Stock Market Crashes: What Have We Learned from October 1987?

Peter Fortune

Professor of Economics at Tufts University. This paper was written while the author was a Visiting Scholar at the Federal Reserve Bank of Boston.
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This is the third article in a trilogy assessing the performance of the U.S. stock market. The first paper examined the historical record of volatility in the markets for bonds and common stocks, concluding that the volatility of the stock market has not increased in recent years but that bond markets are more volatile now than they had been in the 1970s (Fortune 1989). The second paper reviewed the recent literature on stock market efficiency, concluding that the Efficient Market Hypothesis, widely held in the 1970s and early 1980s, is not supported by the evidence (Fortune 1991). The existence of significant inefficiencies suggests that fundamentals do not play as central a role in market performance as has been thought.

The purpose of this article is to investigate the possible reasons for, and public policy responses to, very sharp short-term declines in stock prices. The focus will be the Crash of 1987, the most prominent stock market decline experienced in several decades. Of particular concern will be the role played by fundamentals and market mechanisms in this event, and the effects of recent financial innovations on the depth of the Crash.

This effort has not uncovered the "smoking gun" that would make the Crash a clearly understood phenomenon. In part, the inability to find "the" reasons for the Crash stems from the unique character of the experience; it does not allow easy generalizations. The Crash was the economic equivalent of a "hundred-year storm," a dramatic event on a scale beyond the capacity of established protective mechanisms, which occurs so rarely that its ultimate causes are often poorly understood.

A second reason for difficulty in understanding the Crash is that it was not a rational phenomenon, capable of being understood with the standard tools of economics. Some markets failed to perform properly, and these probably exacerbated—but did not create—a situation that turned into a panic. While public policy responses must be devoted to improving the functioning of those markets, the recurrence of a hundred-year storm cannot be avoided indefinitely.

The article begins with an introductory section that describes the Crash of 1987 and its history. Section I reviews daily volatility of stock prices in the 1980s. Section II discusses some possible fundamental causes of the Crash, including the filing of legislation to limit tax benefits of takeovers, a rise in interest rates, and the end of a speculative bubble. Section III discusses those features of the securities markets that have been blamed for the Crash, namely program trading, portfolio insurance, and index arbitrage. The next section discusses the efficacy of proposed policy responses to the Crash. The paper concludes with a brief summary.

The October 1987 Crash was the economic equivalent of a "hundred-year storm," an event beyond the capacity of established protective mechanisms.

The Chronology of the Crash

The peak before the crash occurred on Friday, October 2 for both the S&P 500 and the Dow Jones 30 Industrials. The following week saw the S&P 500 fall over 5 percent, and in the period from October 12 to 15 it fell an additional 9 percent. The latter four trading days were chaotic. The strong downward trend was accompanied by a high volume of trading in S&P index futures, and during brief periods stocks' futures prices were lower than cash prices. This "backwardation" provided a strong signal to sell stocks. By the Friday close the S&P 500 had fallen by 5 percent, and the S&P 500 index futures price was about equal to the S&P 500 index.

Sell orders accumulated over the weekend, and on Monday, October 19, opening prices were sharply lower. Almost 200 stocks failed to open on time because of order imbalances. Selling pressure built up as futures contracts continued to sell below stock prices. Long delays arose in the execution of sales, breaking the link between prices at the time orders were submitted and final execution prices. By the end of the day, the Dow Jones 30 index was down 508 points or 22.6 percent, with trading volume over three times that for a normal heavy day.

High anxiety about the market was widespread on Tuesday, October 20. Overnight the Nikkei 225 index had fallen over 13 percent, and by the New York open, the London FTSE was down sharply. Before the open, the Chairman of the Federal Reserve Board, Alan Greenspan, announced that the Fed would provide "a source of liquidity to support the economic and financial system."

The open on Tuesday saw a significant excess demand for stocks and within one hour the Dow Jones 30 rose by 200 points. While initially the S&P 500 index futures contract rose sharply, by 10:00 a.m. it began a fall that continued until noon, at which time trading in the S&P 100 and S&P 500 index futures contracts was halted by the Chicago Mercantile Exchange because trading had been halted in a significant number of S&P 500 stocks. At 1:00 p.m. the Chicago Mercantile Exchange restarted trading in stock index futures contracts and, during the afternoon, stock prices recovered and futures prices remained above the lows experienced at midday. By the end of the day, both the S&P 500 and the Dow Jones 30 were above their opening levels. Throughout the day the futures market remained at a significant discount to stock indices.

I. Short-Run Stock Price Movements in the 1980s

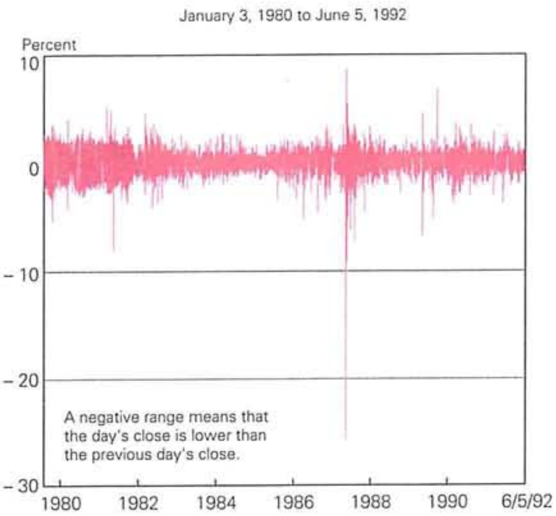
The adjusted intraday trading range of the Standard & Poor's 500 Composite Price Index provides a useful measure of very short-run price variability in the stock market. The adjusted intraday trading range is calculated by dividing the daily range (S&P 500 high less S&P 500 low) by the previous trading day's closing price. It can be interpreted as the difference between the daily "high" and "low" percentage changes in price. For example, an adjusted intraday range of 5 percent means that if the S&P 500 had been sold at its daily high, the percentage change over the previous close would have been 5 percent greater than if it had been sold at its daily low.

Overview of Daily Volatility: 1980 to 1992

Figure 1 shows the adjusted intraday trading range for the 3,141 trading days in the period January 3, 1980 to June 5, 1992. Though the range is, by definition, always a positive number, Figure 1 reports

Figure 1

Adjusted Intraday Price Range, S&P 500



Source: Author's calculations.

the trading range as negative on "down" days (when the close is below the previous close). This distinguishes between trading ranges on "up" and "down" days. No trend in daily volatility is apparent. The 1980–1981 period shows higher than normal volatility, but this is followed by abnormally low volatility during the bull market of 1982 to 1986. The most prominent revelation in Figure 1 is the occurrence of rare, unsustained bursts in daily volatility.

The analysis reported in Box I, "Time Series Analysis of Adjusted Intraday Trading Range," suggests several observations about the behavior of short-term volatility. First, no apparent trend in volatility occurred over the 1980s. Second, while days of high volatility tend to be followed by other high-volatility days, the effect disappears quickly. Third, volatility is particularly high on "down" days. Finally, volatility appears to be high after lengthy periods of closed markets.

The implication that trading halts will increase subsequent volatility must be accepted with caution, however. These halts are not the same as halts due

Box I: Time Series Analysis of Adjusted Intraday Trading Range

This box reports a simple ARIMA model of the *logarithm* of the absolute value of the adjusted intraday trading range.[1] An "intervention variable," named "DOWN" and defined as +1 on "down" days and zero on "up" days, was added to assess the possible asymmetry of the trading range on "up" and "down" days. In addition, two dummy variables were introduced to reflect breaks in market trading due to weekends or holidays: "BREAK1_2" is +1 when a trading day has been preceded by a one- or two-day break, such as weekends or holidays (0 otherwise), while "BREAK3" is +1 following a three-day break (0 otherwise). Experiments revealed that an ARMA(1,1) process captured the data. The results, with t-statistics in parentheses, are:

$$(1)\quad \log(AITR_t) = \underset{(.31)}{+.0274} + \underset{(327.9)}{.9898} * \log(AITR_{t-1}) + \epsilon_t - \underset{(-99.3)}{.9075} * \epsilon_{t-1} + \underset{(1.16)}{.0271} * BREAK1\_2_t + \underset{(2.53)}{.1665} * BREAK3_t + \underset{(3.53)}{.0659} * DOWN_t$$

$$R^2 = .27 \qquad Q(24) = 21.47\ [.37]$$

The first part of this equation reports the Autoregressive–Moving Average estimates. These indicate significant autocorrelation in the adjusted intraday trading range: a surprise in the trading range has effects on future trading ranges. However, these effects dissipate rather quickly.

The coefficient on DOWN indicates that days of downward price movements (close-to-close) tend to have higher trading ranges than "up" days, confirming the notion that "crashes" tend to be accompanied by particularly high trading ranges. BREAK1_2 is positive but not statistically significant, while BREAK3 is both positive and statistically significant. Thus, it appears that long breaks in trading—at least of the prescheduled variety, like three-day weekends—are followed by a higher trading range.

[1]Because the adjusted intraday trading range (AITR) is necessarily non-negative, it cannot conform to the assumption of a normal distribution. The use of log(AITR) is a transformation that results in a variable more likely to conform to the normal distribution. As a result, the statistical properties of the ARIMA estimates for log(AITR) are more desirable than estimates for AITR.

directly to stock market performance (price crashes, execution backlogs, general chaos). Too few of the latter type of halt have occurred to allow generalizations. Even so, calendar and time-of-day halts are of some interest.

