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The Effect of Volatility Changes on the Level of Stock Prices and Subsequent Expected Returns

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ABSTRACT

This paper estimates volatility changes in daily returns to the Dow Jones Industrial Average over the sample period 1897 through 1988. This allows a direct investigation of the reaction of the level of stock prices and subsequent expected returns to these estimated changes in volatility. We provide empirical evidence consistent with relatively large and systematic revisions in stock prices and subsequent expected returns to volatility changes. However, there appears to be an asymmetry in the market's reaction to volatility increases as opposed to volatility decreases. A majority of our volatility changes cannot be associated with the release of significant economic information.

THE CONTROVERSIAL PAPERS BY Shiller (1981a,b) and LeRoy and Porter (1981) suggest that stock prices are more volatile than would be predicted by a present value model where future dividends are capitalized at a constant discount rate. From the outset of the controversy surrounding this finding (for example, Long (1981)), nonstationary discount rates have been offered as a potential explanation for the apparent inconsistency. Pindyck (1984), among others, argues that excess volatility may be explained by changes in risk which in turn induce changes in risk premia.

Poterba and Summers (1986) dismiss this possibility after examining the autoregressive character of stock market volatility. They argue that changes in market volatility dissipate too quickly to induce the relatively large changes in the long-run rate of discount needed to account for the excess volatility documented by Shiller and LeRoy and Porter. Poterba and Summers, however, do not directly examine the reaction of stock prices to changes in volatility. Rather, they incorporate their estimates of the autoregressive structure of volatility into an equity valuation model along with an assumed level of market risk aversion. They conclude that, given the estimated autoregressive character of volatility, changes in stock prices in response to shifts in volatility are likely to be small.

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In this paper we directly estimate the reaction of the level of stock prices and subsequent expected returns to changes in volatility. The roots of our investigation extend back to Merton (1980) who introduced a longitudinal approach to measuring reward to risk ratios for a stock market index with stochastic volatility. His methodology assumes that market volatility is constant within calendar months and that changes in volatility occur at monthly transition points. French, Schwert, and Stambaugh (1987) extend Merton's methodology by separating (through ARIMA and GARCH-M models) monthly market volatility into its expected and unexpected components. French, Schwert, and Stambaugh then estimate the relationship between realized monthly returns and the two volatility components. They find a significant negative relationship between returns and unexpected changes in volatility as well as a significant positive relationship between returns and expected volatility under the GARCH-M procedure.

As with Merton, the methodology of French, Schwert, and Stambaugh assumes that changes in market volatility occur at monthly transition points. Violations of this assumption may induce an autoregressive character in the resultant time series as market volatility changes **within** months give the appearance of 2-month transitions from one level of volatility to another. Since the reaction of the stock market to the unexpected change in volatility will be buried in the transition month, no reaction will be observed in the month following, although a second spurious change in volatility will also be observed in that month. Thus, changes in market volatility at other than monthly transition points may induce errors in both the measurement of the time series properties of market volatility as well as in the measurement of the reaction of the price level to changes in volatility.

The bulk of the literature on the evolution of volatility has modeled changes in volatility as a continuous process. However, changes in volatility may also be sudden in nature, induced by the release of significant economic information, for example. If such shifts are significant and, furthermore, can be successfully placed in time, they provide a unique opportunity to measure the market's reactions to changes in volatility more precisely. This paper attempts to estimate the transition points for changes in volatility. We then examine the price level adjustments to the volatility shifts immediately following the transition points and the magnitude of realized returns in periods subsequent to these price adjustments.

Turner, Startz, and Nelson (1989) have recently developed and tested a model in which stock market volatility is assumed to shift between two states —high and low. Using monthly data on the Standard and Poor's 500 stock index, they determine the probability of being in either state within a given month. In the most general form of their model, which allows for learning by the market **within** a given month, they find no evidence for the hypothesis that the risk premium increases in magnitude with the level of volatility. In this paper we employ daily data, and we detect a higher frequency of volatility shifts. Moreover, our results support the hypothesis that, after a price adjustment which occurs during a period in which the market learns that the variance has changed, the expected return increases in the **next** period are in the same direction.

Estimating the transition points for changes in volatility also yields a second advantage. Having estimated the change points for volatility shifts, we can provide further insight as to the source of these shifts by attempting to associate them with the release of significant information. Moreover, since the reactions to volatility increases and decreases are analyzed separately, we can search for the presence of asymmetries in the reactions and in the nature of the events that lead to these volatility shifts. Indeed, we do find interesting asymmetries in the magnitude, structure, and timing of the reactions as well as in the nature and number of the triggering events.

Contrary to the conclusion of Poterba and Summers (1986), we provide direct evidence consistent with relatively large and systematic revisions in discount rates following volatility changes. Increases in volatility are associated with a significant subsequent decline in stock prices and higher realized future returns. Conversely, decreases in volatility are associated with a significant subsequent rise in stock prices and lower realized future returns. The difference in realized returns following volatility increases and decreases is of a surprisingly large magnitude. The fact that volatility changes are frequent and associated with significant revisions in risk premia, offers a plausible explanation for the apparent excess volatility in stock prices. While the detected volatility changes do seem to be of relatively short duration, the frequency and magnitude of such shifts, as well as the measured price and expected return reactions, imply that the excess volatility originally detected by Shiller (1981a,b) may indeed be attributed to underlying changes in risk premia. Interestingly, as few as one-quarter of the volatility shifts are associated with the release of significant information. This finding is consistent with the results of others (Roll (1988), Schwert (1989), and Cutler, Poterba, and Summers (1989)) who find it difficult to relate volatility, changes in volatility, and significant price movements to real economic events.

The plan of this paper is as follows. In Section I we describe the statistical technique used to identify volatility shifts and the data used in our analysis. In Section II we present our results on the characteristics of the volatility shifts and the associated changes in price levels and expected returns. In Section III we further examine our results and conduct a Monte Carlo investigation of our statistical methodology. Finally, we summarize and offer suggestions for future research in Section IV.

I. Methodology for Identifying Volatility Changes

That the variance of daily common stock returns is not constant is well known. In an early study of shifts in stock price volatility, Wichern, Miller, and Hsu (1976) present a methodology for identifying variance change points in a time series of data. Wichern, Miller, and Hsu assume variance changes occur at infrequent time points. Intuitively, if variance remains constant within a subset or block of data, then by considering consecutive blocks of data it is possible to detect points of variance change statistically.

