "leverage effect" in IVs is very strong, but only when the market falls. The monthly estimates show essentially no effect of a 10 percent price rise, but a 10 percent fall would increase (log) IV nearly 50 percent, corresponding to a rise from the 1991-5 mean volatility level of 0.101 to 0.165.

To summarize what we see in Table 2, there is evidence of a "leverage effect" in both realized and implied volatilities for the OEX index and its options, but it is only statistically significant for IV at the monthly interval. However, the effect is strongly asymmetrical, operating dependably only in down markets. Implied volatilities show an extremely strong volatility response to falling stock prices, with an estimated elasticity of more than 5. This contrasts sharply with the theoretical argument behind the leverage effect, that suggests it should be symmetrical to up and down price changes.

Turning to the results for individual stocks shown in Table 3, we see a similar pattern to what was found for index options. The overall "leverage effect" is present, with all a_1 coefficient estimates negative and highly significant in the equation (7) specification. However the magnitude of the effect is much smaller with the individual stocks than with the index. For example, with monthly data the a_1 estimate is -1.758 for the OEX index but only -0.241 for the stocks that are in the index.

Like the OEX results, the "leverage effect" for individual stocks is asymmetric between up and down markets. In all cases, the equation (8) regression shows a highly significant negative value for a_2, indicating a substantially larger effect when the return is negative. The a_1 coefficient varies considerably, depending on the time period and the differencing interval. It ranges from -0.130 to 0.292, both estimates statistically significant, exhibiting both significant and insignificant values in between. Four of the six point estimates are positive. Overall, these results seem fairly consistent with the existence of a "leverage effect" that is actually a "down market" effect. But, as we saw for a_1 in the simpler specification, the point coefficient estimates for a_2 in the equation (8) regression are much smaller for individual stocks than for the index.

Another property of a true leverage effect is that because a firm's financial leverage is a "level" variable, a permanent change in leverage should produce a permanent change in stock volatility. It should be the amount of leverage in the firm's financial structure that determines volatility, not the change in leverage. Firm leverage as of a given date will be the cumulative sum of the changes that have occurred prior to that date, and the volatility of the stock price should be the cumulative sum of the volatility changes induced by those changes in leverage. Since each month's leverage change has equal weight in the cumulative sum, the effect of a leverage change in a specific month (or of a price change that affects leverage) should be permanent; it should not die out over time. By contrast, a volatility spike resulting from a non-permanent factor, such as a burst of "irrational exuberance" in the market, may be expected to die out once the market calms down again.

We can examine whether the "leverage effect" related to price changes on the underlying stock is permanent or dies out over time by running the following regression.

$$(9) \qquad \Delta\sigma = a_0 + a_1 R_t + a_2 R_{t-1} + a_3 R_{t-2}$$

where $\Delta\sigma$ is the change in the volatility over 3 months and R_t, R_{t-1}, and R_{t-2} are the returns in the last month, middle month and first month of the period, respectively. If the "leverage effect" is entirely due to the actual change in firm leverage associated with a change in the stock price, the estimates for a_1, a_2, and a_3 should be of about equal size. But if the "leverage effect" dies out over time, these coefficients should get smaller and less statistically significant for returns that are further back in time.

Since we found significant asymmetry in the "leverage effect" between up and down markets, we also fit a version of equation (9) with three Down market dummies:

$$(10) \qquad \Delta\sigma = a_0 + a_1 R_t + a_2 R_{t-1} + a_3 R_{t-2} + a_4 R_t \times \text{Down}_t + a_5 R_{t-1} \times \text{Down}_{t-1} + a_6 R_{t-2} \times \text{Down}_{t-2}$$

Table 4 shows the results for the OEX index and for the individual OEX stocks in Panel A and Panel B, respectively.

All three Panel A regressions without the Down dummies exhibit a negative a_1 coefficient on the OEX return in the most recent month, although it is significant at the 5% level only for implied volatility. The estimates for the a_3 coefficient on the third lag, are insignificant, and positive in two cases. These results suggest that the "leverage effect" related to returns does tend to die out over time.

Once the three Down market variables are added, the patterns become more complex. Nearly all estimates of a_4, a_5 and a_6 are negative and large, consistent with a large, but one-sided "leverage effect." The results are not monotonic, although it does seem that the coefficients become less negative and less significant as the returns age. Moreover, note that the full impact of a given negative return is given by the sum of two coefficients. For example, the effect of a negative 10% OEX return is estimated to be an increase in implied volatility of $-.10 \times (-0.440 + -4.661) = 51.01$ percent in the next month, but the longer term effect is only 43.59 percent and 11.52 percent 2 and 3 months later, respectively. All of the other equation (10) regressions show the same result, that the full impact of a negative OEX return dies out over time.

Turning to the individual stock results in Panel B, we find a similar overall pattern to that for the OEX index. Without dummies, the coefficients on returns are consistently negative and they become smaller for older observations. In contrast to Panel A, each of the individual coefficients is highly significant. They also tend to be substantially smaller. The coefficients on the down market returns are also smaller than for the OEX, mostly statistically significant, and show a leverage effect that diminishes over time. As with Panel A, adding coefficients to obtain the full effect of a given negative return reveals a monotonic decrease over time for all three regressions involving the dummies.

To summarize what we have seen in this section, both the S&P 100 stock index and the individual stocks in the index were found to exhibit a strong "leverage effect" connecting stock price changes in the market to subsequent changes in price volatility. However, several of our results are inconsistent with a "leverage effect" that is entirely due to changes in the actual financial leverage of the underlying firms. First, while the theory predicts a leverage effect that is symmetrical for increases and decreases in leverage, we find it to be highly asymmetrical, to the point that the "leverage effect" in most cases appears to be only operative in down markets, when leverage increases. Second, there is no obvious reason why the effect should be quantitatively different for a stock index than for the individual stocks that compose the index, yet our results show a distinctly larger "leverage effect" for the OEX index. Also, since a change in leverage should affect the volatility of the underlying stock itself, the size of the effect should be the same for implied volatilities as for realized volatilities, but our results show a much larger "leverage effect" in IVs. Finally, a leverage effect that really stems from a change in the underlying firm's effective capital structure should be permanent. But the results in Table 4 indicate that volatility changes from the "leverage effect" for both the OEX index and the individual stocks tends to die out quickly over time.

V. The Leverage Effect with Measured Leverage

The "leverage effect" is normally invoked to explain the effect of market returns on subsequent volatility, and much of the research on the subject makes no attempt to look at the actual financial leverage in the capital structures of the underlying firms. Section IV presented evidence relating volatility changes to returns. In this section we will examine the "leverage effect" using measures of actual firm leverage constructed from Compustat data on firm debt and equity for our sample of OEX stocks.