To investigate the behavior of stock markets during crashes, criteria to identify a crash must be chosen. In order to focus attention on the most prominent episodes, this study has identified all trading days between January 3, 1980 and June 5, 1992 that meet two criteria: (1) the day is a "down" day, in other words, the closing price is less than the previous close, and (2) the absolute adjusted intraday trading range was at or above the 95th percentile of all 3,141 values in the sample. Table 1 reports the 21 days that meet those two criteria. The range of 25.74 percent on October 19, 1987, is clearly the most extreme intraday volatility in the sample, dwarfing the next highest range (9.21 percent), which occurred one week later.

Table 1
Days of Stock Market Crash[a]
January 3, 1980 to June 5, 1992

Date	Adjusted Intraday Trading Range (AITR) (Percent)	Daily Price Change (Close to Close) (Percent)
19 October 1987	−25.74	−20.47
26 October 1987	−9.21	−8.28
21 October 1981	−8.15	−.15
08 January 1988	−7.44	−6.77
13 October 1989	−6.81	−6.12
30 November 1987	−6.32	−4.18
22 October 1987	−6.28	−3.92
16 October 1987	−6.15	−5.16
27 March 1980	−5.43	−.47
11 September 1986	−5.27	−4.81
26 January 1990	−5.26	−.09
03 November 1987	−5.17	−1.93
14 April 1988	−4.70	−4.35
23 January 1987	−4.65	−1.39
13 August 1980	−4.20	−.87
25 October 1982	−4.12	−3.97
03 December 1987	−3.86	−3.53
03 August 1990	−3.85	−1.88
15 November 1991	−3.80	−3.66
14 December 1982	−3.76	−1.83
08 March 1982	−3.75	−1.83

[a]A crash is defined as a "down" day for the S&P 500, with an AITR at or greater than the 95th percentile. For the 3,141 trading days in the sample, the median AITR was 1.10 percent, the interquartile range was 0.73 percent to 1.77 percent, and the 95th percentile was 3.72 percent.

The adjusted intraday trading range is the difference between the "high" daily percentage change (intraday high vs. previous close) and the "low" daily percentage change (intraday low vs. previous close). A positive (negative) sign indicates that the day's close was higher (lower) than the previous day's close.

II. Did Fundamentals Trigger the Crash?

One of the fundamental factors cited as a trigger was the *filing of takeover legislation* to limit tax benefits of corporate takeovers. This legislation, introduced on October 13 and approved by the House Ways and Means Committee on October 15, would have eliminated the deductibility of interest paid on debt issued for takeovers and other corporate restructurings.[2] What role did this play in the Crash?

The Brady Commission Report shows that the prices of stocks that were prime candidates for takeover fell sharply relative to the S&P 500 in the week before Black Monday. However, these takeover stocks had also outperformed the market for the year: between December 31, 1986 and mid October 1987, an index of eight takeover candidates had risen by over 70 percent, while the S&P 500 had risen by roughly 25 percent. Unfortunately, a decline of target firm prices relative to the market does not establish causation—an equally plausible hypothesis is that target firms are more volatile than the market and would suffer more in a down market, just as they did better in up markets.

A more subtle approach to assessing the role of takeover legislation is provided by the event study of Mitchell and Netter (1989), who identify five announcements associated with the anti-takeover legislation that would have affected takeover stock prices. Two that would have depressed prices occurred on October 13 and October 15, when the market first learned of the filing and subsequent approval of takeover legislation by the House Ways and Means Committee; these would affect trading on October 14 and 16. The other three took place after the crash, on October 29, October 30, and December 16. Public announcements on these dates concerned the moderation of the proposed legislation's restrictions on takeovers and the eventual loss of support for the legislation; these announcements would have led to increases in takeover stock prices.

Mitchell and Netter found that the rate of return on the S&P 500 Index on those five days conformed to

[2] The legislation limited interest deductibility for acquisition of a majority interest to $5 million per year. It also eliminated entirely any deductibility for hostile acquisitions of over 20 percent of a target's stock.

the predicted effects of the announcements on all five occasions: unusually negative returns on the first two events were followed by unusually positive returns on the next three events. They also found that target firm stock returns conformed to the predictions, with even stronger responses in returns. In addition, information on transactions by risk arbitragers indicates that they were responding to the information.[3]

It comes as no surprise that risk arbitragers respond to information on the tax benefits of takeovers, or that the prices of stocks of candidates for takeover are also sensitive to tax benefits. However, it is more difficult to understand why the general market, measured by the S&P 500, should be so sensitive to takeover legislation. Mitchell and Netter argue that the possibility of takeover is a way of dealing with agency problems: a reduction in the probability of a takeover allows management to ignore the interests of shareholders. Hence, shareholders of all firms benefit from low barriers to takeover. Even so, it seems unlikely that the general market could be so dominated by news that might affect only a select category of stocks.

A second candidate for triggering the Crash is *interest rate increases subsequent to a poor international trade report*. In August, when stocks were at an all-time high, the 30-year Treasury bond yield had averaged below 9 percent. But by Tuesday, October 13, Treasury bond yields had closed at 9.92 percent. By Wednesday's close—after the merchandise trade balance report in the morning—Treasury bonds were at 10.12 percent. As the decline unfolded, Treasury bond yields continued to increase until the close on Friday, October 16, at a rate of 10.24 percent.

Equation (1) is the most commonly used stock pricing model, for which m is the price-earnings multiple, r is the rate of discount, and g is the anticipated growth rate of earnings per share.

$$m = 1/(r - g) \quad (1)$$

According to this model, the proportional change in the multiple when the rate of discount changes is $dm/m = -m * dr$. The rise in the long-term Treasury bond yield from Tuesday to Wednesday was 0.20 percent (or 0.0020). At a multiple of 20 (the September 1987 average for the S&P 500), this implies a decline in stock prices of about 4 percent during Wednesday; the actual decline in the S&P 500 was about 3 percent. The model implies a stock price decline of about 6.4 percent from Tuesday through Friday; the actual decline was about 10 percent.

Thus, significant increases in long-term interest rates provide a plausible explanation of the trigger for the general stock price decline in the week prior to Black Monday. These increases were largely the result of an adverse trade balance report and the consequent loss of confidence in the dollar and in dollar-denominated securities.[4]

Yet another fundamental factor cited as a trigger for the crash is a *worldwide downward revision of expectations* that affected global stock markets. Roll (1988) argues that both the initiation of the U.S. stock market crash, and much of its depth, can be "ascribed to the normal response of each country's stock market to a worldwide market movement." In support of this, Roll notes a positive correlation among returns on common stocks in 22 countries from 1981 to September of 1987, with October of 1987 being the only month in that period when all 22 stock markets declined. Thus, he concludes, a general collapse in global expectations in a world of interconnected stock markets explains the October Crash.

The proximate cause of the Crash was the sharp increase in interest rates, combined with uncertainty about foreign holdings of U.S. securities, that followed the October 14 merchandise trade report.

Roll rejects institutional arrangements as a primary cause of the global crash, but he does examine the relationship between the magnitude of the crash in each country and the existence of several institutional arrangements. The results, while inconclusive, are interesting: countries with continuous auction markets tended to fare worse than countries with a specialist system, and countries with computer-directed order systems tended to fare better than those with manual systems. Thus, the United States

[3] Risk arbitrage is the term applied to purchase or sale of stocks in anticipation of mergers and acquisitions.

[4] Long-term interest rates had been increasing since January, while stock prices also increased. Over this longer period, it seems likely that earnings growth anticipations were the primary source of stock price increases. However, over the few days in October, earnings expectations were probably constant, so interest rates can be isolated as a factor.

should—and did—experience a smaller collapse in stock prices than other countries. Roll found no significant relationship between the magnitude of the crash and the existence of margin requirements, trading in stock index options or futures, or price limits.

A global speculative bubble might well have existed prior to October of 1987, but Roll's argument lacks one convincing detail: an indication of why global expectations should have been revised so sharply. Roll's hypothesis does serve, however, as a reminder that U.S. stock markets are connected with markets in other countries.

While fundamental factors may have played some role in triggering the October 1987 Crash, it seems clear that the magnitude of the Crash was far greater than fundamentals would indicate. This conclusion is supported by evidence on insider trading around the time of the Crash. Presumably, corporate insiders will be able to judge the fundamental values of their firm's shares, and will be net sellers of their firm's shares in the case of a downward revision in fundamental values. Seyhun (1990) examined monthly Securities and Exchange Commission (SEC) data on insider transactions for over 6,000 firms from 1975 to 1988, and found that during October of 1987 insider purchases were unusually high and insider sales were unusually low. This was true of top executives as well as lower-level management, and it was true of firms identified as takeover targets as well as other firms. Fundamental factors clearly were not recognized as a factor in the Crash by those best positioned to identify them.

Thus, we conclude that the magnitude of the decline in stock prices was considerably greater than fundamental factors can explain, and that an understanding of the extent of the Crash requires an examination of the non-fundamental factors that existed at that time.

Was the Crash the End of a Speculative Bubble?

One explanation of the Crash states that it was the inevitable consequence of unprecedented, and unwarranted, high stock prices. In short, the Crash occurred because an inexplicable boom had preceded it. This explanation is, of course, inconsistent with the notion of stock market efficiency.

