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The October Crash: Some Evidence on the Cascade Theory

"It's the nearest thing to a meltdown that I ever want to see."
John J. Phelan, Jr., Chairman of the New York Stock Exchange

THE record one-day decline in stock prices on October 19, 1987, stripped roughly 22 percent from stock values. More disconcerting, however, were the speed of the adjustment, the tumultuous trading activity in financial markets and the uncertainty that prevailed during the week of October 19. These aspects of the crash bore a surprising resemblance to previous financial panics that many thought were historical artifacts outmoded by modern regulatory and surveillance systems as well as by advances in the financial sophistication of market participants. The crash shocked this complacency and reawakened considerable interest in financial panics and their causes.

As with its 1929 predecessor, the list of popular explanations for the panic of 1987 runs the gamut from the purely economic and financial to the frailties inherent in human nature (see opposite page). Recently, a number of more-or-less official investigating agencies have released reports about the October panic.[1] Generally speaking, these reports do not attempt to identify the reason for the decline in stock prices. Rather, they focus on the factors that characterized it as a panic: the *sharpness* of the decline on October 19 and the *tumultuous* trading activity that occurred on this day and during the following week.

Virtually all of the reports agree that the inability of the New York and other cash market exchanges to process the unprecedented volume of trades quickly contributed importantly to the market turmoil. They disagree widely, however, about the reasons for the sharpness of the decline.

The Brady Commission Report attributes the downward "cascade" in stock prices to programmed trading — more specifically, to the trading strategies known as index arbitrage and portfo-

[1]See, for example, the *Report of the Presidential Task Force on Market Mechanisms* (1988); U.S. General Accounting Office (1988); U.S. Commodity Futures Trading Commission (1988); and the report of Miller, Hawke, Malkiel and Scholes (1987).

Some Popular Notions Regarding the Crash of '87

"Wall Street has supplanted Las Vegas, Atlantic City, Monte Carlo and Disneyland as the place where dreams are made, where castles appear in the clouds. It was Pinocchio's Pleasure Island, where children (and the adults whose bodies they inhabited) could do and have whatever they wanted, whenever they wanted it.

But now it's morning and the binge seems to be over. Many have hangovers. Many have worse. The jackasses are clearly identifiable. And the rest of us, who pretended not to notice, are left with the job of cleaning up the mess."

Robert B. Reich, *New York Times*
(October 22, 1987)

"People are beginning to see that the five-year bull market of the Eighties was a new Gatsby age, complete with the materialism and euphoric excesses of all speculative eras. Like the Jazz Age of F. Scott Fitzgerald's . . ., the years combined the romance of wealth and youth with the slightly sinister aura of secret understandings."

William Glaberson, *New York Times*
(December 13, 1987)

"We've been through quite a few years in which we felt we had reached the millennium, which was high rewards and no risk. We are now understanding that that is not the case."

Peter G. Peterson, *New York Times*
(December 13, 1987)

"Ultimately, we will view this period as one in which we made a very important mistake. What we did was divorce our financial system from reality."

Martin Lipton, *New York Times*
(December 13, 1987)

"Investors knew that stocks were overpriced by any traditional valuation measure such as price/earnings ratios and price to book value. They also knew that the combination of program trading and portfolio insurance could send prices plummeting."

Anise C. Wallace, *New York Times*
(November 3, 1987)

"On Monday, October 19, Wall Street's legendary herd instincts, now embedded in digital code and amplified by hundreds of computers, helped turn a sell-off into a panic."

David E. Sanger, *New York Times*
(December 15, 1987)

"Futures and options are like barnacles on a ship. They take their life from the pricing of stocks and bonds. When the barnacles start steering the ship, you get into trouble, as we saw last week."

Marshall Front, *Christian Science Monitor*
(October 30, 1987)

"One trader's gain is another's loss, and the costs of feeding computers and brokers are a social waste."

Louis Lowenstien, *New York Times*
(May 11, 1988).

"We probably would have had only a 100- to 150-point drop if it hadn't been for computers."

Frederick Ruopp, *Christian Science Monitor* (October 30, 1987)

"This [restrictions on programmed trading] will make it a market where the individual investor can tread without fear of the computers."

Edward A. Greene, *New York Times*
(November 3, 1987).

"In my mind, we should start by banning index option arbitrage and then proceed with other reforms which will restore public confidence in the financial markets. The public has every reason to believe that the present game is rigged. It is. Many would be better off in a casino since there people expect to lose but have a good meal and a good time while they're doing it."

Donald Regan, U.S. Senate Hearing, Committee on Banking, Housing and Urban Affairs (May 24, 1988, pp. 76–77).

The Trading Strategies

Portfolio insurance is an investment strategy that attempts to insure a return for large portfolios above some acceptable minimum. For example, if the acceptable minimum return is 8 percent and the portfolio is currently returning 13 percent, the portfolio's managers may want to decrease the share of the portfolio held in bonds and cash, which are safe but yield relatively low returns, and increase the share of the portfolio held in higher-yielding stock. This increases the expected return of the portfolio but exposes it to more risk. On the other hand, a stock price decline that reduced the return of the portfolio to, say, 10 percent puts the return close to the minimum. In this event, the managers may want to reduce the risk exposure of the portfolio. This can be accomplished by reducing the share of the portfolio held in stock and increasing the shares held in cash and bonds.[1]

This strategy results in stock purchases when stock prices rise significantly and stock sales when stock prices decline significantly.[2] Initially, these portfolio adjustments typically are made by trading in stock index futures, because the transaction cost for large baskets of stock are lower in futures than in the cash market.[3]

Index arbitrage is a trading strategy based on simultaneous trades of stock index futures and the corresponding basket of stocks in the cash market. This trading strategy attempts to profit from typically small and short-lived price discrepancies for the same group of stocks in the cash and futures markets.