Quarterly data on outstanding debt and equity for 98 of the firms in the S&P 100 index as of December 1992 were obtained from Compustat, as described above. They are used to compute values of the leverage measure L, where $L_t = (1 + D_t/E_t) = (1 +$ the firm debt/equity ratio for date t). One problem with this specification, shared with previous articles on this subject, is that leverage should be measured using market values for firm securities, but only the book value of debt is available from Compustat. We can easily compute the market value of equity using CRSP data, but no easy solution exists for debt. We have constructed a monthly series for L by assigning changes in outstanding bonds to the final month of the quarter in which they occur. Although this solution is not entirely satisfactory, there is no perfect way to do this without introducing errors, given the data we have. We therefore report results both with the constructed monthly data and also with quarterly data for which the allocation problem does not arise.

The first exercise is to look again at the basic "leverage effect" using directly measured leverage changes in place of price changes in regression equations (7) and (8). The specifications become

$$\text{(11)} \qquad \Delta\sigma = a_0 + a_1 \, LEV ,$$

$$\text{(12)} \qquad \Delta\sigma = a_0 + a_1 \, LEV + a_2 \, LEV \times LevUp ,$$

where

$\Delta\sigma$ = $(\ln \sigma_{t+1} - \ln \sigma_{t-i})$ for i=1 (monthly) or i=3 (quarterly), and σ is the indicated historical or implied volatility variable;

LEV = $(\ln L_t - \ln L_{t-i})$, for i=1 or 3;

LevUp = dummy variable, equal to 1 if LEV is positive (leverage increases), 0 otherwise.

The coefficient a_1 is the estimate for θ_L, the elasticity of equity volatility with respect to a change in leverage. We saw above that θ_L should be equal to 1 if all changes in firm value are transmitted to the equity and firm volatility is constant. If, instead, overall firm volatility rises when firm value falls, as is quite plausible, the elasticity will be greater than 1. On the other hand, when a firm is close to insolvency, a portion of the fluctuations in firm value will be borne by the debt and the elasticity of equity volatility will be reduced. However, since we are working with only very large and financially sound firms, we do not expect this offsetting effect to play a role in our analysis. If the "leverage effect" for these firms is really the result of changes in the degree of leverage in their capital structure, we expect θ_L to be 1 or higher. Notice that the expected signs for the coefficients in these regressions should be opposite to those in the earlier regressions with returns. A negative return produces a positive change in leverage.

Table 5 presents the results from regression equations (11) and (12). Notice that we only examine individual firm volatilities here. We make no attempt to calculate a value for the actual financial leverage of the S&P 100 index. Overall, the results are quite similar to those in Table 3. This is to be expected, because most of the variation in L comes from changes in the market value of firm equity as the stock price fluctuates. Only the relatively infrequent issuance or retirement of bonds and new shares (not resulting from stocks splits) will alter the leverage measure other than because of market stock price changes.

Without dummies, the a_1 coefficients at both the monthly and quarterly intervals are all estimated to be positive, and all but one is highly significant. They are also highly significantly less than 1, however, well below the theoretical value. The equation (12) regressions allowing increasing and decreasing leverage to have different effects produce positive and mostly highly significant estimates for a_2. As in Table 3, the "leverage effect" is very asymmetrical, to the point that it is not statistically significant for falling leverage in 4 of the 6 regressions. Adding the two coefficients to get the full effect of an increase in leverage, the asymmetry appears to be larger than in Table 3.

We can also use directly measured leverage to test whether the leverage effect is persistent or dies out over time. Equations (13) and (14) are the equivalent regressions to (9) and (10) with LEV instead of returns.

$$\text{(13)} \qquad \Delta\sigma = a_0 + a_1 \, LEV_t + a_2 \, LEV_{t-1} + a_3 \, LEV_{t-2}$$

$$\begin{aligned}\text{(14)} \qquad \Delta\sigma = {} & a_0 + a_1 LEV_t + a_2 LEV_{t-1} + a_3 LEV_{t-2} \\ & + a_4 LEV_t \times LevUp_t + a_5 LEV_{t-1} \times LevUp_{t-1} + a_6 LEV_{t-2} \times LevUp_{t-2}\end{aligned}$$

Table 6 shows the results. The a_1, a_2, and a_3 coefficients in the equation (13) regression are uniformly positive and significant. The effect on historical volatility does appear to die out over time, but the IV results do not confirm that. Once the dummies are added, the patterns become quite mixed. There are negative coefficient estimates in some cases, statistically insignificant estimates and non-monotonic differences across the lags. It is difficult to draw firm conclusions from these results as to whether the leverage effect with measured leverage persists or dies out over time.

If the "leverage effect" is just due to changing leverage, it should not matter what the cause of the leverage change is. In particular, a change in a firm's capital structure as a result of issuing new bonds or new shares (or retiring outstanding securities) should have the same impact on volatility as a leverage change from a rise or fall in the market price of the stock. The next table looks at that issue.

We first decompose the LEV variable into the portions due to changes in outstanding debt, outstanding shares (not resulting from a stock split), and stock price.

Let D = face value of debt; N = number of shares outstanding; S = share price in the market. We have

$$L = 1 + \frac{D}{E} = 1 + \frac{D}{N\,S}$$

$$d\ln(L) = \left[\frac{\partial \ln(L)}{\partial D} dD + \frac{\partial \ln(L)}{\partial N} dN + \frac{\partial \ln(L)}{\partial S} dS\right]$$

$$= \frac{1}{L}\left[\frac{\partial L}{\partial D} dD + \frac{\partial L}{\partial N} dN + \frac{\partial L}{\partial S} dS\right]$$

$$= \frac{1}{L}\left[\frac{1}{N\,S} dD - \frac{D}{N^2\,S} dN - \frac{D}{N\,S^2} dS\right]$$

$$= \left(\frac{1}{L}\,\frac{D}{N\,S}\right)\left[\frac{dD}{D} - \frac{dN}{N} - \frac{dS}{S}\right]$$

Simplifying the first term, this becomes

$$d\ln(L) = \left(1 - \frac{1}{L}\right)\left[\, d\ln D - d\ln N - d\ln S \,\right] \tag{15}$$

which leads to the following regression specification in terms of discrete log differences:

$$\Delta\sigma = a_0 + a_1\, K\, \Delta D + a_2\, K\, \Delta N + a_3\, K\, R \tag{16}$$

$$\begin{aligned}\Delta\sigma = {} & a_0 + a_1\, K\, \Delta D + a_2\, K\, \Delta N + a_3\, K\, R \\ & + a_4\, K\, \text{Down}\, \Delta D + a_5\, K\, \text{Down}\, \Delta N + a_6\, K\, \text{Down}\, R\end{aligned} \tag{17}$$

where $\Delta\sigma$ = log(stock j volatility in month t+1) – log(stock j volatility in month t-3); $K = (1 - 1 / L)$ is a multiplicative constant; ΔD is the quarterly change in the log of book value of firm debt; ΔN is the change in the log of the number of shares outstanding; R is the change in log stock price per share; and Down is a dummy variable, equal to 1 if stock return is negative over the quarter, 0 otherwise. From (15), we see that the coefficients on the three sources of leverage changes should be equal in magnitude, and positive for increases in debt, negative for increases in equity from either new share issuance or positive stock returns in the market.