The daily return to a common stock for day t, r_t is given by

$$r_t = \ln\left(\frac{P_t}{P_{t-1}}\right),$$

where P_t is the price of the common stock on day t. We consider the N-day sample $(r_1, \ldots, r_N)$ where it is assumed that daily returns are independently and normally distributed with zero mean. We form a sequence of adjacent data blocks, each containing $n < N$ observations:

$$\{\underline{r}_{1i}, \underline{r}_{2i}\} \quad i = 0, 1, \ldots, N - 2n,$$

where

$$\underline{r}_{1i} = (r_{i+1}, \ldots, r_{i+n})$$
$$\underline{r}_{2i} = (r_{i+n+1}, \ldots, r_{i+2n}).$$

For the ith-pair of adjacent blocks, under the null hypothesis of no variance change within the two adjacent blocks,

$$\text{var}(r_t) = \sigma_i^2 \quad t = i + 1, \ldots, i + 2n,$$

the joint density of $(\underline{r}_{1i}, \underline{r}_{2i})$ is given by

$$f(r_{1i}, r_{2i}) = (2\Pi\sigma_i^2)^{-n}\exp(-Q_i/2\sigma_i^2),$$

where

$$Q_i = \sum_{t=1}^{2n} r_{i+t}^2.$$

Alternatively, noting that

$$Q_i = Q_{1i} + Q_{2i} = \sum_{t=1}^{n} r_{i+t}^2 + \sum_{t=n+1}^{2n} r_{i+t}^2,$$

this joint density can be written as

$$f(\underline{r}_{1i}, \underline{r}_{2i}) = (2\Pi\sigma_i^2)^{-n}\exp(-Q_{1i}/2\sigma_i^2)\exp(-Q_{2i}/2\sigma_i^2).$$

It follows that Q_{1i}/σ_i^2 and Q_{2i}/σ_i^2 are independently $\chi^2_{(n)}$ distributed. Therefore, under the null hypothesis of no variance change within the i-th pair of adjacent blocks, the statistic $v_i = Q_{2i}/Q_{1i}$ is distributed F with n and n degrees of freedom. That is, if $F_\alpha(n, n)$ denotes the upper 100α percentage point of an F variable with n and n degrees of freedom, then under the null hypothesis of no variance change,

$$\Pr\{F_{1-\frac{1}{2}\alpha}(n, n) < v_i < F_{\frac{1}{2}\alpha}(n, n)\} = 1 - \alpha.$$

Wichern, Miller, and Hsu's moving block procedure requires computation of the sequence $v_0, v_1, \ldots, v_{N-2n}$. Evidence against the null hypothesis of no variance change occurs if $v_i < F_{1-\frac{1}{2}\alpha}(n, n)$, i.e., a variance decrease, or if $v_i > F_{\frac{1}{2}\alpha}(n, n)$ i.e., a variance increase.

We analyze the daily changes in the Dow Jones Industrial Average (DJIA) over the sample period January 4, 1897 through July 6, 1988.[1] The DJIA represents a portfolio of large, actively traded firms. Through October 3, 1916 the average was based on 12 stocks. Thereafter, it was expanded to 20 stocks until October 1, 1928, when the number of stocks was expanded to the current 30. Problems associated with nonsynchronous trading should be minimal with these, the largest and most actively traded companies, allowing a more precise empirical investigation into the dynamics of this proxy for the large capitalization industrial firm component of the market portfolio.[2]

To implement the Wichern, Miller, and Hsu methodology we chose a block size representing 4 trading weeks. Since Saturday trading sessions were eliminated on June 1, 1952, the block size prior to this date is $n = 24$ days, while the block size after this date is $n = 20$ days. As suggested by Wichern, Miller, and Hsu, the significance level is set at $\alpha = 0.01$, and we generate a sequence of sample statistics (v_i) by moving the data blocks one trading day at a time.

If a particular v_i is such that $v_i < F_{1-\frac{1}{2}(0.01)}(n, n)$ then we conclude that a variance decrease has occurred. Alternatively, we conclude that a variance decrease has occurred if $v_i > F_{\frac{1}{2}(0.01)}(n, n)$. If several v_i ratios in a sequence satisfy either of the above criteria, we identify the variance increase (decrease) points as the time points corresponding to the maximum (minimum) significant v_i in that sequence. Using these procedures, we identify 217 variance increases and 224 variance decreases.

To further eliminate associated events, we apply the following screening procedure to the identified variance increases and decreases. If consecutive variance changes of the same type (both an increase or both a decrease) occurred within overlapping data blocks, a single event of a variance change is assumed to occur, at the time point corresponding to the maximum significant v_i. However, if consecutive variance changes of opposite type occurred within overlapping data blocks, they are treated as separate events. This screening procedure has a relatively small effect on the number of reported variance changes; the number of variance increases is reduced from

[1] We conducted the analysis with arithmetic as well as geometric returns. None of our results are sensitive to the choice of method in computing returns.

[2] For further details see Lakonishok and Smidt (1988).

217 to 205, while the number of variance decreases is reduced from 224 to 197.[3]

II. Characteristics of Market Volatility Changes and Price Reactions

We first examine the magnitude and frequency of the volatility changes in the DJIA detected by the Wichern, Miller, and Hsu (1976) methodology. We then turn our attention to investigating the nature of the price level and subsequent return reactions to these volatility changes.

II.1. The Nature and Frequency of Volatility Changes

For the 205 events identified as increases in market volatility, the ratio of variances ranges from 2.70 to 33.44. For the 197 documented decreases in market volatility, the ratio of variances ranges from 0.04 to 0.37. Figure 1 summarizes these results over the 92-year sample period by plotting the log

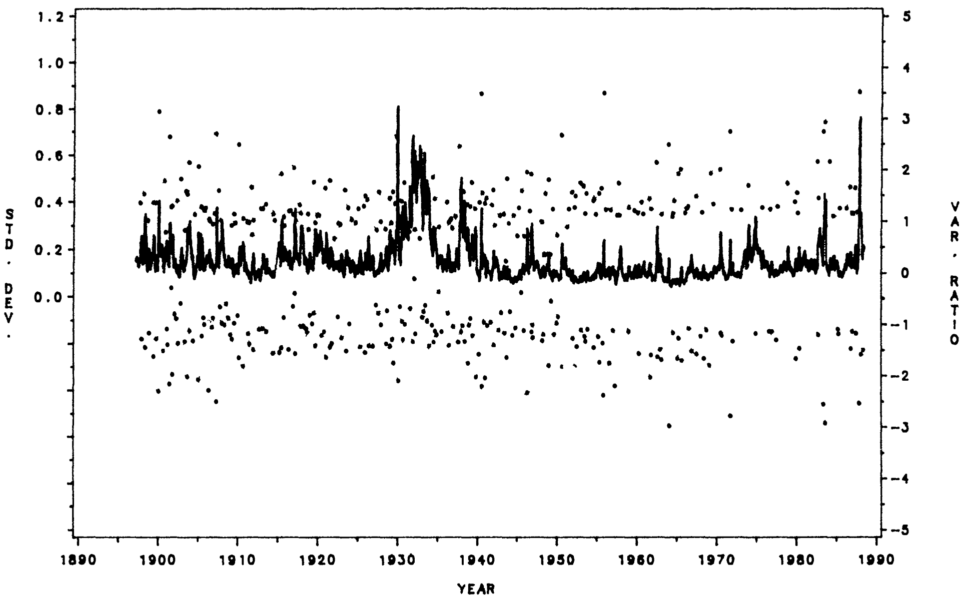


Figure 1. Time series of identified up and down events relative to the volatility of price relatives.