Cash and futures prices for the same stock or group of stocks typically differ. The difference — called the basis — results from the "cost of carrying" stocks over the time interval spanned by the futures contract. These costs depend on the relevant interest rate and the dividends the stocks are expected to pay during the interval. On occasion, the observed basis may diverge from the cost of carry. If so, arbitrageurs can expect to profit *if simultaneous trades* can be placed in the two markets — purchasing the relatively low-priced instrument and selling the relatively high-priced instrument. These trades move the basis back to the cost of carry.

[1]See Miller, Hawke, Malkiel and Scholes (1987), p. 12.

[2]The purpose of this paper is not to evaluate the wisdom of these trading strategies. Rather, it is to evaluate the proposition that they contributed importantly to the panic.

[3]For example, the transaction costs of trading one futures contract based on the Standard and Poor's 500 are about $500 lower than trading the equivalent basket of stocks in the cash market. See Miller, Hawke, Malkiel and Scholes (1987), p. 11, and U.S. General Accounting Office (1988), p. 20.

lio insurance (see above for a discussion of these strategies).[2] This conclusion, however, is questioned seriously in reports filed by the Commodity Futures Trading Commission (CFTC) and Chicago Mercantile Exchange (CME).[3] These reports attribute the swift decline in stock prices to a massive revision in investors' perceptions of the fundamental determinants of stock prices.[4] Furthermore, since different rules govern trading in the cash and futures markets, a careful analysis of the effect of these different rules may better explain the evidence advanced by the Brady Commission in support of the cascade theory.[5]

This paper examines minute-by-minute price data gathered from the cash and futures market for stocks from October 15–23 to determine if the data are best explained by the cascade theory or the different trading rules in the two markets.

Resolving this issue is important because of the legislative and regulatory proposals spawned by the October panic. For example, the regulatory

[2]See the *Report of the Presidential Task Force on Market Mechanisms* (1988), pp. v, 15, 21, 29, 30 and 34–36.

[3]See U.S. Commodity Futures Trading Commission (1988), pp. iv, v, viii and 38–138 (especially p. 137); and Miller, Hawke, Malkiel and Scholes (1987), pp. 6, 8, 10–11, 41–43 and 55–56.

[4]See U.S. Commodity Futures Trading Commission (1988), p. ix; and Miller, Hawke, Malkiel and Scholes (1987), p. 6.

[5]See Miller, Hawke, Malkiel and Scholes (1987), pp. 21–23, 25, 37 and 49–50.

proposals advanced by the Brady Commission include:

(1) One agency to coordinate regulatory issues that have an impact across all financial markets;
(2) Unified clearing systems across related financial markets;
(3) Consistent margin requirements in the cash and futures markets;
(4) Circuit breaker mechanisms (such as price limits and coordinated trading halts); and
(5) Integrated information systems across related financial markets.[6]

Proposals 3 and 4 clearly reflect the Commission's belief that programmed trading contributed significantly to the panic. Furthermore, the action taken by the New York Stock Exchange (NYSE) to restrict use of its Designated Order Turnaround (DOT) system by program traders suggests that the officials of this exchange also subscribe to the Brady Commission's explanation.[7] This belief was reaffirmed more recently. Beginning February 4, 1988, the NYSE has denied use of the DOT system to program traders whenever the Dow Jones Industrial Average moves up or down by more than 50 points from its previous day's close.

THE CASCADE THEORY

The Brady Commission suggests that the stock market panic is best explained by the "cascade theory." This theory argues that "mechanical, price-insensitive selling" by institutions using portfolio insurance strategies contributed significantly to the break in stock prices.[8] In an effort to liquidate the equity exposure of their portfolios quickly, these institutions sold stock index futures contracts in the Chicago market. Such sales lowered the price of the futures contracts *relative* to the price of the equivalent basket of stocks in the New York cash market. The decline in the futures price relative to the cash price induced index arbitrageurs to purchase futures contracts in the Chicago market (which, in their view, were undervalued) and sell (short) the underlying stocks in the New York market (which, in their view, were overvalued relative to futures). Thus, index arbitrage transmitted the selling pressure from the Chicago futures market to the New York cash market causing cash prices in New York to decline.

The story does not end here. According to the theory, the decline in cash prices triggered a further selling wave in the Chicago market by portfolio insurers that index arbitrageurs, again, transmitted to the New York market. This process was repeated time after time causing a "downward cascade" in stock prices.[9]

The Brady Commission suggests that support for the cascade theory can be found by examining the behavior of the spread (the basis) between the price of stock index futures contracts and the cash prices of the shares underlying the contracts.[10] The basis is normally positive. Stock index futures prices generally exceed cash prices because the net costs of carrying stock forward (interest cost less expected dividends) are typically positive.[11] During the panic, however, the basis turned negative. The Commission suggests that this observation is consistent with the cascade theory.

Chart 1 plots both the price of the December Standard and Poor's 500 futures contract and the Standard and Poor's index of 500 common stocks. The latter represents the cash price of the stocks underlying the futures contract. The data cover half-hour intervals during October 15–23, 1987. Chart 2 plots the basis — the difference between the two prices shown in chart 1. As one can see, the basis fell below zero in the late afternoon of October 16 and, with a few exceptions, remained negative for the rest of the week. In the Brady Commission's view, this evidence provides important support for the cascade theory.

THERE IS LESS TO THE CASCADE THEORY THAN MEETS THE EYE

The Negative Basis

As mentioned, proponents of the cascade theory suggest that their theory is supported by the nega-

[6] *Report of the Presidential Task Force on Market Mechanisms* (1988), p. vii.