Table 7 shows the estimated coefficients for equations (16) and (17). One clear result is that leverage changes resulting from issuance or retirement of debt appear to have no significant impact on volatility, whether realized or implied. The a_1 coefficient estimates in every equation are very small and statistically insignificant. There is also a major difference between an equity-related leverage change that comes from a change in outstanding shares versus one that comes from a price change in the stock market. Both

a_2 and a_3 should be negative--an increase in firm equity will reduce leverage and volatility--and they should be of equal size. Here, a_3 is negative and highly significant in the specification without the Down dummy, while a_2 is positive and insignificant. Again, the "leverage effect" really looks like a down market effect. This is supported by the results when terms incorporating the Down market dummy are added to the equation. Debt changes do not have any significant effect on volatility either in up or down markets and neither do changes in shares outstanding. Changes in stock prices in the market seem to account for the entire "leverage" effect, with combined influence (a_3 + a_6) being over 1.0 in all three regressions. For implied volatilities, the "leverage effect" is clearly associated with negative stock returns only: the coefficient a_3 is significantly positive, meaning that volatility also rises in up markets, a reverse leverage effect.

VI. A Closer Look at the Leverage Effect in Implied Volatilities

Volatility is a property of the underlying stock. A change in volatility, therefore, should be reflected equally in the prices of all options written on that stock. However, it is well known that option implied volatilities differ systematically across strike prices, with low strike options (out of the money puts and in the money calls) having higher IVs than high strike options. This is the volatility skew pattern. It is also common for puts to have different IVs (generally higher) than calls, as we see in the summary statistics shown in Table 1. In this section we will examine how the "leverage effect" is manifested in implied volatilities of different options, according to moneyness and whether they are calls or puts.

The data samples are all drawn from the shorter 1991-1995 time period. Again, for individual stocks we report results from both monthly and quarterly data because of our greater confidence in the measured leverage LEV variable that is constructed from the quarterly Compustat capital structure data. Option IVs are divided into two subsamples by moneyness. On each date, we try to draw three calls and three puts from the options database, with strikes centered on the current stock price. Those with the two lower strikes are placed in the Low Strike subsample and those with the high strike go into the High Strike subsample. Somewhat surprisingly, we do not find large differences between the samples in average IV. For example, the mean IV for low strike (out of the money) puts was 0.294, while it was 0.289 for high strike puts. Call IVs averaged 0.259 and 0.255, respectively, for low strike (in the money) and high strike options. This suggests a smile pattern that is quite mild for individual stock options. However, since we are averaging IVs across options on 98 different stocks, we must be cautious about drawing general conclusions from these overall mean results.

We wish to be able to compare results across several dimensions: calls versus puts, up markets versus down markets, high strikes versus low strikes, leverage measured directly versus leverage proxied by returns, and monthly versus quarterly differencing intervals.

The first two dimensions are incorporated in the regression specification, as follows.

(18) $$\Delta\sigma = a_0 + a_1 lev \times Call + a_2 lev \times Put$$

(19) $$\Delta\sigma = a_0 + a_1 lev \times Call + a_2 lev \times Put + a_3 lev \times Call \times Down + a_4 lev \times Put \times Down$$

where

$\Delta\sigma$: log(implied volatility month t+1) – log(stock j volatility of t-i), for i=1 (monthly) or i=3 (quarterly);

lev : log price change (Panels A and B) or change of LEV (Panels C and D), respectively;

Call : dummy variable, equal to 1 for calls, 0 otherwise;

Put : dummy variable, equal to 1 for puts, 0 otherwise;

Down: dummy variable, equal to 1 if stock return is negative over the period, 0 otherwise.

The other dimensions are reflected in the different regressions and panels in Table 8. Each panel shows estimation results for regression equations (18) and (19) for all options together and the high and low strike samples. Panels A and B examine the "leverage effect" with returns, and C and D use the directly measured leverage variable LEV. Panels A and C use monthly data, while B and D use quarterly.

Overall, without distinguishing between up and down markets, both calls and puts show a significant "leverage effect" of about the same size, with returns and with measured leverage at the monthly, but not the quarterly, interval. There is some evidence that the effect is a little larger for calls than for puts. When a Down market dummy is added to the specification (equation (19)), the asymmetry seen earlier appears again. In nearly every case, a down market (or increase in LEV) produces a significant increase in IV for both calls and puts. For up markets, however, the results are more ambiguous. At the monthly interval, both with returns and with directly measured leverage, call and put IVs exhibit a significant "leverage effect." But these results are reversed at the quarterly interval, where they both exhibit a reverse leverage effect in rising markets (estimates for a_1 and a_2 that are positive in Panel B and negative in Panel D). These anomalous results may be partly related to the effect dying out over time, so that a leverage change in the most recent month has a bigger and more consistent immediate effect than does a change over the last three months. Comparing results for high strike versus low strike options, we find only minor differences that do not appear to obey any systematic pattern.

Table 9 looks at the same regressions with OEX options. In this case, without measured leverage data for the index, we only report results using return as a proxy for the leverage change. The contrast with Table 8 is striking. Without distinguishing between up and down markets, all but one of the monthly coefficients shows a large and significant "leverage effect" for both calls and puts. Coefficients are a little larger for calls than for puts. Note that these elasticities are not only large, they are too large. As we argued above, the elasticity of stock volatility with respect to stock returns should be negative and well under 1.0 in absolute value.

When the Down dummy is added to the specification, the estimated "leverage effect" becomes much larger still, with a total effect (adding a_1+a_3 for calls and a_2+a_4 for puts) in the range of -3 to -5. By contrast, the elasticity when returns are positive is negative, but much smaller (less than 1/10th the elasticity in a down market in several cases) and statistically insignificant. Once again, the "leverage effect" looks more like a "down market effect." Calls and puts behave very similarly, except that the effect appears to be stronger for Low strike calls than puts.