[3] We also have calculated variances taking into account daily serial correlation:

$$\sigma^2 = \left(\sum_{t=1}^{n} r_t^2 + 2 \sum_{t=1}^{n-1} r_t r_{t+1} \right) / (n - 1)$$

with negligible differences in our results.

of the variance ratios of all the events together with the corresponding time-series levels of volatility measured for each date by the annualized market volatility in the 2-month period preceding that date.[4] Notice that the frequency of events has tended to decrease somewhat in recent years.

Table I details the average levels of volatility in the blocks preceding and subsequent to our identified volatility shifts. For volatility increases, the annualized daily standard deviation in the subsequent block increased to an average of 23.0% from an average of 10.2% in the prior block. Conversely, for volatility decreases, the annualized daily standard deviation in the subsequent block decreased to an average of 11.0% from an average of 23.1% in the prior block. By comparison, the annualized daily standard deviation of returns to the DJIA for the entire 92-year period is 18.5%. There appears then to be a relation between the level of volatility and volatility changes: volatility increases tend to occur when the level of volatility is relatively

Table I

Identified Volatility Shifts

Time Period	Number of Events	Average Prior Volatility	Average Subsequent Volatility
A: VOLATILITY INCREASES			
1897-1988	205	.102	.230
1897-1899	6	.125	.295
1900-1909	28	.101	.234
1910-1919	28	.108	.222
1920-1929	23	.110	.243
1930-1939	24	.183	.404
1940-1949	27	.074	.171
1950-1959	23	.064	.141
1960-1969	20	.063	.133
1970-1979	10	.093	.215
1980-1988	16	.105	.291
B: VOLATILITY DECREASES			
1897-1988	197	.231	.110
1897-1899	5	.263	.129
1900-1909	32	.235	.107
1910-1919	24	.226	.107
1920-1929	21	.208	.103
1930-1939	32	.374	.196
1940-1949	28	.161	.075
1950-1959	18	.143	.067
1960-1969	18	.143	.064
1970-1979	9	.207	.101
1980-1988	10	.337	.125

[4] Plots of monthly standard deviations of stock returns are also presented by French, Schwert, and Stambaugh (1987) and Schwert (1989), using different data and computational techniques.

low, while volatility decreases tend to occur when the level of volatility is relatively high.[5]

Table I also contrasts the average levels of volatility in the blocks preceding and subsequent to our identified volatility shift for each decade separately. Notice again that the majority of variance shifts occurred in the first half of the sample. Furthermore, the more pronounced variance shifts also occurred in the first half of the sample.

II.2. Significant Events Associated with Volatility Changes

In an attempt to identify the causes for the identified volatility shifts, we use *Day by Day*, *Facts on File*, and *Keesing's Contemporary Archives* to search over the last day of the first block as well as all the days in the second block for the release of extraordinary information for all events. These extraordinary events are reported in Table IIa (volatility increases) and IIb (volatility decreases). For volatility increases, 28 events were determined while 18 were determined for volatility decreases. Thus, only one out of every nine events was associated with extraordinary releases of information. In the case of event-related volatility increases, one-half are associated with acts of violence by individuals, countries, or by nature. In the case of event-related volatility decreases, the majority are associated with enactments or announcements by political leaders. Interestingly, in many cases the same type of event associated with one type of volatility change is also associated with the other.

II.3. Price Level and Expected Return Reactions to Changes in Volatility

Having sketched the basic nature and patterns of the historical shifts in market volatility, we now examine the reaction of stock prices and subsequent expected returns to the documented changes in volatility. If a volatility shift induces a change in discount rates, one would expect a price response in the opposite direction to that of the volatility change to occur within the second (leading) block. If the volatility shift is induced by the release of a single piece of information which can be interpreted without ambiguity, we expect to see an immediate price response in an efficient market. If, on the other hand, there is uncertainty with respect to the prevailing level of volatility, as in the model of Turner, Startz, and Nelson (1989), the stock price reaction will occur subsequent to the volatility change point. Because of the possibility of a multiday reaction in the price level, we measure the price reaction in the 4-week period following the volatility shift. In addition, once investors have revised their discount rates, this should also affect the magnitude of returns **subsequent** to the second block. Consequently, we also

[5] This finding is consistent with the results of Merville and Pieptea (1989) for implied volatilities and supports the common assumption in the recent option pricing literature in which the volatility process of stock prices is assumed to be mean reverting (e.g., Scott (1987), Wiggins (1987), and Hull and White (1987)).

examine mean returns in a third 4-week period immediately following the second. With revised discount rates, there should be significant differences in third-block mean returns for volatility increases and decreases.

For each 4-week period, we estimate daily excess returns by subtracting the prevailing risk-free rate from the daily return to the Dow-Jones index. The risk-free rates for the period 1927–1988 are estimated using monthly Treasury bill rates from the CRSP bond file (average of bid and ask). For the earlier period, 1897–1926, data on the shortest term-to-maturity choice com-

Table IIA

Extraordinary 2nd Block Events Associated with Volatility Increases

Volatility Shift Date	Event	Return in 2nd Block	Variance Ratio
02/14/1898	Battleship Maine explodes in Havana, effectively beginning Spanish-American War	−10.47%	4.12
08/13/1898	Spanish American War ends	2.52%	4.05
04/15/1901	Philippine rebellion ended by proclamation	−4.92%	13.45
09/06/1901	President McKinley shot in Buffalo	−14.02%	5.73
12/05/1904	Monroe Doctrine strengthened and reasserted by Roosevelt	−3.17%	8.88
08/29/1905	Treaty of Portsmouth signed	−1.01%	6.73
04/18/1906	Major earthquake in San Francisco	−3.68%	4.60
10/09/1907	Bank panic	−13.61%	3.15
06/16/1916	U.S. invades Mexico	−6.75%	4.00
02/01/1917	President Wilson informs Congress he has broken diplomatic relations with Germany	−2.27%	4.16
08/01/1927	President Coolidge announces that he will not run for reelection	3.75%	6.24
09/17/1931	Bank panic	−14.90%	11.93
02/09/1933	Federal banking holiday	−.36%	12.15
07/16/1934	The first general strike in U.S. history	−8.86%	4.89
08/18/1937	Miller-Tydings Enabling Act	−13.36%	13.37
08/16/1939	Germany invades Poland	9.60%	5.67
05/10/1940	Germany invades Holland and Belgium	−21.36%	31.37
12/02/1941	Japan bombs Pearl Harbor	−1.77%	4.63
06/05/1944	D-Day	4.32%	3.83
11/01/1948	President Truman upsets Dewey	−7.99%	6.98
10/19/1951	President Truman signs tax increase bill	−4.72%	4.69
09/22/1955	President Eisenhower's heart attack	−6.42%	33.05
08/06/1956	National steel strike ends	−3.46%	3.34
10/30/1963	President Kennedy's assassination	−1.13%	12.03
11/01/1971	President Nixon's economic policy	.08%	15.57
04/15/1983	U.S. Embassy in Lebanon blown up	5.09%	15.52
02/03/1984	Soviet President Andropov dies	−3.36%	8.58
03/27/1987	President Reagan announces 100% tariffs on Japanese electronics	−5.55%	5.13
	Averages	−4.56%	9.21