[7] The DOT System is a high-speed, order-routing system that program traders use to execute simultaneous trades in the cash and futures markets.

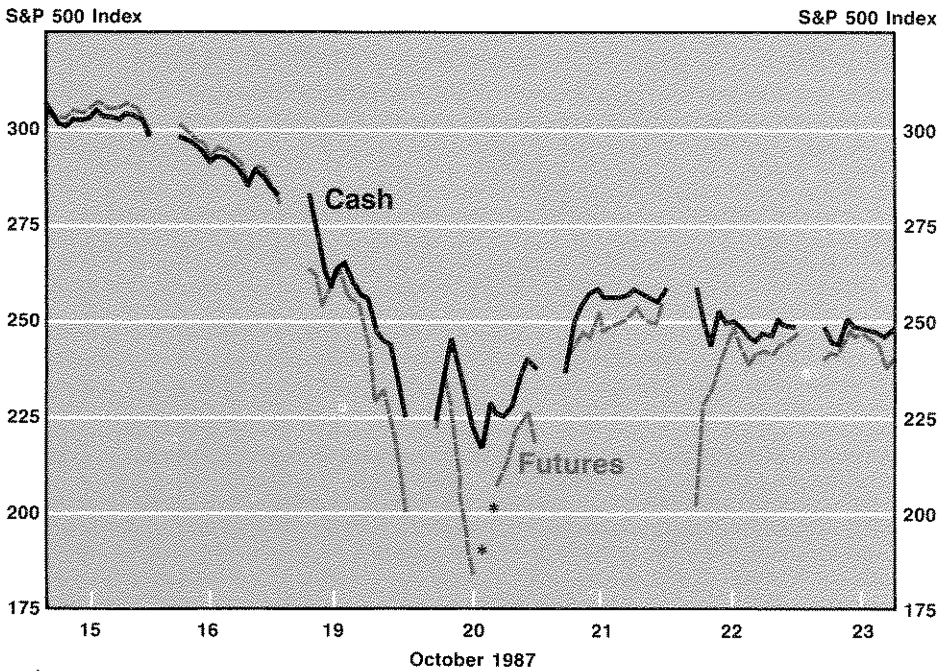
[8] *Report of the Presidential Task Force on Market Mechanisms* (1988), p. v.

[9] *Ibid.*, pp. 15, 17, 21, 30–36 and 69. It is apparent that our knowledge of stock market panics has advanced considerably in the 58 years since the 1929 crash. "Black Tuesday" was caused by a downward price "spiral." "Bloody Monday" was a "cascade."

[10] *Report of the Presidential Task Force on Market Mechanisms* (1988), pp. III.1–III.26, especially III.16–III.22.

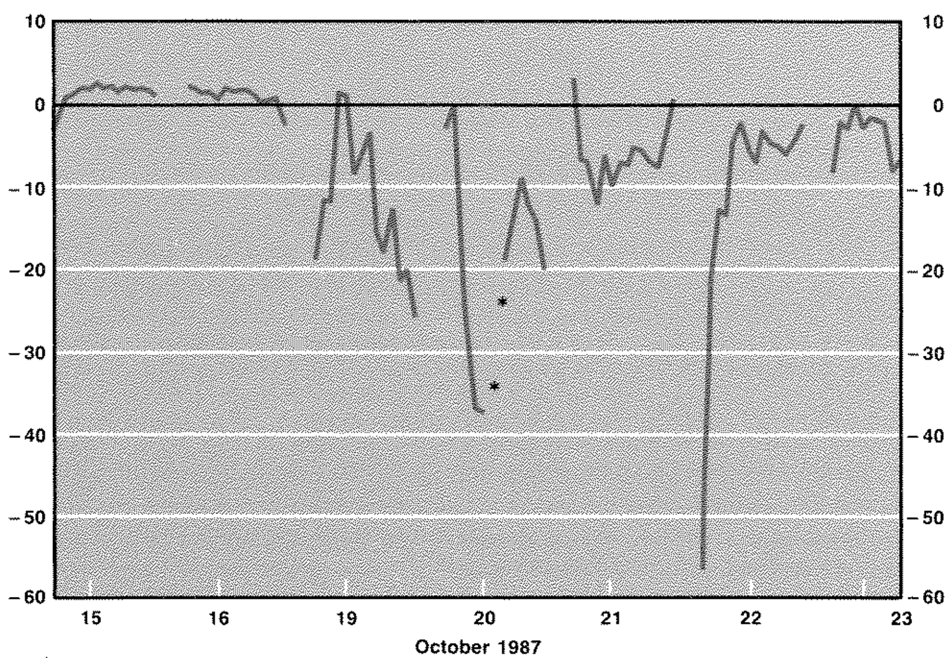
[11] See Figlewski (1984), pp. 658–60; Burns (1979), pp. 31–57; Cornell and French (1983), pp. 2–4; Modest and Sundaresan (1983), pp. 22–23; Santoni (1987), pp. 23–25; Schwarz, Hill and Schneeweis (1986), pp. 326–46; Working (1977); Kawaller, Koch and Koch (1987), p. 1311.