VII. Conclusion

The "leverage effect" refers to the well-established relationship between stock returns and volatility: volatility increases when the stock prices fall. This is directly observable in the implied volatilities embedded in market option prices and it has been found empirically in realized stock volatilities. A standard explanation for the phenomenon ties it to the effect that a change in market valuation of a firm's equity has on the degree of leverage in its capital structure. A fall in the market value of equity makes the firm more levered, so that with constant volatility for the overall firm, the volatility of the levered equity will increase. Our objective in this paper has been to examine this hypothetical explanation for the "leverage effect" critically.

We first analyzed the theoretical relationship between equity volatility and equity returns in a levered firm. Holding other things constant in a firm with just equity and default free debt in its capital structure, the elasticity of stock volatility with respect to share price is a function of firm leverage and is given by $-D/(D+E)$. This number, which must lie between 0.0 and -1.0, averaged about -0.4 in our sample of firms. We also showed that the elasticity of equity volatility with respect to firm leverage, measured as $(1 + D/E)$, should be -1.0. When we regressed volatility changes on equity returns for 98 of the firms included in the Standard and Poor's 100 index (OEX) and for the index itself, we obtained statistically significant negative elasticities that were about the right order of magnitude for individual stocks, but much too large for the OEX, especially with implied volatilities.

If the "leverage effect" is really just the result of changing financial leverage, several other conditions should hold. In particular, the effect should be the same for implied volatilities as for historical or realized volatilities; it should also be the same size whether the market goes up or down; and a permanent change in leverage should produce a permanent change in volatility. But in the empirical investigation, nearly all of these properties seem to be violated for both individual stocks and the OEX index. Only the results for individual stocks showed a "leverage effect" of about the same size for realized as for implied volatilities. By contrast, for the OEX index using monthly data, the "leverage effect" with IVs was 3 to 4 times larger than with realized volatilities.

By far the strongest and most regular discrepancy we uncovered is the striking asymmetry of the "leverage effect" between up and down markets. In general, the key coefficients turned out to be insignificant and often of the "wrong" sign when returns were positive, while negative returns systematically produced a strong and highly significant increase in volatility (often too strong, in fact). We also found some evidence that the effect is not permanent, but tends to die out over a few months.

The "leverage effect" typically refers to the connection between stock returns and volatility changes. One of our contributions in this paper is to examine whether directly measured changes in leverage, computed from data on the actual amounts of outstanding debt and equity, are also associated with a "leverage effect" for our sample of firms. What we found was that there is a "leverage effect," but that it tends to show some of the same anomalies as were seen with returns. It is not the right magnitude--less than half of the theoretical elasticity of -1.0--and it is highly asymmetrical between up and down markets. In one of the more telling regressions, we separated the sources of leverage changes into those due to changes in outstanding debt, changes in outstanding shares, and changes in the market valuation of existing shares. A true leverage effect should not depend on the cause of the change in leverage, but we found that neither changes in outstanding bonds nor stock produced a significant change in volatility. Only changes the stock's market price did, and then, only when the market fell.

Finally, we looked more closely at the behavior of implied volatilities from options on individual stocks and on the OEX index. We were somewhat surprised to find little difference between calls and puts or between options with high and low strikes. The overall results, however, were consistent with our earlier results. The "leverage effect" appears to be much more related to falling stock prices than to leverage per se, and it is much too strong for index option implied volatilities.

In the end, is the "leverage effect" a leverage effect? Our results suggest that it mostly is not. The evidence is much stronger that the "leverage effect" should more properly be termed a "down market effect." The true explanation for the phenomenon is yet to be determined.

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APPENDIX

Table A1: Stocks in the S&P 100 Index as of December 31, 1992

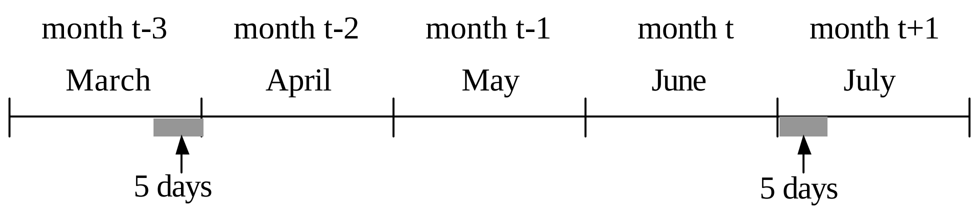
(Shaded firms have been excluded from the sample.)

Aluminum Company America	Coastal Corp	Harris Corp	Paramount Communications
American Electric Power Inc	Champion International Corp	Humana Inc	Pepsico Inc
American General Corp	C I G N A Corp	Hewlett Packard Co	Polaroid Corp
American International Group	Colgate Palmolive Co	First Interstate Bancorp	Harrahs Entertainment Inc
Ameritech Corp	Computer Sciences Corp	IBM	Ralston Purina Group
Allegheny Teledyne Inc	Unicom Corp Holding Co	Int'l Flavors & Frag Inc	Rockwell International Corp
A M P Inc	Delta Air Lines Inc	Mallinckrodt Inc New	Raytheon Co
Amoco Corp	Du Pont E I De Nemours & Co	International Paper Co	Sears Roebuck & Co
Atlantic Richfield Co	Digital Equipment Corp	I T T	Skyline Corp
Avon Products Inc	Disney Walt Co	Johnson & Johnson	Schlumberger Ltd
American Express Co	Dow Chemical Co	K Mart Corp	Southern Co
Boeing Co	Eastman Kodak Co	Coca Cola Co	A T & T Corp
Bankamerica Corp	Entergy Corp New	Litton Industries Inc	Tandy Corp
Baxter International Inc	Ford Motor Co Del	Limited Inc	Tektronix Inc
Brunswick Corp	Federal Express Corp	Mcdonalds Corp	Toys R Us Inc
Boise Cascade Corp	Fluor Corp	Massmutual Corporate Invs Inc	Texas Instruments Inc
Black & Decker Corp	First Chicago Corp	Merrill Lynch & Co Inc	U A L Corp
Bell Atlantic Corp	General Dynamics Corp	Minnesota Mining & Mfg Co	Unisys Corp
Baker Hughes Inc	General Electric Co	Mobil Corp	Upjohn Co
Bristol Myers Squibb Co	General Motors Corp	Merck & Co Inc	United Technologies Corp
Burlington Northern Santa Fe	Great Western Financial Corp	Monsanto Company	Williams Cos
Bethlehem Steel Corp	Halliburton Company	Norfolk Southern Corp	Wal Mart Stores Inc
Capital Cities Abc Inc	Homestake Mining Co	National Semiconductor Corp	Weyerhaeuser Co
Citicorp	Heinz H J Co	Northern Telecom Ltd	Exxon Corp
Ceridian Corp	Honeywell Inc	Occidental Petroleum Corp	Xerox Corp