Table IIB

Extraordinary 2nd Block Events Associated with Volatility Decreases

Volatility Shift Date	Event	Return in 2nd Block	Variance Ratio
03/02/1901	Pratt Amendment adopted	2.49%	.18
01/20/1902	U.S. buys Virgin Islands from Denmark	2.80%	.30
10/10/1902	Commission named to settle coal miner's strike	−1.27%	.35
08/01/1905	Peace conference opens to end Russo-Japanese War	6.71%	.20
01/11/1909	U.S. and Great Britian sign U.S.-Canada boundary waters treaty	−.82%	.26
07/01/1909	Congress proposes the adoption of income tax	4.24%	.34
01/14/1932	Congress creates the Reconstruction Finance Corporation	−14.45%	.32
05/15/1933	Tennessee Valley Authority is established	20.12%	.36
06/16/1934	Securities Exchange Commission created	.43%	.22
03/11/1941	President Roosevelt signs Lend-Lease Act	.02%	.18
07/30/1941	President Roosevelt and Prime Minister Churchill sign Atlantic Charter	−2.02%	.32
11/18/1942	President Roosevelt orders nationwide gas rationing	2.22%	.35
09/20/1945	Coal mines close as strikes break out	3.27%	.29
11/07/1946	President Truman removes wage, price, and salary controls	.96%	.24
01/17/1963	Strike of East and Gulf Coast longshoremen ends	1.92%	.18
09/08/1971	President Nixon discloses his intentions for Phase II of his economic program	−2.74%	.06
04/23/1980	Iranian hostage rescue mission fails	5.44%	.23
04/15/1988	U.S. and Iran clash in Persian Gulf	−1.82%	.22
	Averages	1.51%	.26

mercial paper (60 days or less) was collected from *The Wall Street Journal* (average of bid and ask.)[6]

II.4. Price Adjustments in the Second Block

Table III reports the average holding-period returns and average excess holding-period returns over the 4-trading-week period immediately **prior** to and **subsequent** to our identified variance increases.[7] The results are tabulated for the entire sample, as well as by decade. We also provide probability levels of the *t*-statistic for testing the null hypothesis that mean returns equal zero, and a nonparametric sign test for testing the null hypothesis that

[6] The conversion to daily rates was based on 295 compounding days prior to June 1, 1952 and on 252 days thereafter.

[7] Dividend yields are ignored throughout the analysis. This should not affect the measured differences in returns between adjacent blocks. However, the absolute magnitude of excess and total holding returns measured are biased downward.

Table III

Market Response to Volatility Increases

This table tabulates mean holding returns and mean excess holding returns surrounding volatility increases. These results are presented for the entire sample period, as well as by decades. Directly below a mean return we provide, respectively, the probability levels of the t-statistic for testing the null hypothesis that the mean return equals zero, and the probability level of nonparametric sign test for testing the null hypothesis that the sign of returns is randomly distributed within the corresponding time period.

Time Period	Number of Events	Mean Total Returns 1st.Block	Mean Total Returns 2nd.Block	Mean Excess Returns 1st.Block	Mean Excess Returns 2nd.Block
Total	205	1.269%	−2.622%	1.002%	−2.883%
Period		.001	.000	.006	.000
		.000	.000	.000	.000
1890's	6	3.604%	−6.596%	3.285%	−6.893%
		.040	.020	.055	.017
		.036	.059	.036	.059
1900's	28	2.007%	−2.837%	1.627%	−3.214%
		.046	.016	.103	.007
		.067	.008	.119	.005
1910's	28	2.416%	−2.068%	2.067%	−2.405%
		.023	.062	.069	.031
		.054	.078	.108	.035
1920's	23	3.132%	−3.048%	2.759%	−3.386%
		.016	.037	.032	.022
		.017	.035	.025	.014
1930's	24	−.558%	−4.395%	−.589%	−4.428%
		.769	.052	.757	.050
		.830	.031	.853	.029
1940's	27	.727%	−2.847%	.694%	−2.879%
		.101	.013	.115	.012
		.133	.009	.160	.008
1950's	23	1.580%	−2.188%	1.443%	−2.327%
		.015	.001	.025	.001
		.009	.003	.011	.002
1960's	20	−.079%	−2.825%	−3.521%	−3.092%
		.917	.006	.647	.003
		.896	.008	.723	.005
1970's	10	−2.811%	−2.618%	−3.270%	−3.087%
		.020	.042	.009	.023
		.032	.053	.019	.025
1980's	16	1.863%	1.549%	1.294%	.986%
		.047	.474	.156	.644
		.047	.339	.141	.485

the sign of returns is randomly distributed, respectively. Over the entire sample period, significant negative average returns (−2.62%) and average excess returns (−2.88%) are realized **subsequent** to volatility increases. Using a Behrens-Fisher test,[8] our empirical evidence is consistent with a

[8] See Welch (1949) for further details.

statistically significant decrease in returns and excess returns around these volatility increases. This tendency also appears to be consistent by decade, with the exception of the most recent decade.

Table IV reports the companion results pertaining to variance **decreases**. Over the entire sample, significant positive average returns (1.70%) and

Table IV

Market Response to Volatility Decreases

This table tabulates mean holding returns and mean excess holding returns surrounding volatility decreases. These results are presented for the entire sample period, as well as by decades. Directly below a mean return we provide, respectively, the probability levels of the t-statistic for testing the null hypothesis that the mean return equals zero, and the probability level of nonparametric sign for testing the null hypothesis that the sign of returns is randomly distributed within the corresponding time period.