Chart 1
Cash and December Futures



*Futures market closed

Chart 2
Basis = December Futures – Cash



*Futures market closed

Table 1
Calculating the Basis

Panel A

Assumptions:

$D_t = \$1.00$

$g = 5.0\%$

$E_tD_{t+1} = D_t(1+g) = \$1.05$

$r = 11\%$

(1) $P_t = E_tD_{t+1}/(r-g) = \$1.05/.06 = \$17.50$

(2) $E_tP_{t+1} = P_t(1+r) - E_tD_{t+1} = \$17.50(1.11) - \$1.05 = \$18.38$

(3) $B = E_tP_{t+1} - P_t = \$18.38 - \$17.50 = \$\ .88$

Panel B

Assumptions: Same as A except $g' = 3.0\%$

(1) $P'_t = E_tD'_{t+1}/(r-g') = \$1.03/.08 = \$12.88$

(2) $E_tP'_{t+1} = P'_t(1+r) - E_tD'_{t+1} = \$12.88(1.11) - \$1.03 = \$13.27$

(3) $B' = E_tP'_{t+1} - P'_t = \$13.27 - \$12.88 = \$\ .39$

where:

D_t = the current dividend

E_tD_{t+1} = the expected dividend at year end

P_t = the current share price

g = the expected growth rate in dividends

r = the relevant long-term interest rate

tive basis observed on the afternoon of October 16 and on subsequent trading days during the week of October 19. However, a negative basis does not necessarily support the cascade theory.

Panel A of table 1 calculates the current price of a stock, P_t, assuming that the currently observed dividend, D_t, is \$1; the long-term interest rate, r, is 11 percent and the expected growth rate in dividends, g, is 5 percent.[12] Under these assumptions, the current price of the stock is \$17.50(= \$1.05/[.11 − .05]). In addition, panel A calculates the expected price of the stock one year from now, E_tP_{t+1}. This expected price is the amount to which P_t would grow if invested at r less the dividend expected at the end of the year, E_tD_{t+1}.[13] This amount is \$18.38(= \$17.50[1.11] − \$1.05). Assuming that arbitrageurs are rational and that transaction costs are very low, the basis between the price of a futures contract dated to mature in one year and the current cash price of the stock is the difference between the expected price of the stock one year from now and its current price, \$.88(= \$18.38 − \$17.50).

Panel B performs similar calculations assuming that the expected growth rate in dividends, g, falls from 5 percent to 3 percent, while everything else

[12] See Brealey (1983), pp. 67–72.

[13] The example assumes that the yield curve is flat.

remains constant. Notice that this results in a decline in the current price of the stock from \$17.50 to \$12.88, a reduction of about 30 percent. Furthermore, since the expected price of the stock one year from now falls to \$13.27, the basis falls to \$.39(= \$13.27 − \$12.88). Other things the same, a decline in the expected growth rate of dividends causes a decline in the current price, the futures price and the basis. For reasons discussed later, futures prices typically respond to new information more rapidly than indexes of cash market prices. This was particularly so during the crash. In terms of our example, if the futures price declines immediately to \$13.27 but cash prices adjust less quickly, the *observed* basis may be negative during the adjustment period. In short, there is no need for a special theory, like the cascade theory, to explain the behavior of the basis during the week of October 19.[14]

Irrational Price-Insensitive Traders

Stock prices declined throughout the day of October 19, 1987. The decline was particularly sharp in the afternoon (see chart 1). At about 1:30 p.m. EST, the price of a December S&P 500 futures contract was about 15 points lower than the cash prices of the stocks underlying the contract (that is, the basis was −15 points, see chart 2). This means that liquidating the basket of stocks underlying the S&P 500 through futures market sales was about \$7,500 more costly (before transaction costs) than liquidating the same basket in the cash market.[15] Yet, according to the cascade theory, portfolio insurers continued to liquidate in the futures market. In the words of the Brady Commission, this apparently anomalous behavior was the result of "mechanical price-insensitive selling." Put more bluntly, the theory attributes the observation to irrationality on the part of portfolio managers who, by most accounts — including those of the Brady Commission — are credited with being highly sophisticated financial experts.

The Missing Arbs

The cascade theory depends on index arbitrage activity to transmit selling pressure from the futures to the cash market. Yet, by all accounts, index arbitrage virtually ceased about 1:30 p.m. EST on October 19.[16] Cash market prices, however, fell sharply between 1:30 and the market's close. The S&P 500 index lost about 30 points during this time, while the Dow fell by more than 300 points. Furthermore, index arbitrage was severely restricted in subsequent trading days because the NYSE limited use of its DOT system by arbitrageurs. However, this did not prevent a further sharp decline in stock prices on October 26.

Foreign Markets and Previous Panics

The cascade theory fails to explain why stock market panics in foreign markets occurred at the same time as the U.S. panic. Programmed trading is virtually nonexistent in overseas markets. Yet these markets crashed as quickly and by as much as the U.S. market. Between October 16 and 23, for example, the U.K. stock market declined 22 percent, the German and Japanese markets fell 12 percent, the French market fell 10 percent and the U.S. market declined 13 percent. What's more, programmed trading dates back no further than 1982 when stock index futures contracts began trading. U.S. stock market panics have a much longer history. Since the cascade theory does not explain these other panics, there is some reason to be skeptical about its usefulness in explaining the latest U.S. panic.

AN ALTERNATIVE EXPLANATION: EFFICIENT MARKETS

A long-standing proposition in both economics and finance is that stock prices are formed in efficient markets.[17] This means that all of the relevant information currently known about interest rates, dividends and the future prospects for firms (the fundamentals) is contained in current stock prices. Stock prices change only when new information regarding the fundamentals is obtained by someone. New information, by definition, cannot be predicted ahead of its arrival; because the news is just as likely to be good as it is to be bad, jumps in stock prices cannot be predicted in advance.

If the efficient markets hypothesis is correct, past price changes contain no useful information

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[14]See, in addition, Malkiel (1988), pp. 5–6.

[15]The value of a S&P 500 futures contract is \$500 times the level of the index. Consequently, if the cash market index is about 255 and the futures market index is about 240 as they were at 1:30 p.m. EST on October 19, the value of the basis: $B = \$500(240) - \$500(255) = -\$7{,}500$.