The data are certainly consistent with this hypothesis. Prior to the Crash of October 1987, the stock market had been rising sharply: over 1986 the S&P 500 had risen by 14.6 percent, well above the normal rate of increase, while from January to the October 13 peak, the S&P 500 rose at an annual rate of 33.5 percent! At the time considerable debate took place about the reasons for this, but most financial economists considered the market to be unsustainably high.

This has led some observers to conclude that there was a *speculative bubble* in stock prices. The concept of a "rational" speculative bubble has been discussed elsewhere (Fortune 1991). This type of speculative bubble is an economic concept that should be distinguished from the layman's definition of a speculative bubble, which rests on hindsight: a lay interpretation of a bubble is merely what happens before a crash! A rational speculative bubble exists when asset prices become separated from fundamental values, *and* when investors believe that this will continue. Note that transitory departures from fundamental values, due, perhaps, to changes in conditions of liquidity, to adverse behavior of market-makers, or to "uninformed" traders' misperceptions about price, are not speculative bubbles. A necessary characteristic of a rational speculative bubble is that it be self-fulfilling, that either investors are not aware that it exists and so behave in ways that perpetuate it, or investors are indifferent to the existence of the bubble because they believe that a "greater fool" will rescue them from the consequences of overpayment.

The data are consistent with the hypothesis that the Crash occurred because an inexplicable boom had preceded it.

Rational bubbles, which can exist even in the presence of rational expectations about future dividends and earnings, have received a great deal of attention from theorists in recent years. While their existence is consistent with modern financial theory, it is extremely difficult to actually determine whether a bubble is present, that is, to distinguish between the part of the price that is due to fundamental value and the part due to the bubble.

The difficulty can be seen as follows. The standard discounted cash flow theory of stock prices results in the following description of the process generating movements in fundamental values: $P^*_{t+1} = (1 + r)P^*_t - E_tD_{t+1}$, where r is the required return on stocks, P^*_t is the fundamental value, and E_tD_{t+1} is the dividend expected next period (the expectation formed in this period). Now assume the existence of a bubble, denoted by B_t. Then the price of the stock will be $P_t = P_t^* + B_t$. If the bubble is self-fulfilling, investors must expect it to earn a normal rate of return. Hence, it would be expected to grow at the rate r, and $E_tB_{t+1} = (1 + r)B_t$. The stock price cum bubble will be $P_{t+1} = (1 + r)P_t - E_tD_{t+1}$, which is precisely the same path as the fundamental value. Thus, investors will never know that a rational bubble exists, because prices with a rational bubble follow exactly the same process as prices without a bubble. Furthermore, even if investors believe that a bubble is present, they will be willing to pay the higher price because they believe that the premium will earn the required rate of return.

Rational bubbles are subject to some restrictions. First, as noted above, they must increase at the required rate of return on stocks. Second, bubbles can never be negative. To see this, note that if a stock pays cash dividends the rate of increase of the stock price will normally be less than the rate of increase in the bubble. The bubble must then be an ever-increasing portion of stock price. If a bubble were negative, eventually the stock price would go to zero. No investor would knowingly hold a stock with a negative bubble because it will eventually become valueless; thus, any indication of a negative bubble must be immediately self-correcting.

Efforts to determine whether rational bubbles occur in stock prices have been inconclusive, though most studies have not supported bubbles. However, the focus has been primarily on the existence and continuation of rational bubbles, rather than on the bursting of bubbles. The bursting of a bubble is an infrequent occurrence, which economists are not well equipped to explain.

III. Market Factors: Program Trading, Portfolio Insurance, and Index Arbitrage

While fundamental factors can explain part of the price decline that occurred during the Crash, they cannot account for its most dramatic and alarming features, namely the panic selling and the precipitousness of the accompanying price fall. Program trading in general has been widely blamed in the aftermath of the Crash, though it is not clear whether the bad press was due to the poor popular reputation of futures-related trading, or to the notion of computer generation of orders. In fact, program trading is not the use of computers to initiate orders. The New York Stock Exchange (NYSE) defines a program trade as an order of $1,000,000 or more involving at least 15 stocks. While program trades are often initiated and transmitted via computers, and are usually associated with derivative securities such as stock index futures, no clear association exists between the volume of program trading and stock market volatility. A causal connection is even less clear. This has been established in a number of studies.

Fundamental factors cannot account for the panic selling and the precipitousness of the accompanying price fall during the Crash.

One prominent example is Grossman (1988). Using daily data for 1987, Grossman found that SuperDOT volume was positively correlated with market volatility. (SuperDOT is a NYSE computer order and transaction system.) However, he found no relationship between stock market volatility and program trading volume, using several measures of program trading. Thus, high-volume days tend to be days with high volatility, and these are also days with more intensive use of SuperDOT. But the volatility-program trading nexus appears to be absent.

Most program trading is done either for the purpose of limiting risk through "portfolio insurance" or for index arbitrage; both involve trading in stock index futures. While program trading in general does not appear to be at fault, both the Brady Commission (1989) and the Securities and Exchange Commission (1988), having carefully examined the chronology of the Crash, concluded that the problem lay in a destabilizing interplay between index arbitrage and portfolio insurance strategies involving index futures. This view has become known as the *Cascade Theory* of the Crash. While an analysis of various portfolio insurance strategies and their effectiveness is outside the scope of this article, Box II, "Stock Index Futures, Hedging, Portfolio Insurance, and Index Arbitrage" provides background to help the reader understand the mechanics of the Cascade Theory.

Box II: Stock Index Futures, Hedging, Portfolio Insurance, and Index Arbitrage

Stock Index Futures

A futures contract on a stock index is an agreement for the purchase or sale of that index at a specified future date and at a price determined at the time the contract was made. The first stock index contracts were approved for trading in 1982. At present, five stock index futures contracts are traded on several different exchanges: the S&P 500, traded at the Chicago Mercantile Exchange; the Major Market Index, traded at the Chicago Board of Trade; the NYSE Composite Index, traded at the New York Futures Exchange; the Value Line Index (Kansas City Board of Trade); and the Nikkei 225 Index, traded at the Chicago Mercantile Exchange. By far the most active trading is in the S&P 500 Stock Index futures contract, initiated in April of 1982. Open interest of 153,853 contracts on July 20, 1992 was six times the open interest on the next most popular stock index futures contract (the Nikkei 225, with open interest of 26,091).

For example, consider the Box Table, which shows the report of closing prices for the S&P 500 Index futures contract on Monday, July 20, 1992, when the index itself closed at 413.75. (The dollar value of a contract is 500 times the index.) If a trader bought a September S&P 500 Index futures contract at its closing price of 413.95 per unit, he would be obligated to take delivery of 500 units of the S&P 500 at the expiration date for a total cost of $206,975 (= 500 × 413.95). The profit or loss on that position will depend upon what happens to the index. If, for example, the index rises to 420, the investor can exercise the futures contract by taking delivery of 500 units of the S&P 500 at $206,975, then selling these units for $210,000 (= 500 × 420), realizing a net profit of $3,025. However, if the index falls to 410 he can take delivery of $206,975 of stocks that he can sell only at $205,000, a loss of $1,975.

Dynamic Hedging with Stock Index Futures

Dynamic hedging is the use of index futures, as well as other derivative instruments such as options, to hedge the risk of the stock portfolio. In practice, stock index futures are the least-cost method of risk reduction because they require essentially no investment. Suppose a financial institution wants to hedge the value of its stock portfolio by selling futures against the S&P 500. The first step is to calculate the number of the units of the index whose price variation can be offset by one futures contract, usually known as the hedge ratio, or delta (Δ). In order to fully hedge a portfolio of the S&P 500, the investor would sell $\Delta/500$ S&P 500 futures (each futures contract is for 500 units) for each unit of stock held.

The futures price is, in principle, the expected spot stock price at the expiration of the futures contract. The expected spot price, in turn, is the current spot price times an expected growth factor, which is the excess of the required return on the stock over the dividend yield ($r - d$), where r is the required return on the stock, and d is the dividend yield. If T is the time to expiration of the futures contract, the futures and spot prices are related by the valuation equation $F = Se^{(r-d)T}$. Hence, $\Delta = -(\delta F/\delta S) = -e^{(r-d)T}$ and insuring a unit of the stock index requires selling $[e^{(r-d)T}/500]$ S&P 500 futures contracts.

The ability to convert risky portfolios to riskless portfolios using derivative securities is not guaranteed. Dynamic hedging is designed to deal with normal "small" fluctuations in stock prices. If "jumps" in stock prices occur, the average delta will differ from the marginal delta derived above, and the method will fail to protect the portfolio from the price decline.

Portfolio Insurance

Portfolio insurance is a set of strategies de-

Stock Index Futures Trading, S&P 500 Index (CME)—$500 x Index

Monday, July 20, 1992

	Open	High	Low	Settle	Change	Open Interest
September 92	411.50	415.00	409.75	413.95	−1.10	148,496
December 92	411.30	415.30	410.10	414.35	−1.15	4,506
March 93	415.25	415.25	411.00	415.05	−1.10	751
June 93	—	—	—	415.85	−1.15	102

Estimated Volume 55,740; Friday Volume 51,754; Open Interest 153,853, +1,051 signed to prevent the value of a portfolio from falling below a prespecified floor at a specific point in time. For example, a financial institution with a portfolio currently worth $110 million might wish to ensure that its portfolio value is at least $100 million at year end. This can be done by periodic shifts of the portfolio between stocks and cash in response to actual stock prices. For example, if the stock market has risen, a larger portion of the portfolio can be invested in stock with confidence that the $100 million floor will be achieved. If, on the other hand, stock prices have fallen, the institution will invest a smaller portion in stocks and a larger portion in riskless securities, in order to protect the portfolio from falling below the $100 million floor.