Figure 1

Timelines for Dating Changes in Variables

Quarterly changes



Monthly changes

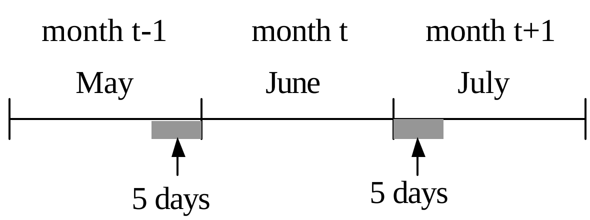


Table 1: Summary Statistics for the Data Sample

	MEAN	STD	MIN	MAX	NOBS
Panel A: Sample of S&P 100 Firms, 1977-1996					
Market Value of Equity (million $)	8935.93	14068.39	103.769	171731	21502
Face Value of Debt (million $)	5147.21	14567.54	0	180645	21502
Leverage	1.767	1.534	1.000	22.952	21502
Historical Volatility	0.273	0.130	0.044	4.219	21497
Panel B: Sample of S&P 100 Firms, 1991-1995					
	MEAN	STD	MIN	MAX	NOBS
Market Value of Equity (million $)	13211.69	17100.15	161.24	120259	5714
Face Value of Debt (million $)	8767.84	21504.33	0	180645	5714
Leverage	1.809	1.575	1.000	19.837	5714
Historical Volatility	0.260	0.131	0.067	4.219	5711
Implied Volatility of Calls	0.254	0.086	0.000	0.972	5170
Implied Volatility of Puts	0.292	0.081	0.797	0.911	4949
Panel C: S&P 100 Index, 1977-1996					
	MEAN	STD	MIN	MAX	NOBS
Historical Volatility	0.136	0.072	0.052	0.967	240
Return on OEX	0.008	0.042	-0.238	0.130	239
OEX Level	197.909	112.766	69.450	541.720	240
Panel D: S&P 100 Index, 1991-1995					
	MEAN	STD	MIN	MAX	NOBS
Historical Volatility	0.101	0.033	0.052	0.206	60
Return on OEX	0.011	0.029	-0.050	0.091	60
OEX Level	311.803	44.162	237.790	431.520	60
Implied Volatility of Calls	0.133	0.020	0.090	0.182	60
Implied Volatility of Puts	0.140	0.026	0.088	0.219	60

Table 2: The "Leverage Effect" with OEX returns.

The regression is

(8) $$\Delta\sigma = a_0 + a_1 R + a_2 R \times Down ,$$

where

$\Delta\sigma$ = $(\ln \sigma_{t+1} - \ln \sigma_{t-i})$ for i=1 (monthly) or i=3 (quarterly), and σ is the indicated historical or implied volatility variable;

R = $(\ln S_t - \ln S_{t-i})$, for i=1 or 3, where S_t is the price at the end of month t.

Down = dummy variable, equal to 1 if R < 0, 0 otherwise.

(t-statistics in parentheses)

PANEL A: Monthly data	Constant a_0	OEX return a_1	Down return a_2	R^2 NOBS
Historical volatility, 1977-96	0.006 (0.263)	-0.452 (-0.710)	–	0.003 238
	-0.043 (-1.382)	1.079 (1.297)	-3.123 (-1.978)	0.019 238
Historical volatility, 1991-95	-0.190 (-0.476)	0.598 (0.377)	–	0.003 60
	-0.037 (-0.468)	1.212 (0.367)	-1.621 (-0.284)	0.004 60
Call and put IV, 1991-95	-0.003 (-0.151)	-1.758 (-2.185)	–	0.105 58
	-0.060 -1.716	0.213 (0.172)	-5.119 (-1.993)	0.175 58
PANEL B: Quarterly data	**Constant a_0**	**OEX return a_1**	**Down return a_2**	**R^2 NOBS**
Historical volatility, 1977-96	-0.044 (-1.177)	-0.644 (-1.206)	–	0.023 79
	-0.160 (-3.245)	1.300 (1.512)	-3.779 (-3.323)	0.118 79
Historical volatility, 1991-95	-0.098 (-1.562)	-0.982 (-0.613)	–	0.019 20
	-0.150 (-1.329)	-0.174 (-0.070)	-3.608 (-0.708)	0.033 20
Call and put IV, 1991-95	0.011 (0.274)	-1.212 (-1.094)	–	0.119 19
	-0.106 (-2.056)	0.903 (0.684)	-7.945 (-3.009)	0.428 19

Table 3: The "Leverage Effect" with Individual Stock Returns.

The regression is

(8) $$\Delta\sigma = a_0 + a_1 R + a_2 R \times Down ,$$

where

$\Delta\sigma$ = ($\ln \sigma_{t+1}$ - $\ln \sigma_{t-i}$) for i=1 (monthly) or i=3 (quarterly) and σ is the indicated historical or implied volatility variable;
R = ($\ln S_t$ - $\ln S_{t-i}$), for i=1 or 3, where S_t is the price at the end of month t.
Down = dummy variable, equal to 1 if R < 0, 0 otherwise.

(t-statistics in parentheses)

PANEL A: Monthly data	Constant a_0	Stock return a_1	Down return a_2	R^2 NOBS
Historical volatility, 1977-96	0.002 (0.612)	-0.340 (-14.218)	–	0.010 21195
	-0.021 (-5.972)	0.117 (2.178)	-0.663 (-9.509)	0.013 21195
Historical volatility, 1991-95	-0.003 (-0.645)	-0.349 (-7.748)	–	0.008 5649
	-0.023 (-3.662)	0.082 (0.801)	-0.631 (-4.736)	0.011 5649
Call and put IV, 1991-95	-0.001 (-0.676)	-0.241 (-13.202)	–	0.009 5224
	-0.006 (-2.488)	-0.130 (-3.137)	-0.157 (-2.488)	0.010 5224
PANEL B: Quarterly data	**Constant a_0**	**Stock return a_1**	**Down return a_2**	**R^2 NOBS**
Historical volatility, 1977-96	0.090 (16.156)	-0.254 (-8.409)	–	0.014 5563
	0.047 (6.052)	0.219 (3.162)	-0.691 (-7.568)	0.025 5563
Historical volatility, 1991-95	0.080 (9.171)	-0.221 (-4.214)	–	0.010 1579
	0.058 (4.711)	-0.035 (0.323)	-0.391 (-2.603)	0.011 1579
Call and put IV, 1991-95	0.035 (7.440)	-0.119 (-4.341)	–	0.004 1413
	-0.000 (-0.056)	0.292 (4.832)	-0.601 (-7.475)	0.024 1413