[16]See the *Report of the Presidential Task Force on Market Mechanisms* (1988), pp. vi, 32 and 40; U.S. General Accounting Office (1988), pp. 43 and 45–46; U.S. Commodity Futures Trading Commission (1988), pp. vi and 46.

[17]See Brealey and Meyers (1984), pp. 266–81; Malkiel (1981), pp. 171–79; Brealey (1983), pp. 15–18; Leroy (1982) and Fama (1970).

about future price changes. With some added assumptions, this can be translated into a useful empirical proposition. If transaction costs are low, the expected return to holding stock is constant and the volatility of stock prices does not change during the time period examined, the efficient market hypothesis implies that observed *changes* in stock prices will be uncorrelated. The sequence of price changes are unrelated; they behave as random variables. This is sometimes called "weak form efficiency."

This implication contrasts sharply with a central implication of the cascade theory. The cascade theory suggests that price changes in both the cash and futures markets are positively correlated with their own past. This follows from the theory's circularity which attributes sharp price declines to immediately preceding sharp declines.

The behavior of U.S. stock prices generally conforms to the efficient markets hypothesis in the sense that past changes in stock prices contain no *useful* information about future changes.[18] However, when data on stock price indexes are observed at very high frequency (intra-day but not day-to-day), changes in the level of *cash* market indexes are correlated and appear to lag changes in futures prices.[19] This behavior appears to favor the cascade theory. When differences in the "market-making" techniques employed in the cash and futures markets are taken into account, however, intra-day data from both markets reject the cascade theory, while, on the whole, they are consistent with the efficient markets hypothesis.[20]

Market-Making in the Cash Market

Trading on the NYSE is conducted by members who trade within an auction framework at posts manned by specialists.[21] Specialists' activities are concentrated on a particular group of stocks that are traded at a particular post. One of the main functions of a specialist is to execute limit orders for other members of the Exchange. A limit order is an order to buy (sell) a specified number of shares of a given stock when and if the price of the stock falls (rises) to some specified level. The specialist maintains a book in which these orders are recorded and to which only he has access. The ability to place a limit order with a specialist frees the broker who places the order from having to wait at the post for a price movement that may never occur.

For example, suppose the information contained in the specialist's book for shares of XYZ corporation is summarized in figure 1.[22] The demand curve aggregates the purchase orders that have been placed with the specialist. These include bids of \$9⅞ for 400 shares, \$9¾ for 300 shares, etc. The supply curve aggregates the specialist's sell orders of 100 shares at \$10⅛, 200 shares at \$10¼, etc. Brokers, standing at the post, trade XYZ shares with each other and the specialist. At any time, a broker may request a quote from the specialist who, given the information in figure 1, would respond "\$9⅞ for 400, 100 at \$10⅛." This indicates that the specialist has buy orders for 400 shares at \$9⅞ and sell orders for 100 shares at \$10⅛. If the buy and sell orders of the other brokers at the post are in balance at the current price, trading in XYZ shares will occur within the price range of \$9⅞ bid and \$10⅛ ask.[23]

Suppose, however, that a broker has a market buy order for 300 shares that he is unable to cross with a broker with sell orders for 300 shares at the quoted spread (in this case, at an ask price of \$10⅛ or less). Since the specialist's quote indicates that he will sell 100 shares at \$10⅛, the broker will respond "Take it." The broker has purchased 100 shares from the specialist at \$10⅛. Since the broker must buy another 200 shares, he will ask for a further quote. If nothing further has occurred, the specialist will quote "\$9⅞ for 400, 200 at \$10¼." The broker will respond "Take it." The broker has satisfied the market buy order for 300 shares of XYZ. He purchased 100 shares at \$10⅛ and 200 shares at \$10¼. Of course, the broker could have acquired 300 shares immediately by offering to pay a price of \$10¼ but the cost would have been greater. Instead, it pays the broker to try to "walk up" the supply curve by executing a number of trades rather than jumping directly to the price that will get him 300 shares in

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[18] Malkiel (1981), Brealey (1983) and Fama (1970).

[19] See Perry (1985); Atchison, Butler and Simonds (1987) and Harris (1988).