	Number of	Mean Total Returns		Mean Excess Returns	
Time Period	Events	1st.Block	2nd.Block	1st.Block	2nd.Block
Total	197	.472%	1.703%	.220%	1.450%
Period		.248	.000	.589	.000
		.485	.000	.998	.000
1890's	5	−.899%	3.157%	−1.213%	2.863%
		.803	.032	.735	.040
		.590	.059	.590	.059
1900's	32	−.240%	1.499%	−.614%	1.123%
		.738	.018	.392	.070
		.786	.009	.355	.034
1910's	24	−.100%	1.762%	−.455%	1.396%
		.925	.020	.669	.059
		.853	.020	.539	.041
1920's	21	1.110%	3.161%	.726%	2.762%
		.323	.000	.511	.000
		.835	.000	.972	.001
1930's	32	1.401%	1.672%	1.351%	1.623%
		.377	.205	.395	.218
		.543	.058	.556	.063
1940's	28	.413%	1.345%	.382%	1.312%
		.632	.010	.659	.011
		.459	.011	.473	.011
1950's	18	−1.138%	2.832%	−1.267%	2.694%
		.184	.000	.142	.000
		.223	.000	.151	.000
1960's	18	.765%	1.860%	.478%	1.568%
		.397	.001	.596	.004
		.514	.003	.896	.008
1970's	9	2.661%	−1.284%	2.206%	−1.709%
		.148	.420	.220	.292
		.236	.636	.407	.343
1980's	10	1.056%	−.106%	.518%	−.609%
		.729	.927	.863	.599
		.476	.838	.610	.760

average excess returns (1.45%) are realized subsequent to a volatility decrease. These results also obtain for each decade separately, except for the last two decades. Based on the larger mean return and excess return responses, their relative statistical significance, and the fact that the long-run returns and excess returns of stocks are positive, it appears that the market response is more pronounced to variance increases than to variance decreases.

Our findings are consistent with the hypothesis that investors respond to shifts in the volatility of stock returns by revising their discount rates, causing a stock price reduction in a direction opposite from the volatility shift. Schwert (1989, p. 1146) suspects that the 1929–1939 period is responsible for most of Shiller's results of the excess volatility in stock prices. From Tables III and IV, however, the responsiveness of stock prices to volatility changes were significant in other decades as well. In fact, Table III indicates that the significance of the results for the 1930's were **weaker** than for other decades, on average.

This empirical evidence leads to a different interpretation of the results of Poterba and Summers (1986). In interpreting the economic significance of their estimates of the elasticity of equity value with respect to variance change, Poterba and Summers conclude that "these estimates imply that a doubling of volatility, which is a large shock by historical standards, would therefore reduce the level of share prices by at most 23 percent and probably by much less" (p. 1150). However, Poterba and Summers take volatility to mean **variance** and, as can be seen in Table I, a doubling of variance is not a large change by historical standards. Of the 205 statistically significant variance increases, the median variance increase is 301%, while the **minimum** percentage variance increase determined to be statistically significant is 170%, clearly in excess of a doubling of variance. In fact, given this median increase in variance, share prices would fall by between 6% and 15% for Poterba and Summer's elasticities estimated at -0.02 and -0.05, respectively. From Table III, comparing mean returns in Block 1 with Block 2, over the entire sample period there is an average decrease in mean returns of 3.9% subsequent to a volatility increase. However, as will be discussed in Section III, there are several reasons to believe that we have **underestimated** the true price reactions in relation to the underlying volatility shifts. In any case, in light of the high frequency and magnitude of the variance changes that we have documented over the past 92 years, price reactions between 6% and 15% hardly seem insignificant.

For more detailed evidence on the pattern of the market reaction to variance changes, cumulative average excess returns are also calculated. Defining day $+1$ as the first date of the second block, excess returns are averaged across all variance decreases or increases, over the event period $t = -20$ through $t = +30$

$$AR_t = \sum_{i=1}^{K} \overline{R}_{it}, \quad t = -20, \ldots, +30,$$

where $\overline{R}$ denotes excess return and K represents the number of events. Cumulative average excess returns are calculated as

$$CAR_t = \sum_{s=-20}^{t} AR_s, \quad t = -20, \ldots, +30.$$

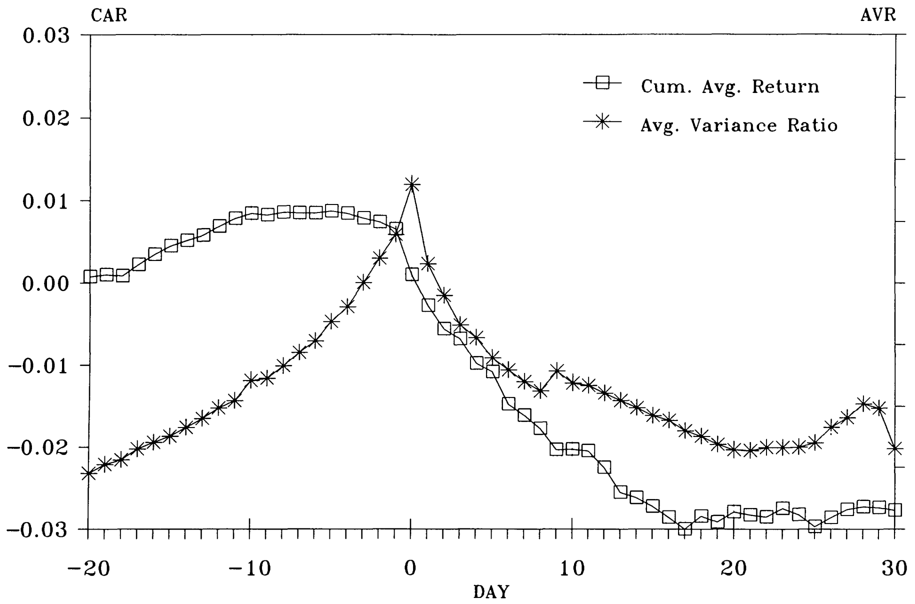
For variance increases, Figure 2 graphs the CAR as well as the corresponding average variance ratios across the event dates $t = -20, \ldots, +30$. Figure 3 presents these results for variance decreases. In comparing Figures 2 and 3, we notice that for both variance increases and decreases the market response continues throughout the majority of the 2nd block. However, the patterns of market reaction to volatility increases and decreases are markedly different. In cases of volatility decreases, the market reaction is more gradual and extends over a longer period of time, compared to volatility increases.

To further examine the relationships between the magnitudes of the volatility shifts and the magnitudes of the price level reactions, we perform a regression analysis. Again separating volatility decreases from increases, we regress the magnitude of the excess return in the 2nd block to the ratio of the variances in the corresponding leading and lagging blocks. The relationship is insignificant for volatility decreases but significant (and of the expected positive sign) for volatility increases. The regression results for volatility increases are presented in Table V. This difference in the significance of the regression results is not surprising in light of the differences in market patterns subsequent to volatility increases and decreases, as exhibited in Figures 3 and 4.