Table 4: Dying Out of the "Leverage Effect" over Time Using Returns

The regression is

$$(10)\quad \Delta\sigma = a_0 + a_1 R_t + a_2 R_{t-1} + a_3 R_{t-2} + a_4 R_t \times Down_t + a_5 R_{t-1} \times Down_{t-1} + a_6 R_{t-2} \times Down_{t-2}$$

where

$\Delta\sigma$ = ($\ln \sigma_{t+1}$ - $\ln \sigma_{t-3}$), and σ is the indicated historical or implied volatility variable;
R_{t-i} = ($\ln S_{t-i}$ - $\ln S_{t-i-1}$), for i=0, 1, 2, where S_t is the price at the end of month t.
$Down_{t-i}$ = dummy variable, equal to 1 if $R_{t-i} < 0$, 0 otherwise; i=0, 1, 2.

(t-statistics in parentheses)

PANEL A: OEX Index	Constant a_0	Return(t) a_1	Return(t-1) a_2	Return(t-2) a_3	Neg R(t) a_4	Neg R(t-2) a_5	Neg R(t-2) a_6	R^2 NOBS
Historical volatility 1977-96	0.017 (0.602)	-1.213 (-1.511)	-1.234 (-1.934)	0.537 (0.589)	–	–	–	0.035 236
	-0.158 (-2.900)	1.133 (1.176)	0.641 (0.550)	2.254 (1.781)	-4.800 (-2.863)	-2.956 (-1.865)	-3.199 (-1.362)	0.084 236
Historical volatility 1991-95	-0.045 (-0.754)	-1.026 (-0.507)	-0.052 (-0.027)	1.009 (-0.425)	–	–	–	0.010 60
	-0.165 (-1.296)	1.986 (0.776)	2.256 (0.849)	-0.194 (-0.044)	-8.442 (-1.434)	-5.499 (-0.919)	3.253 (0.428)	0.070 60
Implied volatility 1991-95	0.000 (-0.014)	-2.249 (-2.211)	-1.272 (-1.206)	-0.294 (-0.317)	–	–	–	0.118 56
	-0.133 (-2.463)	-0.440 (-0.310)	1.081 (0.824)	0.500 (0.362)	-4.661 (-1.639)	-5.440 (-1.881)	-1.652 (-0.663)	0.227 56

Table 4, continued

PANEL B: Individual stocks	Constant a_0	Return(t) a_1	Return(t-1) a_2	Return(t-2) a_3	Neg R(t) a_4	Neg R(t-2) a_5	Neg R(t-2) a_6	R^2 NOBS
Historical volatility 1977-96	0.002 (0.855)	-0.412 (-15.748)	-0.310 (-11.858)	-0.183 (-7.014)	–	–	–	0.020 21003
	-0.032 (-7.055)	-0.005 (-0.079)	-0.005 (-0.085)	-0.122 (-4.367)	-0.589 (-7.732)	-0.425 (-5.576)	1.325 (5.158)	0.025 21003
Historical volatility 1991-95	-0.013 (-2.606)	-0.383 (-7.807)	-0.232 (-4.754)	-0.189 (-3.881)	–	–	–	0.015 5647
	-0.034 (-4.474)	-0.085 (-0.787)	-0.045 (-0.422)	-0.181 (-3.268)	-0.440 (-3.132)	-0.271 (-1.935)	0.292 (0.310)	0.017 5647
Implied volatility 1991-95	-0.013 (-6.623)	-0.279 (-13.246)	-0.173 (-8.206)	-0.188 (-8.938)	–	–	–	0.034 4827
	-0.029 -8.692	-.129 (-2.735)	0.030 (0.642)	-0.185 (-7.656)	-0.222 (-3.594)	-0.290 (-4.659)	-0.073 (-0.183)	0.038 4827

Table 5: The "Leverage Effect" for Individual Stocks Using Measured Leverage

The regression is

(12) $$\Delta\sigma = a_0 + a_1\,\mathrm{LEV} + a_2\,\mathrm{LEV} \times \mathrm{LevUp}\ ,$$

where

- $\Delta\sigma$ = ($\ln \sigma_{t+1}$ - $\ln \sigma_{t-i}$) for i=1 (monthly) or i=3 (quarterly), and σ is the indicated historical or implied volatility variable;
- LEV = ($\ln L_t$ - $\ln L_{t-i}$), for i=1 or 3, and $L_t = (1 + D_t/E_t)$ = 1 + the firm debt/equity ratio for month t.
- LevUp = dummy variable, equal to 1 if LEV is positive (leverage increases), 0 otherwise.

(t-statistics in parentheses)

PANEL A: Monthly data	Constant a_0	LEV a_1	LEV up a_2	R^2 NOBS
Historical volatility, 1977-96	0.001 (0.498)	0.383 (7.367)	–	0.003 21176
	-0.007 (-2.291)	-0.036 (-0.399)	0.699 5.809	0.005 21176
Historical volatility, 1991-95	-0.004 (-0.809)	0.363 (3.403)	–	0.002 5649
	-0.015 (-2.705)	-0.058 (-0.385)	0.989 (3.992)	0.004 5649
Call and put IV, 1991-95	-0.001 (-0.712)	0.382 (8.773)	–	0.003 5224
	-0.005 (-2.374)	0.213 (3.185)	0.354 (3.453)	0.004 5224
PANEL B: Quarterly data	**Constant a_0**	**LEV a_1**	**LEV up a_2**	**R^2 NOBS**
Historical volatility, 1977-96	0.089 (16.032)	0.472 (6.296)	–	0.008 5561
	0.085 (12.968)	0.346 (2.732)	0.223 (1.247)	0.008 5561
Historical volatility, 1991-95	0.079 (8.912)	0.401 (2.728)	–	0.006 1579
	0.070 (6.530)	0.190 (0.882)	0.498 (1.366)	0.007 1579
Call and put IV, 1991-95	0.034 (7.111)	0.038 (0.510)	–	0.000 1413
	0.019 (3.266)	-0.381 (-3.287)	0.942 (4.891)	0.008 1413

Table 6: Dying Out of the "Leverage Effect" over Time Using Measured Leverage

The regression is

(14) $$\Delta\sigma = a_0 + a_1 LEV_t + a_2 LEV_{t-1} + a_3 LEV_{t-2} + a_4 LEV_t \times LevUp_t + a_5 LEV_{t-1} \times LevUp_{t-1} + a_6 LEV_{t-2} \times LevUp_{t-2}$$

where

$\Delta\sigma$ = ($\ln \sigma_{t+1} - \ln \sigma_{t-3}$), and σ is the indicated historical or implied volatility variable;
LEV = ($\ln L_{t-i} - \ln L_{t-i-1}$), for i= 0, 1, 2, and $L_{t-i} = (1 + D_{t-i}/E_{t-i})$ = 1 + the firm debt/equity ratio for month t-i.
LevUp = dummy variable, equal to 1 if LEV is positive (leverage increases), 0 otherwise.