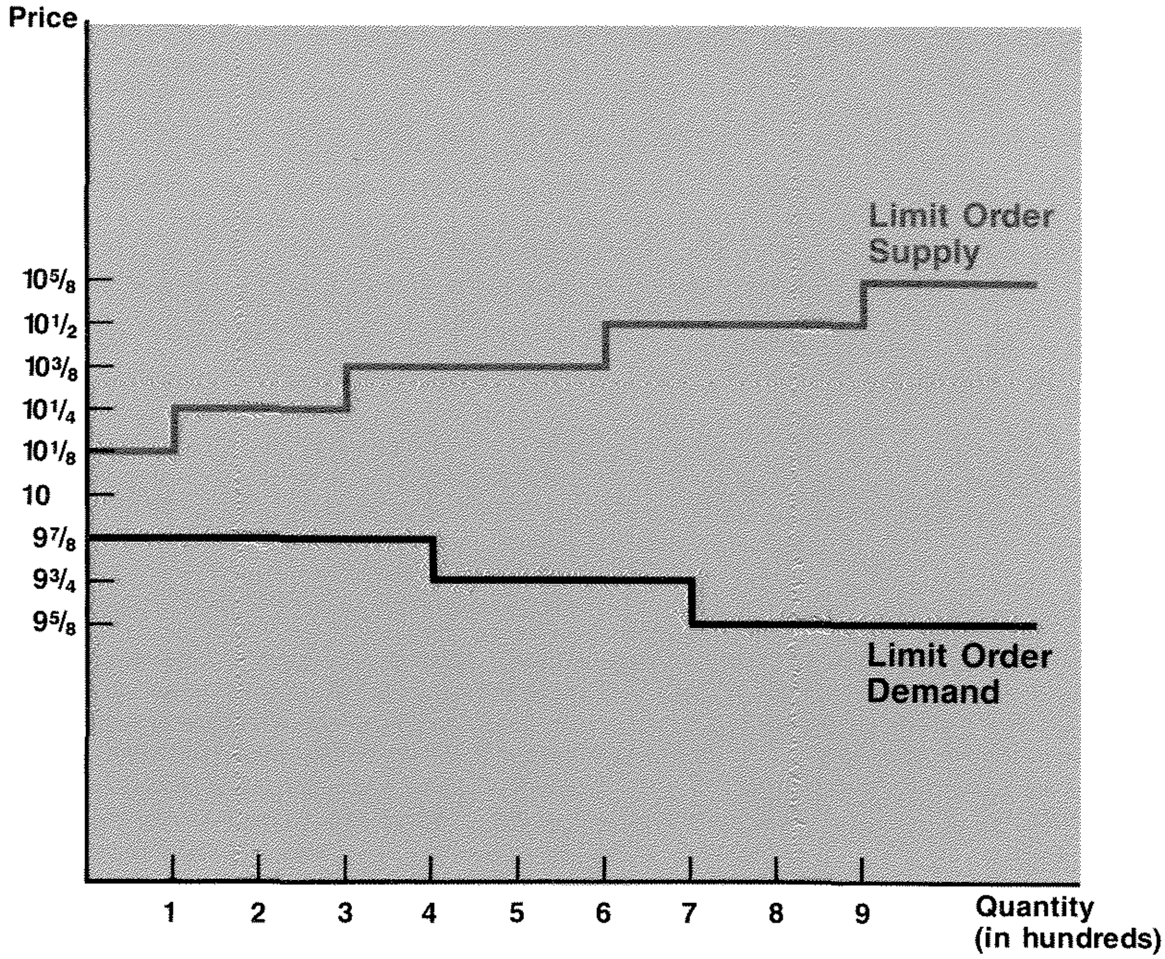
[20] See Grossman and Miller (1988) for a discussion of why trading rules many differ across the markets.

[21] Of course, the NYSE is not the only cash market for stocks, but it is a major market. Because of its relative size, the discussion focuses on this market.

[22] For purposes of exposition, the figure and discussion ignore the effect of "stops" and "stop loss orders" on the book.

[23] See Stoll (1985), Shultz (1946), pp. 119–44 and *The New York Stock Exchange Market* (1979), pp. 14–21 and pp. 30–31.

Figure 1
An Illustration of Limit Order Supply and Demand



one trade.[24] Similar reasoning applies to situations in which excess market sell orders exist at the quoted spread.

Notice that this process of "walking up" the supply curve or "walking down" the demand curve can generate a sequence of recorded transaction prices that run in the same direction. The larger the excess of market buy (or sell) orders is relative to the size of the specialist's limit orders at various prices, the longer the sequence of recorded transaction prices that run in the same direction and the greater the likelihood that recorded price changes over the time interval are correlated. This situation is particularly likely to arise during panics when large order imbalances develop at quoted prices.

Specialist Rule 104

Specialists are required by rule SR 104 to maintain a "fair and orderly" market. More specifically, the rule states that

> [t]he maintenance of a fair and orderly market implies the maintenance of price continuity with rea-

[24]Under NYSE rules, public orders have precedence over specialists' orders at the same price. See Stoll (1985), p. 7.

sonable depth, and the minimizing of the effects of temporary disparity between supply and demand.

In connection with the maintenance of a fair and orderly market, it is commonly desirable that a . . . specialist engage to a reasonable degree under existing circumstances in dealings for his own account when lack of price continuity, lack of depth, or disparity between supply and demand exists or is reasonably to be anticipated.[25]

For example, rule SR 104 requires the specialist to buy shares for his own account to assist the maintenance of an orderly market if, in his estimation, sell orders *temporarily* exceed buy orders at the existing market price and conversely. If these imbalances are truly temporary, the trades required by SR 104 will be profitable for the specialist; evidence indicates that specialists typically sell on up ticks in price and buy on down ticks.[26] If large order imbalances develop that threaten the orderliness of the market, the specialist may institute an opening delay or trading halt. The specialist needs the approval of a floor official or governor to do this and to establish a new opening price.[27]

The effect of SR 104 is to smooth what would otherwise be abrupt movements in stock prices, at least over short periods of time (a few minutes). Rather than allowing the price to move directly to some new level, specialist trading temporarily retards the movement. This can generate a sequence of correlated price changes.

Market-Making in the Futures Market

Trading in futures markets is governed by CFTC rules that require all trades of futures contracts to be executed openly and competitively by "open outcry." In particular, the trading arena, or pit, has no single auctioneer through whom all trades are funneled. Rather, the pit is composed of many traders who call out their bids and offers to each other. The traders are not required to stabilize the market. They may at any time take any side of a transaction even though this might add to an imbalance of buy and sell orders at the quoted price, and they may leave the pit (refuse to trade) at any time. At the time of the crash, there was no rule regarding limit moves in the price of the Standard and Poor's futures contract.

These rules contain no requirement to smooth out movements in the price. Traders are free to move the price immediately to a new level. Unlike the cash market, there are no trading rules in futures markets that are likely to result in correlated price changes. Furthermore, since there were no rules that retarded price changes in the futures market, futures prices were free to adjust more quickly than cash prices so changes in futures prices may lead changes in cash prices.