Portfolio insurance's implications for market dynamics are a subject of considerable concern. Increases in stock prices lead the insuring institution to buy more stocks, while decreases in stock prices result in sales. Thus, the cyclical movements of the stock market are exacerbated by portfolio insurance. This dynamic portfolio reallocation is the source of the charge that portfolio insurance exacerbated the Crash in October of 1987.

Index Arbitrage: the Link between the Stock Index and Index Futures

Riskless index arbitrage occurs when a trader simultaneously buys (or sells) the individual shares in the S&P 500 in proportions indicated by market capitalization, and sells (or buys) an S&P 500 futures contract. The gain or loss from doing this is the difference between the futures price and the cash price; this is called the *spread* or *basis*.[5] For example, if the cash price of the S&P 500 shares is 420.55 and the S&P 500 index futures contract can be bought at 422.40, the spread is +1.85. In the absence of transactions costs, a spread of +1.85 means that a trader can, with certainty, make a profit (gross of transactions costs) of $925 (= 500 × 1.85) by buying 500 units of the S&P 500 and selling one S&P 500 futures contract. Thus, a positive spread provides an incentive to buy the S&P 500 in the spot market and sell the S&P 500 futures contract. A negative spread is an incentive to sell in the cash market (or sell short) and buy futures contracts.

In a world with no transactions costs or carrying costs, index arbitrage will ensure that the spread is zero. However, transactions costs prevent riskless arbitrage: one does not actually trade in all 500 stocks in the exact proportions needed to replicate the S&P 500 because of the commissions and other costs (such as bid-asked spreads) that must be paid. Instead, index arbitragers trade portfolios with a relatively small number of stocks that are highly correlated with the S&P 500. As a result, index arbitragers face *basis risk*, in the form of imperfect correlation between the S&P 500 and the portfolio they choose to trade. This basis risk must carry a reward, and the reward is in the form of a positive spread.

Carrying costs, such as the interest forgone on cash purchases net of dividends received, also induce a positive spread. As seen above, the futures and current stock prices are related by $F = Se^{(r-d)T}$, where r is the rate of interest, d is the dividend yield on the S&P 500, and T is the time to expiration of the contract. Hence, as an approximation, $[(F - S)/S] = (r - d)T$.[6] Because $r > d$, one should observe $F > S$, or a positive spread, even in market equilibrium. When the spread is positive by an amount equal to the cost-of-carry, the futures-spot relationship is in equilibrium and the markets are said to be "carry" markets, or to be in "contango." Carry, or contango, means that the trader experiences a net profit on the arbitrage equal to the costs of carrying the position. Clearly, if the spread is more positive than the cost-of-carry, index arbitragers will buy spot and sell futures until contango is created.

The atypical situation of a negative spread is called "backwardation." Backwardation is not an equilibrium situation because the index arbitrager has an incentive to sell (or to short) the stock index and buy futures. Thus, while a contango market *might* be in disequilibrium, a backwardation market *will* be in disequilibrium. The rational response to backwardation is to sell long positions in stocks, to sell stocks short, and to buy futures, thereby eliminating the disequilibrium. However, as we shall see, lengthy periods have occurred when the futures market was in backwardation with no apparent move to correction. This "mystery" plays a central role in understanding the Crash of 1987.

[5]The basis is typically defined as the cash price less the futures price, while the spread is the futures price less the cash price. However, it is common to use the terms spread and basis interchangeably and define both as futures price less cash price.

[6]Converting the futures valuation equation to natural logarithms gives $\ln(F/S) = (r - d)T$. But $\ln(F/S) = \ln\{1 + [(F - S)/S]\} \approx [(F - S)/S]$. Hence, as an approximation we can say that $[(F - S)/S] = (r - d)T$.

According to the Cascade Theory, the Crash began with a shift in fundamentals in the week before Black Monday but gained a momentum unrelated to any influence of fundamentals. The scenario goes something as follows:

- The initial decline of stock prices caused portfolio insurance programs to sell index futures in an attempt to limit losses on stock portfolios.
- This caused futures prices to fall so far that they traded at a discount from the spot prices, resulting in the backwardation of the index.
- The fall in futures prices fed back into spot stock prices, causing them to fall even further, and triggering further portfolio insurance sales of index futures. This encouraged index arbitragers to sell stocks and purchase index futures.
- This had the effect of reducing stock prices even further and feeding back to further futures price declines from portfolio insurance as well as from downward revisions of expectations about stock prices.

There is considerable reason to be skeptical of this mechanism. First, the observation stressed by the reports of both the Brady Commission (1989) and the Securities and Exchange Commission (1988), that portfolio insurers were selling futures and stocks, does not mean that they were driving futures prices down to unreasonably low levels. Indeed, as we shall see, this does not appear to have been true. Second, October 19 was a day of panic, and significant order imbalances occurred in both stock and futures markets because of expectations of further price declines, which led traders and investors to implement the time-tested method of portfolio protection: bailing out. Attributing the problem to futures-related trading might be a case of blaming the thermometer for the fever.

An additional reason for some skepticism is the empirical evidence. A central feature of the Cascade Theory is that futures prices fall "too much" because of portfolio insurance, pulling stock prices down via a dynamic process of index arbitrage and portfolio insurance. However, Santoni (1988) presents evidence rejecting this. Using minute-by-minute data for the S&P 500 Index and the December 1987 S&P 500 Index Futures contract, Santoni examines the lead or lag relationship between the spot and futures prices on Black Monday. He finds that changes in futures prices tended to lead changes in spot prices. While this result is consistent with the Cascade Theory, it is also expected in an efficient market when new information has its first impact in the futures market. Thus, this does not establish that markets were performing improperly.[7] Santoni also finds, however, that one feature of the Cascade Theory is not supported by the data: changes in spot prices do not generate subsequent changes in futures prices. Thus, changes in the spot market do not "cause" futures market adjustments. This, of course, is not consistent with the Cascade Theory.

Valid criticisms can be made of Santoni's argument and his conclusion. For example, during Black Monday very long lags occurred in the reporting of stock trades because of the unprecedented volume of trades. This raises the possibility that his data are corrupted: if the time stamp on stock trades is delayed, stock price changes will be reported as occurring later than the true time. Futures prices are reported promptly. Thus, the true sequence of leads and lags could be the opposite of that shown by the data. Such mistiming of trades did occur during the Crash. In the absence of direct evidence that it was sufficient to corrupt the data badly, however, Santoni's results remain valid.

Was the Futures Market Really in Backwardation?

Perhaps the most unusual feature of the Crash was the severe backwardation in the futures market. This situation was taken as evidence of a breakdown in relationships among security markets, with the implication being that the primary problem was in the futures market. However, the discounts in futures prices could have occurred because futures prices fell too much, because stock prices fell too little, or because a statistical illusion made it appear that a discount existed when it did not.

The Brady Commission attributed the discounts to an excessive selling pressure in the stock index futures markets arising from portfolio insurance. To the extent that this is true, the opportunity for index arbitrage should bring the cash market down as well, transmitting excessive price declines in futures to excessive price declines in stocks. Since the Brady report, the futures markets have commonly been thought to have failed during the Crash.

An alternative hypothesis to explain the magnitude of the Crash suggests that the discounts on futures were not "real," but were a statistical illusion

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[7] In an efficient market, in which new information is rapidly reflected in market prices, one would expect that futures prices would adjust more rapidly because of the lower costs of transacting in futures contracts, and because the spot index tends to adjust more slowly as a result of "stale prices."

resulting from "stale prices" arising from "nonsynchronous trading" of the stocks comprising the S&P 500 Index. In short, the discounts were smaller than they appeared, perhaps even nonexistent. This, it is argued, had two effects. First, the apparent backwardation incorrectly signaled that cash prices were going to fall even further, thereby inducing institutions and traders to sell stocks to avoid larger losses. Second, the backwardation provided an incentive for index arbitragers to sell stocks or sell short, thereby adding to the pressures on the stock market. These two effects, both of which would induce larger sell orders than appropriate, assume that traders were not able to correctly evaluate the true discount.

The phenomenon of nonsynchronous trading is an inevitable consequence of the way stock indices are computed. Not all stocks in, say, the S&P 500 are trading at each moment, so the index is computed using the price of each stock at its latest trade. Normally this creates no problems, though it does serve to explain why evidence shows that the S&P 500 is serially correlated at high frequencies (say, five-minute data) while the underlying stocks do not exhibit serial correlation.[8] However, under crash conditions the problem of stale prices can be severe. It is common for a significant number of stocks either to open late or to experience trading halts. For these stocks, the last price used is higher than the "true" current price, and the price decline is not reflected in the computed index until the stock begins trading. Thus, trading halts create lags in the decline of the stock index.