II.5. Realized Returns in the Third Block

We now examine the effect of volatility shifts on realized returns **subsequent** to the adjustment in the level of stock prices. If the documented changes in the level of stock prices are risk-induced and investors have revised their expected returns following volatility shifts, expected returns following the 2nd block should be larger than average for volatility increases and smaller than average for volatility decreases. To determine whether this is the case, we examine average returns in a third 4-week period, which immediately follows the 2nd block. Using a Behrens-Fisher test, we provide empirical evidence in Table VI consistent with this hypothesis. In particular, the 3rd block mean return for variance increases significantly exceeds the 3rd block mean return for variance decreases. The annualized mean price return (excluding dividends) in the 3rd block following volatility increases is 12.61%, while for volatility decreases (excluding dividends) it is -0.36%. The differences in discount rates implied here are clearly not trivial and support the notion that time varying risk premia should be considered an important factor in assessing the excess volatility observed by Shiller.[9]

[9] While in the majority of subperiods of the 3rd block mean return for volatility increases exceeded that for decreases, the differences were generally not significant due to the relatively large variance of the daily return series and the relatively small number of observations in the individual subperiods.



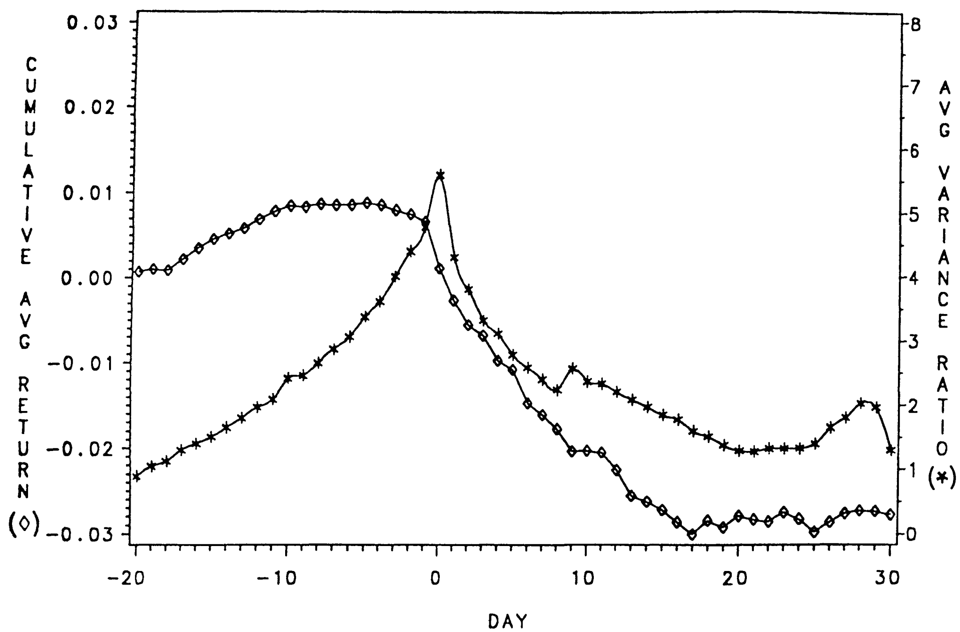


Figure 2. Cumulative average excess returns and average variance ratio for volatility increases.

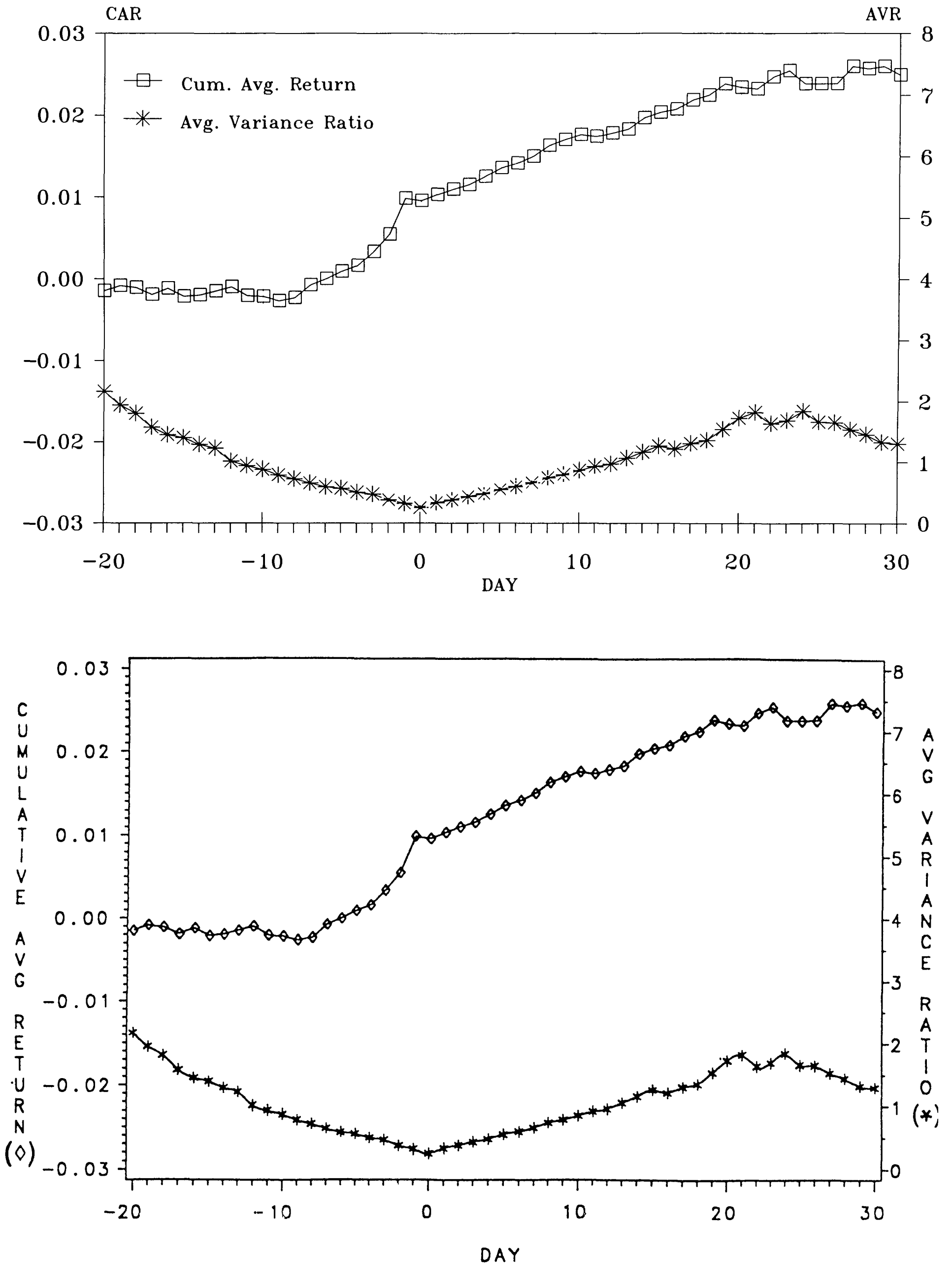


Figure 3. Cumulative average excess return and average variance ratio for volatility decreases.