(t-statistics in parentheses)

Individual stocks	Constant a_0	LEV_t a_1	LEV_{t-1} a_2	LEV_{t-2} a_3	$LevUp_t$ a_4	$LevUp_{t-1}$ a_5	$LevUp_{t-2}$ a_6	R^2 NOBS
Historical volatility 1977-96	0.002 (0.552)	0.605 (10.664)	0.392 (6.903)	0.163 (2.866)	–	–	–	0.008 20984
	-0.003 (-1.018)	0.076 (0.765)	0.621 (6.286)	0.119 (1.996)	0.862 (6.384)	-0.435 (-3.216)	2.455 (2.465)	0.010 20984
Historical volatility 1991-95	-0.014 (-2.769)	0.484 (4.263)	0.348 (3.132)	0.272 (2.470)	–	–	–	0.005 5647
	-0.027 (-4.347)	-0.234 (-1.432)	0.532 (3.366)	0.230 (2.527)	1.623 (5.937)	-0.413 (-1.535)	0.231 (0.953)	0.010 5647
Implied volatility 1991-95	-0.014 (-6.685)	0.364 (6.914)	0.235 (4.624)	0.326 (6.418)	–	–	–	0.013 4827
	-0.020 (-7.869)	0.130 (1.630)	0.185 (2.345)	0.303 (5.514)	0.535 (4.229)	0.134 (1.102)	2.943 (1.584)	0.014 4827

Table 7: Decomposing the Leverage Effect from Changes due to Book Values versus Stock Returns

(17) $$\Delta\sigma = a_0 + a_1 K \Delta D + a_2 K \Delta N + a_3 K R + a_4 K \text{ Down } \Delta D + a_5 K \text{ Down } \Delta N + a_6 K \text{ Down } R$$

where $\Delta\sigma$ = log(stock j volatility in month t+1) – log(stock j volatility in month t-3);
$K = (1 - 1/L)$ is a multiplicative constant;
ΔD is the quarterly change in the log of book value of firm debt;
ΔN is the change in the log of the number of shares outstanding;
R is the change in log stock price per share;
Down is a dummy variable, equal to 1 if stock return is negative over the quarter, 0 otherwise.

(t-statistics in parentheses)

Regression	Constant a_0	Change in Book Value of Debt a_1	Change in Outstanding Shares a_2	Stock Return a_3	Down Market			R^2 NOBS
					Debt chg a_4	Shares chg a_5	Stock return a_6	
Hist vol, 1977-96 no dummies	0.089 (15.628)	0.038 (0.421)	0.101 (0.481)	-0.968 (-9.257)	_	_	_	0.020 5460
Hist vol, 1977-96 with dummies	0.071 (10.316)	0.057 (0.455)	0.100 (0.207)	-0.180 (-0.912)	-0.061 (-0.314)	-0.367 (-0.676)	-1.277 (-4.803)	0.024 5460
Hist vol, 1991-95 no dummies	0.079 (8.753)	0.096 (0.445)	0.055 (0.155)	-0.811 (-4.203)	_	_	_	0.015 1555
Hist vol, 1991-95 with dummies	0.071 (6.587)	-0.082 (-0.323)	0.981 (0.738)	-0.509 (-1.710)	0.511 (1.077)	-1.207 (-0.865)	-0.630 (-1.331)	0.017 1555
IV, 1991-95 no dummies	0.033 (6.846)	0.033 (0.270)	0.270 1.673	-0.234 (-2.293)	_	_	_	1396 0.007
IV, 1991-95 with dummies	0.010 (1.686)	-0.006 (0.041)	-0.082 (-0.123)	0.747 (4.544)	0.002 (0.010)	0.054 (0.078)	-1.807 (-7.354)	1396 0.028

Table 8: The "Leverage Effect" in Implied Volatility for Calls versus Puts on Individual Stocks

The regressions are

(19) $\Delta\sigma = a_0 + a_1 \text{lev} \times \text{Call} + a_2 \text{lev} \times \text{Put} + a_3 \text{lev} \times \text{Call} \times \text{Down} + a_4 \text{lev} \times \text{Put} \times \text{Down}$

where

$\Delta\sigma$: log(implied volatility month t+1) – log(stock j volatility of t-i), for i=1 (monthly) or 3 (quarterly);
lev : log price change (Panels A and B) or change of LEV (Panels C and D), respectively;
Call : dummy variable, equal to 1 for calls, 0 otherwise;
Put : dummy variable, equal to 1 for puts, 0 otherwise;
Down: dummy variable, equal to 1 if stock return is negative over the period, 0 otherwise.

High strike options (out of the money calls and in the money puts) are those with the highest of the 3 strikes on a given day. Low strike options have the lowest and middle strikes.

(t-statistics in parentheses)

Panel A: lev = Returns, monthly data	Constant a_0	Call leverage a_1	Put leverage a_2	Down Market: Call lev, a_3	Down Market: Put lev, a_4	R^2 NOBS
IV, 1991-95 All options	-0.004 (-2.353)	-0.289 (-12.518)	-0.241 (-10.442)	_	_	0.021 9182
	-0.008 (-3.573)	-0.186 (-4.098)	-0.173 (-3.819)	-0.156 (-2.653)	-0.101 (-1.719)	0.021 9182
IV, 1991-95 High strike options	-0.001 (-0.626)	-0.315 (-11.085)	-0.243 (-8.544)	_	_	0.019 7468
	-0.003 (-1.210)	-0.196 (-3.634)	-0.281 (-5.198)	-0.188 (-2.627)	0.062 (0.870)	0.020 7468
IV, 1991-95 Low strike options	-0.004 (-2.074)	-0.264 (-8.761)	-0.267 (-8.867)	_	_	0.002 8080
	-0.009 (-3.245)	-0.187 (-3.260)	-0.142 (-2.465)	-0.116 (-1.532)	-0.193 (-2.548)	0.002 8080