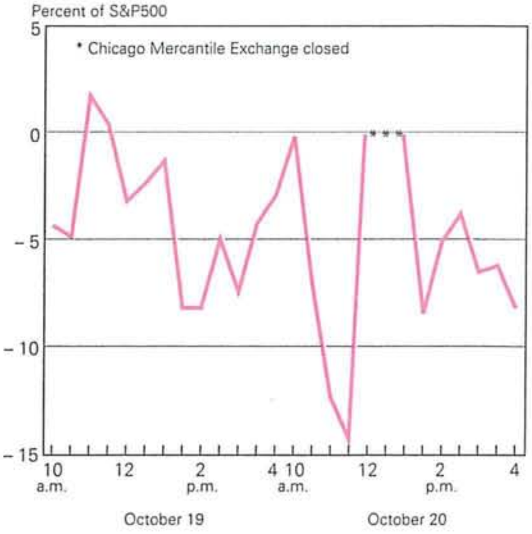
Table 2 shows the reported S&P 500 and the S&P 500 Index Futures prices at half-hour intervals on October 19 and 20, the days when the spread was negative. Figure 2 shows the futures-cash spread for these two days. This spread indicates that index arbitragers who relied on the *reported* S&P 500 index had a very strong incentive to close out their long positions in stocks and to sell short, while buying futures contracts.

Table 2 also shows the S&P 500 corrected for stale prices in two ways. The first correction (column 3) assumes that the price of a stock that is not traded is equal to the last trade price plus an adjustment equal to the proportional change in prices of traded stocks since the last trade of the untraded stock; this correction assumes that during nontrading periods, a stock's price followed the prices of traded stocks. The second correction (column 4) assumes that the price of an untraded stock is equal to the price at which it ultimately opened (if there was a delay in opening) or the price at which it reopened (if trading was halted after the open).

Figure 2

Discount on S&P 500 Futures Contract

October 19 and 20, 1987



Source: Securities and Exchange Commission (1988).

On October 19, some 57 S&P 500 stocks had delayed openings. But by noon, all but six of the S&P 500 stocks had opened, and any significant effect of stale prices due to trading halts had disappeared. Thus, by noon the "corrected" S&P 500 was very close to the reported index. In spite of this, the afternoon hours were all marked by backwardation in the futures market, providing a strong incentive to sell stocks short and to buy futures. Incorrect signals to index arbitragers from nonsynchronous trading do not appear to have been a major source of the backwardation: the backwardation appears to have been "real," in the sense that the reported S&P 500 index was accurate for most of the time.

October 20 was even more difficult as far as delays in opening and intraday closings were concerned. Indeed, the hours of 11:30 a.m. to 1:00 p.m. had more stocks not trading than at the open.[9] While

[8] Using last trade prices for infrequently traded stocks will introduce serial correlation into the index even if "true" prices were not serially correlated.

[9] Because of the significant nontrading during this period, the Chicago Mercantile Exchange suspended futures contract trading.

Table 2
Effect of Halt-Related Stale Prices on S&P 500 Index
Half-Hour Intervals October 19 and 20

			Corrected S&P 500[a]		
Time	S&P 500 Non-Trades (1)	Reported S&P 500 (2)	Equal Proportion (3)	Open/Reopen Price (4)	December S&P 500 Index Futures (5)
Monday Oct. 19					
10:00	95	273.17	267.64	259.88	261.5
10:30*	73	265.77	262.11	254.21	253.0
11:00	37	258.38	257.34	254.41	263.0
11:30	12	263.85	263.79	263.33	265.5
12:00*	6	265.28	265.14	264.93	257.0
12:30*	2	259.89	259.71	259.71	254.5
1:00*	2	257.17	257.01	256.99	254.0
1:30*	0	255.70	255.70	255.70	235.0
2:00*	0	247.00	247.00	247.00	227.0
2:30*	0	245.00	245.00	245.00	233.0
3:00*	0	243.93	243.93	243.93	226.0
3:30*	1	235.78	235.74	235.77	226.0
4:00*	2	225.41	225.25	225.45	219.0
Tuesday Oct. 20					
10:00*	52	238.26	244.31	247.01	238.0
10:30*	19	245.16	245.71	245.35	228.0
11:00*	15	238.14	237.45	237.33	209.0
11:30*	38	223.78	222.75	222.21	192.0
12:00	63	221.39	221.97	219.84	closed
12:30	77	216.64	216.53	215.09	closed
1:00	57	228.39	231.06	227.64	closed
1:30*	33	225.87	225.97	225.88	207.0
2:00*	23	225.22	225.44	225.18	214.0
2:30*	17	227.95	228.32	227.89	219.5
3:00*	10	236.13	236.28	236.06	221.0
3:30*	3	240.20	240.21	240.18	225.5
4:00*	1	237.74	237.74	237.74	218.5

[a]The Corrected S&P 500 is done two ways: (3) Equal Proportion assumes that stocks not trading open with change from last trade equal to the proportional change in the traded stocks; (4) Open/Reopen assumes that stocks not trading have prices equal to the price at open/reopen.
*Times marked with an asterisk are times of backwardation (futures selling at discount from cash) using both measures of corrected S&P 500.
Source: Securities and Exchange Commission (1988), Chart 2–1, pp. 2–44, 2–45.

stale prices played very little role at any half-hour, the futures market was in backwardation at every half-hour during the day.

The above analysis, reported in SEC (1988), is based on rather crude methods. They are supported, however, by Harris (1989), who uses higher-frequency data (five-minute intervals) and a more sophisticated method of assigning prices to untraded stocks. Thus, the problem of *halt-related* nonsynchronous trading was severe around times of daily opening, but it disappeared fairly rapidly as delays in trading ended. The negative spread that was prominent during October 19 to 20 cannot be explained by stale prices caused by nonsynchronous trading.

While nontrading does not appear to have been an important reason for stale prices, a second reason for stale prices appears to have more power. This has to do with the existence of limit orders (see Box III, "Trading Terms") and with the potential for long delays in order submission when stock market volume is unusually high. If a specialist is flooded with sell orders, he will typically match those with limit buy orders in his Book. These limit buy orders were submitted at a time before the flood of sell orders, hence they do not reflect the sudden appearance of extreme pessimism. Thus, the reported price of the stock will remain high even though the "true" price is much lower. In effect, those who placed limit buy

Box III: Trading Terms

A *limit order* is a type of restricted order that sets a price limit which must be achieved. An order to "buy 500 BSX, limit 18," must be executed at a price of 18 or lower, while a limit sell order must be executed at the stated price or higher. If the broker who receives a limit order cannot execute it immediately with a floor broker or with the specialist in the stock, the order is placed on the specialist's Display Book, to be executed on a first come–first served basis when the limit can be met.

A *specialist* is a member of the New York Stock Exchange who buys and sells a specific stock for his own account in an attempt to maintain a fair and orderly market. The specialist also acts as a broker by bringing buyers and sellers together. In either capacity, the specialist provides quotes to the *commission brokers*, who take orders from their firm's trading desk or from registered representatives, and to the *floor brokers*, who can engage in transactions for their own benefit. These quotes, in the form of "BSX bid 17¼—asked 17¾," can be chosen from the Limit Book or, if the rules allow, the specialist can quote for additions to or sales from his own inventory.[10] The broker function of the specialist is to keep the book of limit orders from which quotes can be drawn. Thus, if the book has a high bid of 17 for BSX, and a low ask of 17¾, the specialist can quote that bid and ask; the specialist is then acting as an agent rather than as a principal. An additional important function of the specialist is to provide opening quotes at the beginning of each trading day. These can be difficult to construct when the book is thin or order imbalances have developed over the weekend or overnight.

Orders come to the specialist through two routes. First, and most common, is the commission broker, who approaches the specialist post for the stock and asks for quotes, but who might make a trade with a floor broker if that is more beneficial to the client. If these orders cannot be executed because of stops or limits, they are left on the specialist's book.

A second route, used primarily by office members on behalf of large accounts such as pension funds and mutual funds, is submission of orders through the *SuperDOT* system. (DOT refers to Designated Order Turnaround.) SuperDOT is a computer order and transaction system that has several components. The OARS (Opening Automated Report Service) component of SuperDOT accepts pre-opening market orders of up to 30,999 shares, which are electronically transmitted to the specialist for use in establishing opening prices. SuperDOT also accepts post-opening market orders of up to 30,999 shares and limit orders of up to 99,999 shares. These orders are electronically transmitted to the specialist's book or, in cases where the specialist does not have a Display Book, are printed on cards by high-speed printers on the floor. While these large orders can be carried manually to the specialist, SuperDOT normally provides a more rapid execution. SuperDOT originated in the early 1980s in response to the increasing institutionalization of trading, as mutual funds and pension funds became the primary traders and required a mechanism that could handle large orders quickly. In 1991, orders placed through SuperDOT (in number of shares) amounted to approximately 25 percent of NYSE volume.[11]

[10] BSX is the symbol for Boston Scientific Corporation, a medical devices firm recently listed on the New York Stock Exchange.

[11] SuperDOT trading can be compared to NYSE trading in a variety of ways. This study has chosen to use total orders (number of shares) placed through SuperDOT (both buy and sell orders) relative to total orders (number of shares) executed on the NYSE (both buy and sell). The latter is twice the reported NYSE volume. This corrects for the double counting in NYSE reports of SuperDOT trading.

orders are overpaying for the stock because they did not know that the sell orders would create an imbalance which would have allowed them to buy "at the market" at a lower price.