Different Instruments

It is important to note that different instruments are traded in the cash and futures markets. Stock index futures contracts are agreements between a seller (short position) and a buyer (long position) to a cash settlement based on the change in a stock index's value between the date the contract is entered by the two parties and some future date.[28] The instrument underlying the futures contract is a large basket of different stocks, that is, the stocks contained in the Major Market Index, the Value Line Index, the S&P 500 Index, etc. No such instrument is traded in the cash market, where purchasing or selling 500 different stocks, for example, requires as many different transactions and can only be executed at significantly higher costs.[29]

The different instruments traded in the cash and futures markets have a further implication for the relationship between observed price changes between the two markets. The cash market prices shown in chart 1, as well as those examined by the Brady Commission, are measured by an index. The index is an average of the prices of all the stocks included in the index. When the index is observed at a very high frequency (say, minute-by-minute), some of the stocks included in the index may not have traded during the interval between observations. If not, the level of cash prices measured by the index includes some prices from previous observations. In other words, the index

[25] *Report of the Presidential Task Force on Market Mechanisms* (1988), p. vi–7. Rule 104 is taken seriously. See pp. vi–9.

[26] See Stoll (1985), pp. 35–36.

[27] It was the application of SR 104 that resulted in the opening delays and trading halts that occurred during the week of October 19. For stocks included in the S&P 500, these delays and halts averaged 51 minutes on October 19 and 78 minutes on October 20. See U.S. General Accounting Office (1988), p. 56.

[28] See Schwarz, Hill and Schneeweis (1986), p. 9.

[29] For example, the cost of trading one futures contract based on the Standard and Poor's 500 is about $500 lower than trading the equivalent basket of stocks in the cash market. See Miller, Hawke, Malkiel and Scholes (1987), p. 11, and U.S. General Accounting Office (1988), p. 20.

Table 2
Stale Prices and Correlated Changes in a Price Index: A Simple Example

Period	Share prices A	B	C	Index[1]	Change in index
0	$10	$20	$30	100	
1	9	20	30	98.33	−1.67
2	9	18	30	95.00	−3.33
3	9	18	27	90.00	−5.00

[1] $\text{Index} = \frac{(A+B+C)/3}{\$20.00} \times 100$

includes some "stale" prices. The term used to describe this phenomenon is "nonsynchronous trading."

Typically, nonsynchronous trading does not create a serious measurement problem. Under normal conditions, a buy or sell order is executed in about two minutes on the NYSE. On October 16 and during the week of October 19, however, the time required to execute orders rose markedly.[30] On those days, the index contained a considerable number of stale prices.[31] The subsequent piecemeal adjustment of these stale prices for individual stocks could explain correlated changes in the level of the cash market index. This is shown in the table 2 example. The example assumes that the index is a simple average of the prices of three stocks (A, B and C) divided by the average price in period zero and multiplied by 100. The initial prices (in period zero) are equilibrium prices (i.e., they contain all currently available relevant information). Then, new information becomes available in period 1 that eventually will cause a 10 percent decline in all stock prices. If there is nonsynchronous trading, the revisions will occur piecemeal for each of the stocks. One example of this is shown in the table: the price of stock A falls in period 1, the price of stock B falls in period 2, etc. If the index is reported in each period, it will display positively correlated changes as shown in the table.

The stale price problem is not relevant for futures market prices; futures prices are actual prices. As a result, changes in futures prices will appear to lead changes in the cash market index if the index contains a substantial number of stale prices.

THE DIFFERENT IMPLICATIONS

The central feature of the cascade theory is that declines in cash and futures prices reinforced each other and led to further declines in both markets. The theory suggests that declines in the price of stock index futures contracts *caused* a decline in the cash prices of the underlying stocks, and this drop *caused* a further decline in the prices of index futures contracts. If the theory is correct, changes in cash prices will be positively correlated with past changes in the price of index futures and conversely. The cascade theory further implies that price changes in each market are positively correlated with their own past changes. This follows from the circularity of the theory which attributes sharp declines in stock prices to immediately preceding sharp declines. Finally, since the cascade theory contends that this specific behavior *caused* the panic, these correlations should be observed during the panic, but not at other times.

The efficient markets hypothesis suggests that market-making in the cash market and nonsynchronous trading could produce intra-day *cash* market price changes that are correlated. Furthermore, the hypothesis suggests that changes in futures prices may lead changes in cash prices. These implications are similar to the implications of the cascade theory. The two differ, however, in three important respects. Unlike the cascade theory, the efficient markets hypothesis suggests that:

(1) Changes in the price of stock index futures contracts are uncorrelated,
(2) Changes in cash prices do not lead changes in futures prices, and
(3) Relationships that exist across the two markets are not unique to the panic.

[30] See U.S. General Accounting Office (1988), p. 73.

[31] See Harris (1988); *Report of the Presidential Task Force on Market Mechanisms* (1988), p. 30; Miller, Hawke, Malkiel and Scholes (1987), pp. 21–22 and 34–35; U.S. Commodity Futures Trading Commission (1988), pp. v, 15 and B-1 through B-9.

TESTING THE TWO THEORIES

These theories are tested using minute-by-minute data on the level of the Standard and Poor's 500 index (S&P 500) and the price of the December 1987 Standard and Poor's 500 index futures contract (S&P 500 Futures). The level of the S&P 500 index represents the cash price of the stocks underlying the S&P 500 futures contract. All tests are conducted using first differences of the natural logs of the levels. This transformation of the data approximates one-minute percentage changes (expressed in decimals) in cash and futures market prices. The data cover the trading days immediately before, during and after the panic: October 16, 19 and 20.[32]

A few comments about the data are important. The NYSE, on which the great bulk of the stocks included in the S&P 500 index are traded, was open from 9:30 a.m. to 4:00 p.m. EST on the above days. The CME, which trades the S&P 500 futures contract, was open from 9:30 a.m. to 4:15 p.m. EST on October 16 and 19; on October 20, however, trading in the S&P 500 futures contract was halted from 12:15 p.m. to 1:05 p.m. EST. All tests reported here *exclude* the period on October 20 when trading in the futures market was halted.