Table 8, continued

Panel B: lev = Returns, quarterly data	Constant a_0	Call leverage a_1	Put leverage a_2	Down Market		R^2
				Call lev, a_3	Put lev, a_4	NOBS
IV, 1991-95 All options	0.037 (8.546)	-0.148 (-4.407)	-0.085 (2.545)	–	–	0.001 2554
	0.001 (0.197)	0.221 (3.324)	0.381 (5.730)	-0.523 (-6.148)	-0.676 (-7.948)	0.023 2554
IV, 1991-95 High strike options	0.016 (4.311)	-0.197 (-6.188)	-0.118 (-3.686)	–	–	0.010 2128
	-0.003 (-0.524)	0.008 (0.130)	0.155 (2.480)	-0.290 (-3.575)	-0.392 (-4.841)	0.030 2128
IV, 1991-95 Low strike options	0.007 (1.661)	-0.105 (-3.239)	-0.122 (-3.791)	–	–	0.001 2278
	-0.038 (-3.221)	0.378 (2.924)	0.438 (3.368)	-0.699 (-4.191)	-0.807 (-4.835)	0.014 2278
Panel C: lev = LEV, monthly data	**Constant a_0**	**Call leverage a_1**	**Put leverage a_2**	**Down Market**		**R^2**
				Call lev, a_3	**Put lev, a_4**	**NOBS**
IV, 1991-95	-0.004 (-2.419)	0.502 (9.178)	0.361 (6.590)	–	–	0.010 9182
	-0.005 (-2.981)	0.351 (4.396)	0.356 (4.452)	0.310 (2.685)	0.014 (0.119)	0.011 9182
IV, 1991-95 High strike options	-0.001 (-0.651)	0.525 (8.074)	0.392 (6.034)	–	–	0.011 7468
	-0.002 (-1.101)	0.315 (3.467)	0.494 (5.426)	0.479 (3.445)	-0.214 (-1.537)	0.013 7468
IV, 1991-95 Low strike options	-0.005 (-2.450)	0.398 (5.710)	0.376 (5.396)	–	–	0.001 8080
	-0.007 (-2.925)	0.249 (2.481)	0.350 (3.489)	0.308 (2.102)	0.060 (0.406)	0.001 8080

Table 8, continued

Panel D: lev = LEV, quarterly data	Constant a_0	Call leverage a_1	Put leverage a_2	Down Market Call lev, a_3	Down Market Put lev, a_4	R^2 NOBS
IV, 1991-95 All options	0.035 (8.154)	0.066 (0.761)	-0.014 (-0.156)	–	–	0.000 2554
	0.029 (6.205)	-0.165 (-1.194)	-0.376 (-2.724)	0.548 (2.621)	0.727 (3.480)	0.007 2554
IV, 1991-95 High strike options	0.015 (3.955)	0.246 (2.827)	0.114 (1.312)	–	–	0.004 2128
	0.011 (2.593)	0.059 (0.448)	-0.151 (-1.143)	0.387 (2.038)	0.527 (2.777)	0.011 2128
IV, 1991-95 Low strike options	0.005 (1.309)	-0.062 (-0.771)	0.102 (1.261)	–	–	0.000 2278
	0.002 (0.521)	-0.180 (-1.356)	-0.016 (-0.214)	0.271 (1.471)	0.258 (1.399)	0.001 2278

Table 9: The "Leverage Effect" in Implied Volatility for OEX Calls versus Puts

The regressions are

(19) $\Delta\sigma = a_0 + a_1 lev \times Call + a_2 lev \times Put + a_3 lev \times Call \times Down + a_4 lev \times Put \times Down$

where

$\Delta\sigma$: log(implied volatility month t+1) – log(stock j volatility of t-i), for i=1 (monthly) or 3 (quarterly);
lev : log price change ($\ln S_t - \ln S_{t-i}$), for i=1 or 3, where S_t is the price at the end of month t;
Call : dummy variable, equal to 1 for calls, 0 otherwise;
Put : dummy variable, equal to 1 for puts, 0 otherwise;
Down: dummy variable, equal to 1 if stock return is negative over the period, 0 otherwise.

High strike options (out of the money calls and in the money puts) are those with the highest of the 3 strikes on a given day. Low strike options have the lowest and middle strikes.

Panel A: monthly data	Constant	Call leverage	Put leverage	Down Market		R^2
	a_0	a_1	a_2	Call lev, a_3	Put lev, a_4	NOBS
IV, 1991-95 All options	0.0219 (1.812)	-2.079 (-3.792)	-1.884 (-3.848)	–	–	0.184 116
	-0.019 (-1.187)	-0.586 (-0.850)	-0.542 (-0.875)	-3.972 (-3.080)	-3.394 (-2.473)	0.197 116
IV, 1991-95 High strike options	0.021 (1.712)	-2.001 (-3.715)	-1.748 (-3.461)	–	–	0.155 116
	-0.017 (-0.984)	-0.683 (-0.969)	-0.386 (-0.597)	-3.395 (-2.609)	-3.566 (2.372)	0.189 166
IV, 1991-95 Low strike options	0.022 (1.741)	-2.126 (-3.639)	-2.009 (-4.001)	–	–	0.189 116
	-0.022 (-1.370)	-0.426 (-0.586)	-0.657 (-1.027)	-4.629 (-3.292)	-3.295 (-2.503)	0.248 116

Table 9, continued

Panel B: quarterly data	Constant a_0	Call leverage a_1	Put leverage a_2	Down Market: Call lev, a_3	Down Market: Put lev, a_4	R^2 NOBS
IV, 1991-95 All options	0.012 (0.377)	-1.596 (-1.568)	-1.326 (-1.635)	–	–	0.181 38
	-0.068 (-1.739)	-0.131 (-0.112)	0.087 (0.088)	-5.631 (-2.000)	-5.175 (-2.767)	0.330 38
IV, 1991-95 High strike options	0.007 (0.206)	-1.448 (-1.337)	-1.064 (-1.259)	–	–	0.128 38
	-0.074 (-1.779)	0.037 (0.030)	0.417 (0.406)	-5.587 (-1.920)	-5.553 (-2.955)	0.276 38
IV, 1991-95 Low strike options	0.015 (0.530)	-1.749 (-1.810)	-1.570 (1.970)	–	–	0.229 38
	-0.061 (-1.587)	-0.320 (-0.289)	-0.232 (-0.237)	-5.590 (-2.000)	-4.802 (-2.433)	0.367 38