The effect of limit orders is, therefore, to create stale prices even though the stock continues trading. The illusion of a high stock index in the face of massive sell orders will be greatest when a crash is under way. Furthermore, the problem can be long-lasting if significant delays occur between the time a customer first initiates a limit order and the time it is recorded on the specialist's book. If long delays make the reported index very stale, traders will think the market is higher than it really is, and new limit buy orders that are placed will have too high a price limit. Thus, a continuing fresh supply of outdated limit orders can be generated, exacerbating the staleness in the reported index. This source of stale prices apparently was quite significant on October 19 and 20. The floor printers, which print execution order cards for the specialists, had a backlog of as long as 75 minutes on Black Monday, and electronic orders transmitted to the specialists' Display Books also were subject to significant delays. During the day the New York Stock Exchange requested that orders not be submitted through SuperDOT because it was so backed up, but the manual method involved even longer delays from the time a customer originated an order to the time it was executed.

In addition, the reports of executed trades were delayed because the cards describing them could not be filled out quickly enough. As a result, individual stock price results were delayed and investors had late information on them. Furthermore, traders did not know whether their limit orders had been executed, making it difficult to know whether they should be canceled or modified.

Kleidon and Whaley (1992) have demonstrated that stale limit-order prices were a significant problem on October 19 and 20. Five-minute price changes of individual stocks were not serially correlated during the Crash, but the S&P 100 and S&P 500 stock indices were serially correlated, a symptom of stale prices. While mild serial correlation in the index is normal, the extent of serial correlation was much greater on October 19 than during earlier trading days in October. The result was that "true" stock prices fell sharply, with considerable intraday volatility, while the reported stock price indices showed unusually smooth behavior on their downward trend.

The effect of limit orders is to create stale prices even though the stock continues trading, and this source of stale prices was quite significant on October 19 and 20.

It appears that informed traders were not fooled by the stale price problem. Kleidon and Whaley computed the values of the S&P 100 implied by the November 1987 S&P 100 stock index option contract. The results of their calculations for October 19, done at five-minute intervals, are reproduced here as Figure 3. While the implied S&P 100 tracked the reported S&P 100 quite well in the days prior to the Crash, on October 19 and 20 the implied index levels were far below the reported index levels. Thus, options traders appear to have been aware that the market was "really" trading at levels well below the reported levels. Because the implied S&P 100 index level on October 19 corresponded well with the S&P 500 futures price, it can be concluded that futures traders were not entirely fooled by stale prices.

Thus, significant discounts from the reported S&P 100 and S&P 500 indices appeared in both the options markets and the futures markets, which appear to have given more accurate estimates of the stock index than did the reported index.

Were Stock Index Futures Oversold?

The Brady Commission concluded that the futures markets failed to perform properly during the Crash and selected the stock index futures market as a significant source of destabilization. The futures and options markets appear to have reflected accurately the state of the stock market during the Crash, however, and the primary locus of market failure appears to have been in the New York Stock Exchange, where long delays in limit order submissions resulted in an illusion of discounts on futures contracts. This, in turn, gave incorrect signals to traders that the market was poised for further sharp declines. Option prices indicate that informed traders were not fooled, but the unprecedented high discounts on futures undoubtedly led the less informed traders, also called "noise traders," to engage in protective strategies such as outright sale of stocks.

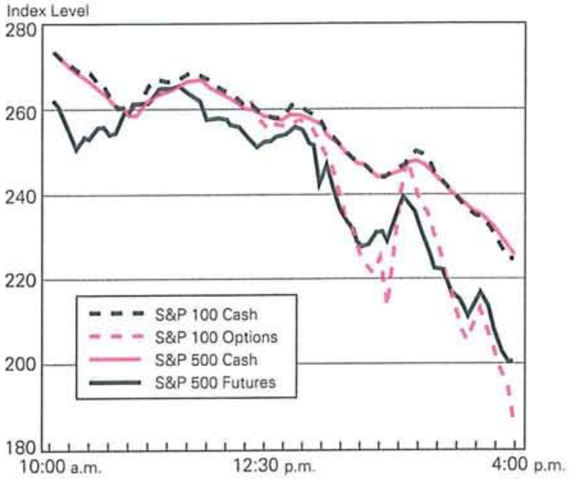
While the primary market failures appeared to be in the cash market, it is useful to ask how well the futures market performed its primary task of price discovery. Were futures prices during the Crash unreasonably low, in the light of actual market performance after the Crash?

If the futures markets were successful in serving their price discovery role, the October 19 and 20 futures price for the December 1987 contract would provide an optimal estimate of the actual S&P 500 on the expiration date, December 18. On the other hand, if futures markets were oversold, the futures price would provide an unusually low forecast of the

Figure 3

Actual and Implied Stock Index Levels

October 19,1987



Note: Index levels at five-minute intervals during the trading day, October 19, 1987. The figure contains the levels of the S&P 500 cash index and the December 1987 S&P 500 futures contract. The S&P 100 cash index level is normalized to the S&P 500 cash index level at 10:00 a.m. (EST). The implied S&P 100 index level is computed on the basis of November 1987 S&P 100 index option price quotes during each five-minute interval, and is normalized using the same proportionate adjustment as is used for the S&P 100 cash index.

Source: Kleidon and Whaley 1992.

December 18 index. Thus, a crude test of the oversold hypothesis is a comparison of the S&P 500 stock index futures price during the Crash with the S&P 500 stock index level on December 18, 1987, when the December S&P 500 futures contract expired.

On Friday, December 18, the S&P 500 closed at 249.16 after a day of trading in the 242.98 to 249.18 range. On October 19, the December S&P 500 futures price closed at 201.50, after trading in a range of 198.00 to 269.00. Thus, the October 19 closing price for the December S&P 500 index future was 47.66 points or about 19.1 percent below the actual December 18 index. This shortfall was certainly in the right direction, and of a magnitude to support the oversold hypothesis. But was it an unusual shortfall?

The analysis in Box IV, "Were Index Futures Oversold on Black Monday?" suggests that an underprediction of 47.66 points would occur about once every three years. While rare, it is not so rare as to suggest that the futures market was drastically out of line.

So What Really Happened?

While offering no definitive test of the hypothesis, this writer believes that the primary factor initiating the October 1987 Crash was the dramatic surge in stock prices that had occurred in 1986 and 1987. The resulting bubble set the stage for a sharp decline, and the proximate cause of the decline was the sharp increase in interest rates, combined with uncertainty about foreign holdings of U.S. securities, that followed the merchandise trade report on Wednesday, October 14.

A sharp increase in interest rates along with unsettling economic news, ending with an adjustment in the level of stock prices, is not a rare event, however, and cannot explain the depth and rapidity of price declines on October 19. What else was happening?

Although the major culprits are widely believed to be program trading, presumably encouraging floods of sell orders, and the existence of a variety of destabilizing strategies involving stock index futures, no evidence suggests that program trading was a causal factor in the Crash, nor did futures markets fail to perform their proper functions. The fundamental problems were largely in the cash market for stocks. The inability to expedite the large volume of orders led to a classic portfolio insurance strategy—if prices are falling and you do not know what is happening, get out! Thus, a large volume of sell orders begat a larger volume of sell orders, and longer backlogs of unfilled orders.

Combined with this was an important information problem. The backlog of unfilled limit orders resulted in stale prices, which made the reported index levels an unreliable measure of the state of the market. This led to an apparent backwardation in the futures market. Evidence from the options and futures markets suggests that many traders were aware of this problem: the implicit S&P index levels embedded in options prices were well below the reported index, and index arbitrage transactions were far smaller than the discount on futures would warrant.[12] But the discounts on futures contracts stood as a strong signal to uninformed traders that prices were headed lower still, hence encouraging the noise trading that created that very result.

[12] The relatively light volume of index arbitrage program trades was also due, in part, to NYSE admonitions against use of program trades during the Crash.

Box IV: Were Index Futures Oversold on Black Monday?

On October 19, 1987, the closing price for the December S&P 500 stock index futures contract was 201.50. The actual closing price for the S&P 500 on December 18, the expiration date, was 249.16, which is 47.66 points above the forecast of the index futures price on Black Monday. Does the forecast error of 47.66 points prove that index futures were oversold on Black Monday?

To answer this a simple statistical test can be employed. Let ${}_tF_{t+k}$ be the futures price at time t for a contract expiring at time t+k. Also, define S_{t+k} as the actual index level on the expiration date and ${}_tS_{t+k}$ as the rationally expected time t+k index level, with expectations formed at time t. Finally let $F = \ln(S_{t+k}/{}_tF_{t+k})$ be the measure of the forecast error.

The evolution of stock prices assures that $\ln S_{t+k} = \ln S_t + \Sigma\epsilon_{t+i}$, where each ϵ_{t+i} is the revision in the logarithm of the rationally expected price due to the arrival of new information at that time. Thus, one can derive the relationship $F = b + \Sigma_{i=1}^{k} \varepsilon_{t+1}$, where $b = [\ln({}_tS_{t+k}) - {}_tF_{t+k}]$ is the bias in the futures price forecast.