Table V

Market Response to Variance Increases

Mean excess returns in the 2nd block subsequent to an identified variance increase are regressed against the log of the ratio of the variance in the 2nd block to the variance in the 1st block for volatility decreases. *T*-statistics are in parentheses.

$$\overline{R_2} = a_0 + a_1 \log\left(\frac{\sigma_2^2}{\sigma_1^2}\right) + \epsilon$$

$\hat{a}_0$	$\hat{a}_1$	R^2	F
.002	−.004	.148	35.27
(3.3)	(−5.9)		

Table VI

Differences in 3rd Block Mean Returns

This table investigates the significance of the difference between the mean returns in the 3rd block following volatility increases and volatility decreases across all events.

	Number of Observations	Mean Daily Return
Volatility Increases	4628	.0457%
Volatility Decreases	4556	−.0014%
Behrens-Fisher test statistic = 2.20 (p = .03)		

Since the annualized price return across the entire data series is 5.79%, there is an **asymmetry** in the adjustment in realized rates of return in the 3rd block between increases and decreases. This asymmetry is consistent with the asymmetry found in the price adjustments in the 2nd block; the mean adjustment in the level of stock prices was −2.62% for volatility increases (Table III) and 1.70% for volatility decreases (Table IV). Given that these adjustments are risk induced, one would expect a larger increase in expected returns for the events associated with volatility increases. This is consistent with the outcomes for mean realized returns. From Table I we see that the absolute changes in volatility are roughly of the same order of magnitude for increases and decreases. Hence, the asymmetry in the reaction of prices and subsequent mean returns is consistent with nonlinear risk aversion.[10]

The fact that we find an asymmetric response in (1) the adjustment in the level of prices, (2) the changes in subsequent realized returns, and (3) the relationship between the magnitudes of the changes in volatility across events and the magnitudes of the corresponding changes in the level of stock prices, raises interesting issues for future research.

[10] For other results on the asymmetric market response to volatility changes, see Campbell and Hentschel (1990).

III. Further Assessment of the Results

There are several reasons to believe that we have in fact **underestimated** the stock price reactions to changes in volatility. First, we may be confounding price level reactions to shifts in volatility with changes in market estimated cash flows. Second, the fact that equities behave as contingent claims may trigger price responses to volatility changes that are unrelated to changes in risk premia. Third, a component of the volatility change may be diversifiable, making the true relationship between volatility changes and price level reactions even more significant than they would first appear. Finally, the Wichern, Miller, and Hsu methodology used for identifying volatility shifts is imperfect, as many of our events are falsely identified through sampling error, providing for a downward bias to our estimates of mean return reaction.

III.1. Confounding Changes in Cash Flows with Changes in Risk Premia

We must be careful to distinguish between price reactions that are induced by changes in volatility and associated risk premia and those that are induced by changes in expected future cash flows. The receipt of important information relating to the magnitude of expected cash flows may trigger sharp price reactions which increase sample volatility sufficiently to trigger the identification of an event as we have defined it. The information relating to future cash flows may or may not be associated with changes in underlying volatility and risk premia, but in any case some part of the measured price reaction may be attributable to changes in expected cash flows.

What is the likely direction of the cash flow bias? Price shocks driven by revisions in cash flow expectations can, of course, be positive or negative. The fact that daily stock returns tend to be positively skewed would lead one to believe that positive price shocks are more prevalent, or tend to be of a larger magnitude than negative shocks. If this is indeed true, our estimates of the reaction to volatility increases would be downward biased in that, more often than not, false events are triggered by positive price shocks. For example, Schwert (1990) finds that, aside from the October 19, 1987 decline of 20.37% in the market, for which there appears to be no well-defined associated economic event, the largest absolute market return for a single day was a 16.61% **increase** which occurred on March 15, 1933 following a federal banking holiday. Schwert also finds that of the 25 largest daily negative market returns, the median was −7.83%, while of the 25 largest positive market returns the median was 8.27%.

What is the likely magnitude of the cash flow bias? Interestingly, the preponderance of our events were not associated with the release of important economic information during the event period. To illustrate, consider the largest 20 volatility increases in our sample. The events are identified in Table VII. Even though the shifts in volatility were obviously extraordinary, most were not associated with the release of extraordinary information. In

Table VII

News Released in Vicinity of Largest Volatility Increases[a]

Event Period	Percentage Increase in Volatility	Release of Extraordinary Economic Information
12/04/1899-01/02/1900	402	None
04/15/1901-05/14/1901	267	None
05/18/1903-06/15/1903	213	None
03/04/1907-04/01/1907	305	None
01/13/1910-02/09/1910	250	None
10/05/1929-11/06/1929	300	None
09/17/1931-10/15/1931	245	Bank panic
02/09/1933-03/21/1933	249	Federal banking holiday
08/18/1937-09/15/1937	266	None
05/10/1940-06/08/1940	460	Germany invades Holland & Belgium
07/26/1943-08/21/1943	221	None
06/28/1945-07/31/1945	238	None
08/27/1946-09/30/1946	239	None
06/05/1950-07/07/1950	329	Korean war begins
09/22/1955-10/19/1955	475	President Eisenhower's heart attack
10/30/1963-11/29/1963	247	President Kennedy's assassination
07/27/1971-08/23/1971	295	President Nixon's economic policy
04/15/1983-05/12/1983	294	None
06/27/1983-07/25/1983	331	None
10/06/1987-11/02/1987	478	None

[a]In this table volatility is measured by standard deviation of returns.

only 7 of the 20 largest increases was the volatility shift accompanied by the release of information which could realistically induce the documented increases in volatility.

The evidence discussed above is consistent with several recent studies attempting to link stock returns and price volatility to real economic events. For example, Cutler, Poterba, and Summers (1989) examine events, as reported in the *New York Times*, that coincide with the 50 largest absolute one-day percentage changes in the Standard and Poor's stock index. They conclude that, on most of these days, the information cited as the possible cause of the market move is not particularly important. Schwert (1989), in an exhaustive study, finds that the volatility of stock returns is not closely related to the volatility of other economic variables such as long- and short-term interest rates, the money supply, and inflation rates. Roll (1988) also finds that after deleting days in which news concerning a given firm appeared in the Dow-Jones news service, the percentage of the firm's returns explained by systematic economic variables does not change significantly. Roll concludes that much of the variance in the equity return series may be related either to private information or occasional "frenzy" unrelated to concrete information. The risk associated with noise in stock returns is nevertheless of concern to portfolio investors, and we document here evidence consistent with a market reaction to what may be changes in its magnitude.

To further free the results from the effects of possible cash flow bias, we form a 2-day gap between the 1st and 2nd blocks, thus eliminating returns in the immediate vicinity of an identified variance shift. The mean returns, and mean excess returns calculated for the resultant 2nd block were not significantly different from those reported in Tables III and IV. To measure the sensitivity of the price reaction, we also re-ran the regressions reported above. The sign and the significance of all the measured relationships remain intact.