If the ϵ_{t+i} are independently and normally distributed with zero mean and standard deviation σ, then $(F - b)$ is normally distributed with standard deviation $\sigma\sqrt{k}$. If σ were known, the statistic $(F - b)/\sigma\sqrt{k}$ would be a standard normal random variable. Because σ is not known, the sample standard deviation, s, must be used and the test statistic $(F - b)/s\sqrt{k}$ will be distributed as Student's t with the number of degrees of freedom for s.

In order to obtain an estimate of s, daily data for 2Jan1987 through 10Oct1987 were used to estimate a regression of the form $\Delta\ln S_t = \alpha + v_t$. Assuming that the logarithm of stock price at each time is the rationally expected value of the realization, the values of v_t are revisions in rationally expected values and can be used as a measure of the forecast revisions, ϵ. Thus, the standard error of estimate from this regression can be used as a measure of s.

There were 282 days in the sample, but only 196 trading days. The estimation procedure, which adjusted for holidays and weekends to estimate a daily standard deviation, generated a daily standard error of estimate of 0.0092. The gap between Black Monday and contract expiration on December 18 was 60 days, so the denominator in the test statistic is $s\sqrt{k} = (0.0092)(\sqrt{60}) = 0.0713$. Assuming that the futures price is an unbiased forecast (so $b = 0$), the numerator in the test statistics is $F = \ln(249.16/201.50) = 0.2123$. Thus, the value of the statistic is +2.98: a 47.66 point underprediction of the S&P 500 index is equivalent to a forecast error 2.98 standard deviations above the mean.

Because of the large sample size, the normal approximation to Student's t can be used. The probability of a standard normal variable of +2.98 or more is 0.0014, or 14/100 of 1 percent. With about 250 trading days per year, an underprediction of this size or larger would occur about once every three years.

IV. Policy Responses to the October 1987 Crash

The Crash resulted in a flurry of recommendations from both official and unofficial sources, each designed to limit the possibility of such a serious event recurring. At the time there was little understanding of the fundamental causes of the Crash. Hence, these recommendations were made in a near vacuum. The genes of the Crash still have not been isolated, so the proposals that have been adopted are not genetically engineered for a crash setting. The primary proposals have been of three types: use of trading halts, introduction of "circuit breakers," and introduction of margin requirements on derivative securities.

Trading Halts

Trading halts can occur at the discretion of the Exchanges or as the result of established rules. In the latter case, the halt is the result of circuit breakers, which will be discussed below. Discretionary trading halts are the subject of this section.

Trading halts have some clearly adverse consequences. First, because an important function of markets is to provide liquidity—the ability to execute transactions rapidly at appropriate prices—trading halts interrupt the normal functioning of markets. Thus, investors will pay lower prices for securities (require higher yields) if they believe that their ability to sell can be weakened by trading halts.

A second consequence of trading halts is that they can become self-fulfilling: if investors anticipate a trading halt, they will take evasive actions that trigger the halt. Thus, the prospect of a halt can create the certainty of the halt. This is particularly true of halts resulting from established rules (circuit breakers).

A third consequence of trading halts is the transmission of pressures to other markets as investors find substitute methods of achieving their goals. For example, a trading halt in stock index futures, as investors attempt to hedge their long positions, can induce larger sales of stocks in the cash market, driving the stock index down further. For example, on October 20, the period with the highest number of stocks not trading on the New York Stock Exchange was also the period during which the Chicago Mercantile Exchange halted trading in stock index futures. While it is widely reported that the CME closing was due to the number of halts on the NYSE, the direction of causation is not clear. In the same way, a halt in trading on the registered stock exchanges can transmit the excess sell orders to the futures market and to other cash markets, such as the over-the-counter market.

The case for halts is based on the concept of the "fog of battle." During periods of sharp price changes and, typically, a high volume of transactions, the information coming to traders is of low quality. They observe major price changes but do not understand whether they are permanent or temporary, due to fundamentals or to market overreaction. The result, it is argued, is that traders look to the recent performance of prices to form judgments about near-term performance: a decline in prices is extrapolated to continue into the future. As a result, markets become chaotic and price declines breed further declines. Furthermore, a natural response to confusion is to seek safety in riskless securities, thereby adding to sales of long positions and to the purchase of safe securities. Indeed, this seemed to characterize Black Monday, for while stock prices plunged, U.S. Treasury bond prices soared.[13]

In order to investigate the effect of trading halts on stock price volatility, it is useful to know whether the implied volatility during trading halts exceeds the normal volatility. For this purpose, a simple norm can be established: if σ is the standard deviation of, say, hourly prices during trading hours, then the standard deviation of prices over T hours of nontrading should be $\sigma\sqrt{T}$. If trading does not affect the volatility of stock prices, the volatility over a T-hour trading halt (from close to open) should also be $\sigma\sqrt{T}$. Higher volatility over halts indicates that trading reduces volatility; lower volatility over halts indicates that trading increases volatility.

The evidence on the effect of trading halts is, unfortunately, based on calendar or time-of-day events that are known in advance, such as holidays or weekends. In a well-known paper, French and Roll (1986) compared variability over weekends, midweek holidays, and holiday weekends with variability during trading sessions. The sample was all NYSE and AMEX stocks during the period 1963 to 1982. Defining price changes during trading as open-to-close, and overnight changes as close-to-open, they concluded that volatility over these calendar halts was considerably lower than volatility during trading sessions. Indeed, the differences were dramatic, with holiday weekends and normal weekends having about 10 percent of the normal volatility, while midweek holidays showed 27 percent of normal volatility. Thus, the act of trading itself appears to increase volatility in prices, suggesting that even under normal circumstances trading halts can be a stabilizing influence.

Trading halts interrupt the normal functioning of markets, and can become self-fulfilling.

On the other side, Amihud and Mendelson (1987) found that open-to-open price variation is significantly greater than close-to-close variation for the 30 stocks in the Dow Jones Industrials. In a second paper, Amihud and Mendelson (1991) examined the Tokyo Stock Exchange, which has two separate sessions in each day, hence a midday trading halt, and found the same result. These results suggest that the task of finding an opening price introduces variability, and that trading halts might increase volatility.

[13] Thirty-year U.S. Treasury bond yields were 10.25 percent at the Black Monday close but had fallen to 9.11 percent by Friday's close.

The results of French and Roll seem more relevant, because they deal directly with the implied volatility during halts. Neither approach, however, really gets at the main question of the effect of halts under chaotic trading conditions. At this point, no conclusion can be reached on the consequences of trading halts.

During the Crash several interventions occurred that might be similar to trading halts. The admonition not to use SuperDOT on October 19, and the CME closing on October 20, are examples. It appears likely that these were the wrong steps, and that they interfered with investors' access to timely information and trades in a fashion that increased the fog of battle.

Circuit Breakers

Circuit breakers consist of rules to halt trading or to alter the order process in a fashion designed to allow gathering of information. Among these rules are price limits, which prevent trading at prices sufficiently above or below the previous close, and trading halts, which prevent trading at any price.

Box V, "Circuit Breakers in Cash and Futures Markets," describes the circuit breakers adopted by the Chicago Mercantile Exchange and the New York Stock Exchange on October 20, 1988 and amended in 1990. The CME circuit breakers for the S&P 500 index futures contracts are based on price limits. First is a five-point open price limit on changes in the S&P 500 opening price over the previous close. This triggers a 10-minute delay in trading, designed to prevent chaotic openings that might result in inappropriate transactions in the cash markets as well as in the futures markets.

In addition, the CME adopted two other levels of price limits. Under the initial daily limit, if the S&P 500 futures price falls more than 12 points from the previous close, the 12-point floor must be maintained for 30 minutes or until 2:30 p.m. Chicago time. Also, a maximum daily price limit prohibits trading at futures prices more than 20 points below the previous close. Finally, if the NYSE declares a halt in trading, the CME also halts futures transactions until 50 percent of S&P 500 stocks have resumed trading.

The NYSE circuit breakers are more moderate. First, under Rule 80A, a 12-point decline in the S&P 500 futures price (which triggers a 30-minute floor on the CME) triggers two mild circuit breakers on the NYSE: (1) a "sidecar," in which program trades submitted to SuperDOT are delayed for five minutes before execution (manual program trades are not delayed), and (2) a prohibition on stop or stop-limit orders for a member firm's account for the remainder of the day. Also under Rule 80A, a 50-point change in the DJ 30 subjects index arbitrage orders to a "tick test": if the DJ 30 is down 50, sell orders must be executed on an up tick; if the DJ 30 is up 50 points, buy orders must be executed on a down tick.

Under rule 80B, there is a sequence of trading halts based on declines in the DJ 30. A 250-point decline triggers a one-hour trading halt, and a 400-point decline triggers a two-hour halt; these have never come into effect.

Circuit breakers are subject to the criticisms lodged against any trading halts. In addition, because they are triggered by clearly announced rules, they are more easily anticipated and potentially more likely to be triggered because of evasive actions. Several additional criticisms have been made. First, in order to work well they should be coordinated across markets: a circuit breaker tripped in one market should not allow trading to be diverted to substitute markets. The circuit breakers adopted in October of 1988 did not have that feature. This lack of coordination has been somewhat reduced by the amendments adopted in 1990. At present, a trading halt on the NYSE automatically creates a halt in trading on all other equity, index options, and index futures markets. However, the reverse is not true: trading halts in derivative securities are not necessarily matched by equity market halts.

Lack of coordination can exacerbate short-term volatility as the natural mechanism for inducing price stability—allowing competitive trading in substitute products—is eliminated. For example, if a sharp fall in the S&P 500 index futures contract initiates a futures trading halt, it also eliminates the ability to hedge a long position using futures, inducing investors to sell more sharply in the cash market.

A second problem with circuit breakers is that the triggers must be adjusted continuously as markets change over time. For example, in October of 1988 the five-point limit on open prices in the S&P 500 futures contract translated to a 1.8 percent change in futures price at an S&P 500 index level of 275; at the present index level of 415, a five-point limit translates to only 1.2 percent. Furthermore, a trigger of 250 points in the DJ 30 was equivalent to an 11.6 percent decline in October of 1988, but is only about 7.5 percent at present.

The need to adjust the trigger points is also affected by changes in relationships across markets.

Box V: Circuit Breakers in Cash and Futures Markets
(First Adopted October 1988, Amended December 1990)

New York Stock Exchange Circuit Breakers

NYSE RULE 80A

1. Trigger: *S&P Index Futures price falls 12 points* below previous close.
   Results: (i) *Sidecar*. Program trading orders submitted to SuperDOT will be routed to a separate file (the "sidecar") and held five minutes; there is no sidecar for manually transmitted orders. At the end of the five-minute period, the orders will be transmitted to the appropriate specialists.
   (ii) *Stop Order Prohibition*. New stop and stop-limit orders for a member firm's account are prohibited for the remainder of the day; stop and stop-limit orders for 2,099 shares or less submitted on behalf of an investor are allowed.

2. Trigger: *DJ30 moves ±50 points* from previous close.
   Results: *Tick Test*. Index arbitrage orders for component stocks in the S&P 500 can be executed only if they meet a "tick test"; this prohibits selling on a downtick or buying on an uptick. This tick test remains in effect for the remainder of the day or until the DJ30 moves back to ±25 points from the previous close. The tick test does not apply to index arbitrage orders submitted on exercise dates for liquidation of positions involving derivative securities.

NYSE RULE 80B

3. Trigger: *DJ30 index falls 250 points* below previous close.
   Results: *One-hour trading halt* on NYSE and all other equity, options, and futures markets. If the trigger was pulled between 3:00 p.m. and 3:30 p.m., the NYSE has the discretion to permit trading to reopen before 4:00 p.m.

4. Trigger: *DJ30 index falls 400 points* below previous close.
   Results: *Two-hour trading halt* on NYSE and all other equity, options, and futures markets. If the trigger was pulled between 2:00 p.m. and 3:00 p.m., the NYSE has the discretion to permit trading to reopen before 4:00 p.m.

Chicago Mercantile Exchange: Circuit Breakers for S&P 500 Index Futures Contracts

1. Trigger: *Open Limit*. S&P 500 futures opens ±5 points from its previous close.
   Results: 10-minute delay in futures trading.

2. Trigger: *Initial Daily Limit*. The S&P 500 Index Futures price falls 12 points below its previous close.
   Results: *Trading halt for 30 minutes* or until 2:30 p.m. Chicago time. If the futures contract is still limit down after 30 minutes or at 2:30 p.m., a 2-minute halt will occur, after which trading resumes.

3. Trigger: *Maximum Daily Limit*. S&P 500 futures falls 20 points from its previous close.
   Results: *No trading* can occur at a price below the maximum daily limit.

4. Trigger: *NYSE Trading Halt*. The NYSE halts trading under rule 80B.
   Results: Trading in the CME S&P 500 Index Futures contracts will be halted. Trading will be resumed only after 50 percent of the component S&P 500 stocks (measured by capitalization) have resumed trading on the NYSE.

For example, the period for which the 30-point circuit breaker on the CME is in effect depends upon whether or not the DJ 30 has fallen more than 250 points. However, a 250-point variation in the DJ 30, though unlikely, becomes more likely over time because of the natural increase in prices and in their variability.

Actual experience with circuit breakers has been limited. The major circuit breakers on the NYSE have never been triggered. Rule 80A of the NYSE and the 12-point S&P 500 circuit breaker on the CME and NYSE have been triggered, but only rarely. Thus, it is difficult to generalize about the effects of circuit breakers. Two examples are interesting.

On Friday, October 13, 1989 the stock market experienced its most significant one-day decline since the 1987 Crash. The DJ 30 dropped 190 points and the 12-point S&P 500 circuit breakers on the CME and NYSE were triggered at about 2:00 p.m. and lifted at 2:30 p.m. Then at 2:45 p.m. the 30-point S&P 500 circuit breaker in effect at that time was triggered, introducing a one-hour price floor on the CME. It does not appear that the halts in futures trading helped stabilize the stock market on that day, and the additional 105-point drop on the following Monday suggests that the circuit breaker was fighting against a drop in fundamental values.

On Monday, July 23, 1990 a sharp fall in prices in early morning trading triggered the 12-point circuit breaker and S&P 500 futures trading was stopped for 16 minutes. Resumption of trading was accompanied by a sharp rebound in the S&P 500 futures to a level that was maintained throughout the day and into the next day. Thus, in this case it appears that the circuit breaker did help restore stability.

Margin Requirements

A third set of proposals is an increase in margin requirements and the extension of those requirements to the futures markets. Two primary arguments can be made for margin requirements. The first is that they provide adequate protection against customer default for "counterparties" (brokerage firms, the Options Clearing Corporation, and futures clearing houses) by establishing higher equity requirements than the firms themselves would establish. The reason for the inability of firms to determine appropriate equity requirements is not clear, but much of the 1930s security markets legislation, which included establishing margin requirements, was predicated on the assumption that firms would choose to engage in inappropriately risky activities.

Warshawsky (1989) analyzed the maintenance margin requirements for stocks and stock index derivatives prevailing in early October of 1987. The actual margins required were compared with the margins necessary to protect the counterparty from several levels of price variation over one to five days. This study concluded that maintenance margin requirements imposed by the exchanges were adequate to protect the counterparty from having to make margin calls for 99 percent of one-day price movements. For individual stocks, the 25 percent maintenance margin was sufficient for 99 percent protection over five-day periods as well. Margins for options were adequate to protect against 95 percent of five-day price movements. Less protection was available, however, for the S&P 500 stock index futures: the maintenance margin of about 3.5 percent on October 16 covered 90 percent of five-day price movements. It should be noted that judging the adequacy of margin requirements in terms of not having to make a margin call is a tough standard, and it tends to understate the ability of the counterparty to avoid losses. Indeed, most margin calls are met without trouble.

> *The stock index option and futures markets performed appropriately during the Crash. The market that failed was the stock market, which performed poorly because of its inability to deal with the large volume of orders.*

The second reason for margin requirements is more relevant to the question of stock market volatility. Some traders (called "noise traders") trade on the basis of fads and fashions rather than fundamental information. Noise traders are responsible for prices deviating from fundamental values, and are the creators of bubbles and busts. Restricting their access to markets will stabilize financial markets. It seems unlikely, however, that margin requirements will screen out those with faulty information and poor methods of analysis. No relationship may exist between a trader's ability to meet margin calls and the quality of the trader's information. Indeed, it is quite possible that noise traders could be given more influence in the market if margin requirements screen out the informed traders.

Therefore, no strong evidence suggests that margin requirements are too low to protect broker-dealers and options or futures clearing houses, or that margin requirements will stabilize markets. This conclusion is buttressed by the lack of convincing evidence that margin requirements on stocks have affected the stability of the market since they were first imposed by the Federal Reserve System in 1934.

A paper by Hardevoulis (1990) found that periods of higher initial margin requirements were associated with lower stock market volatility. However, this often-cited paper has been discounted in recent work for several reasons. First, the result was almost entirely due to the inclusion of the 1930s in the sample, and does not carry over to the postwar period. Second, statistical problems with the method have been corrected and Hardevoulis' result has been rejected. On this point, see the papers by Kupiec (1989) and Salinger (1989).

V. Summary and Conclusions

The purpose of this article has been to investigate the possible reasons for, and public policy responses to, the Crash of 1987, the most prominent stock market decline experienced in several decades. This study is particularly concerned with the role played by fundamentals and market mechanisms in this event, and with the effects of recent financial innovations on the depth of the Crash.

A review of the extensive literature surrounding the Crash of 1987 reveals some important insights. The markets that have received considerable blame (the stock index options and futures markets) actually performed appropriately during the Crash: they accurately reflected market conditions and did not provide inappropriate signals to traders that would have magnified the Crash. The market that failed was the stock market, which performed poorly because of its inability to deal with the large volume of orders—a problem that exacerbated sell orders.

A corollary must be that the attention devoted to extending regulations to the stock index futures markets is misplaced. Those markets did what was expected of them, and the primary problem was elsewhere.

This study has not uncovered the "smoking gun" that would make the Crash a clearly understood phenomenon. In part, the inability to find "the" reasons for the Crash results from the fact that it was such a unique experience that it does not allow easy generalizations. In a sense, the Crash was a "hundred-year storm," a meteorological event with drastic consequences because it is of a magnitude for which protective systems are not designed, one that occurs so rarely that its ultimate causes are often poorly understood.

Observers tend to focus on the events of October of 1987, and to forget that the Crash really left very few lasting effects. Clearly, while some traders and investors were damaged, the financial system recovered rapidly with no apparent macroeconomic effects. All in all, the Crash is a tribute to the resilience of our financial markets.

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