As another assurance that we are not confusing risk aversion with cash flow revision, the events associated with the release of extraordinary information reported in Tables IIa and IIb are removed from our analysis. The results of our tests are not significantly affected by this deletion. The mean returns in the 2nd blocks remain negative (−2.32%) and positive (1.76%) for volatility increases and decreases, respectively, and both remain overwhelmingly significant. The significance of the differences between the mean returns in the 3rd block and the overall mean also remains intact for both volatility decreases and increases. Finally, the regression results and the patterns of the cumulative average excess return are not adversly affected by the deletion of these events.

The fact that we find a highly significant, positive price reaction to volatility decreases (Table IV), together with the fact that price adjustments are followed by directionally consistent adjustments in mean realized returns (Table VI) further reinforce our confidence that, on average, we are documenting a reaction to changes in risk as opposed to changes in expected cash flows.

III.2. Stocks Reacting as Contingent Claims

As is well known, given limited liabilities and financial leverage, common stocks can be expected to have the characteristics of contingent claims. As such, holding other factors constant, one would expect their prices to increase with the volatility of the underlying assets to which they have a claim (see Christie (1982)). To the extent that the observed changes in equity volatility reflect changes in underlying uncertainty relating to the returns of the firms' invested assets, we might expect that changes in stock prices should be **directly** related to changes in volatility. To illustrate, under risk neutrality, if there is an increase in the volatility of returns to a levered firm with no change in the market value of its assets, one would expect an increase in the market value of the firm's stock and a corresponding decrease in the market value of its debt. Thus, under risk aversion, price reactions stemming from changes in risk premia should be partially neutralized by offsetting price reactions stemming from this contingent claims effect. Thus, it may be argued that our results relating to price-adjustments in the 2nd block are consistent with even greater increases in risk premia than we have actually documented.

The well-known relationship between volatility and the level of stock prices working through changes in financial leverage resulting from changes in the value of equity does not affect our conclusions. We observe a stock price reaction **following** a change in volatility. Indeed, for volatility increases the magnitude of the returns in the **1st** block are significantly **positive**. Therefore, the financial leverage hypothesis would imply a **lower** level of volatility in the 2nd block.

III.3. Changes in Nonsystematic Volatility

The Dow-Jones Industrial Average is a relatively small fraction of the global market portfolio. As such, an important component of the volatility of its return is likely to be considered diversifiable and therefore not priced. We have attempted to identify changes in the total volatility of the series. Obviously, some of our events may be falsely identified in that they are triggered by changes in the **unsystematic** component of total volatility. This induces a downward bias in the estimate of the mean price reaction over all identified events. Moreover, even for events that are correctly identified, one must remember that only a fraction of the mean change in volatility is likely to be systematic. Thus, while our estimates of the mean change in price level are likely to be downward biased, our estimates of the mean change in volatility are likely to be upward biased—again making the results consistent with an even higher level of risk aversion than is apparent in the data.

III.4. Sampling Error

To assess any biases stemming from our statistical procedures we conduct the following Monte Carlo experiment. We generate 100,000 independent, normally distributed data points, each representing a daily security return. In the simulation, the annualized standard deviation of returns switches from a value of 9.4% (the median value immediately following variance decreases over all "down" events in our sample) and 18.9% (the median value over all "up" events). Alterations are made at intervals of 100 data points. To perform the simulation under conditions as similar as possible to the real data, we took into account the change in mean return induced by variance changes in our DJIA sample. Accordingly, the returns for the 20 data points following a variance decrease are taken from a distribution with an annualized mean of 30%. For the 20 data points following a variance increase, the annualized mean return is taken to be −30%; for all other points it is taken to be 0%. We then use an identical screening procedure to identify events as was employed in the tests discussed above.

Using the same screening procedures as with the DJIA sample, we identified in the simulation 674 variance increases and 649 variance decreases. Of the 674 identified variance increases, 418 (or roughly 84%) of the actual variance increases were identified, while 256 spurious variance increases were identified. With regard to the 649 identified variance decreases, 386 (or roughly 77%) of the actual variance decreases were identified. However, 263 spurious variance decreases were also identified. Thus, in the context of our sampling experiment, the Wichern, Miller, and Hsu methodology identifies a majority of but certainly not all the points of variance change. Moreover, numerous spurious points of variance changes are falsely identified.

Our simulation experiment is, of course, an idealized test. The true, underlying stochastic process for stock volatility may have complex autoregressive properties that lead to further problems. For example, Figure 3 documents that the process leading to a reduction in market volatility is less dramatic than the shift to a volatility increase. This being the case, we may have identified a smaller fraction of the true volatility decreases, and the fraction of identified events that are in fact real may also be smaller. This may explain why we find a smaller mean price reaction to volatility decreases. It may also explain the lack of a significant estimated relationship between the magnitude of the volatility decrease and the magnitude of the price reaction.

All in all, the results of the Monte Carlo simulation do suggest that we have significantly underestimated the response of the level of stock prices and expected return adjustments to volatility shifts. This is notable in light of the significant magnitude of the reactions actually uncovered in the study.

IV. Conclusion

Given the magnitude and frequency of volatility shifts identified, as well as the estimated market reactions to these shifts, the results of this paper are consistent with the hypothesis that investors revise risk premia frequently and significantly. We observe adjustments in the level of stock prices and realized returns following changes in stock volatility consistent with accompanying revisions in discount rates and high levels of risk aversion. Significantly, subsequent to the price level adjustments, we observe that subsequent mean realized returns are unusually large following volatility increases and unusually small following volatility decreases. This result reinforces the hypothesis that stock price adjustments are induced by changes in volatility as opposed to changes in expected future cash flows. These apparent frequent revisions in discount rates may serve to partially explain excess volatility in stock prices first identified by Shiller (1981a, b) and LeRoy and Porter (1981).

The large number of volatility shifts that we detect, and the fact that we are unable to find significant, real economic events in the neighborhood of a majority of these shifts, lead us to the conclusion that we may be observing instability in the noise component of volatility stemming from the microstructure of the stock market. Thus, while our findings support the notion that changes in risk premia may serve to partially explain the excess volatility observed in stock prices, the apparently excessive volatility of volatility which we observe only serves to raise further questions regarding our ability to account fully for the behavior of stock prices through current financial markets paradigms.

As such, our results call for additional research. We have documented an interesting asymmetry in the response of price levels and subsequent returns to volatility increases and decreases. There also appears to be a corresponding asymmetry in the relationship between the magnitude of the volatility change and the associated price response. Beyond this, our methodology can be applied to the return series for individual firms. Return variance can be separated into residual and various systematic components. Thus, the price reactions to shifts in each component can be measured to identify the components of stock volatility that are priced by the market.

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