Were Changes in Stock Prices Correlated?

Table 3 presents the results of a test (called a Box-Pierce test) based on the estimated autocorrelations of percentage changes in cash market prices. This test is designed to determine whether the data are significantly correlated, that is, whether current changes in cash market prices are related to their own past changes. Both theories discussed in this paper suggest that intra-day, high-frequency cash market price changes will be positively correlated, although the reasons for the positive correlation are considerably different. As a result, these data do not help discriminate between the two theories. If the data prove inconsistent with this implication, however, neither theory performs well in explaining the behavior of cash market prices.

The data in table 3 indicate that minute-to-minute changes in the S&P 500 Index are significantly correlated. Furthermore, the correlations are positive at least over the initial lag.[33]

Table 3

Cash Market (Autocorrelation Coefficients and Box-Pierce Statistics for First Differences of Logs of the Minute-by-Minute S&P 500 Index)

Panel A: October 16, 1987 (9:30 a.m. – 4:00 p.m. EST)

To lag	Autocorrelation coefficient	Box-Pierce statistic[1]
1	.570*	112.09
2	.530*	209.00
3	.385*	260.14
6	.178*	333.81
12	–.148	352.51
18	–.208	406.39
24	–.072	462.80

Panel B: October 19, 1987 (9:30 a.m. – 4:00 p.m. EST)

To lag	Autocorrelation coefficient	Box-Pierce statistic[1]
1	.342*	37.78
2	.397*	88.69
3	.406*	141.93
6	.264*	237.78
12	.231*	345.66
18	.124	385.52
24	.054	396.34

Panel C: October 20, 1987 (9:30 a.m. – 4:00 p.m. EST)

To lag	Autocorrelation coefficient	Box-Pierce statistic[1]
1	.535*	84.15
2	.561*	176.68
3	.590*	279.02
6	.521*	548.61
12	.311*	845.55
18	.324*	1026.74
24	.250	1155.57

[1]Critical value for 24 lags is 33.20. A Box-Pierce statistic in excess of this indicates significant autocorrelation.
*Exceeds two standard errors

Table 4 presents the results of the same test for the December S&P 500 futures contract. The efficient markets hypothesis and the absence of specialist traders suggest that these changes are not correlated. Conversely, the cascade theory

[32]Minute-by-minute price data were also examined for October 15 and 21–23. In each case, the qualitative results were the same as those presented here.

[33]These correlations are analyzed further below.

Table 4

Futures Market (Autocorrelation Coefficients and Box-Pierce Statistics for First Differences of Logs of the Minute-by-Minute Price of the December S&P 500 Futures Contract)

Panel A: October 16, 1987 (9:30 a.m. – 4:15 p.m. EST)

To lag	Autocorrelation coefficient	Box-Pierce statistic[1]
1	.090	2.89
2	.035	3.33
3	−.047	4.12
6	−.020	8.25
12	−.020	16.02
18	.017	19.10
24	−.044	22.29

Panel B: October 19, 1987 (9:30 a.m. – 11:00 a.m. EST)

To lag	Autocorrelation coefficient	Box-Pierce statistic[1]
1	−.309*	8.49
2	.140	10.24
3	.005	10.24
6	−.131	15.41
12	.110	18.95
18	.043	21.69
24	−.020	23.13

Panel C: October 19, 1987 (11:00 a.m. – 4:15 p.m. EST)

To lag	Autocorrelation coefficient	Box-Pierce statistic[1]
1	−.072	1.63
2	.090	4.17
3	−.004	4.18
6	.091	7.21
12	.020	9.60
18	.073	14.95
24	.000	22.37

Panel D: October 20, 1987 (9:30 a.m. – 4:15 p.m. EST)

To lag	Autocorrelation coefficient	Box-Pierce statistic[1]
1	.029	.26
2	.022	.41
3	.042	.95
6	.046	4.22
12	−.071	9.28
18	.033	11.81
24	−.035	17.62

[1]Critical value for 24 lags is 33.20. A Box-Pierce statistic in excess of this value indicates significant autocorrelation.
*Exceeds two standard errors

predicts that percentage changes in the futures price will be positively correlated.

The data presented in table 4 are consistent with the efficient markets hypothesis, not the cascade theory. None of the test statistics for October 16 (panel A), October 20 (panel D) and for the bulk of the trading day on October 19 (panel C) indicate significant correlations at conventional significance levels. These price changes are serially uncorrelated.[34] Data for the first 90 minutes of trading on October 19 (panel B) are an exception. During this period, changes in the futures price were significantly correlated with the change the previous minute. This correlation, however, is negative, not positive as the cascade theory implies.[35] Thus, the evidence presented in table 4 is inconsistent with the cascade theory, while, on the whole, it conforms to the efficient markets hypothesis.

Is the Cash Market Efficient?

The table 3 results indicate that intra-day changes in cash market prices are correlated. Put another way, past price changes contain some information about future changes for the next few minutes. Is this information useful in the sense that it can be profitably exploited by traders? If so, it would suggest that cash market traders do not incorporate information efficiently. This, of course, would provide evidence against the efficient markets hypothesis.

In part, the answer to this question depends on the length of the time period over which the price changes are related. If the time period is short, shorter than the time required to execute a transaction, the information contained in past price changes cannot be exploited profitably and the cash market is efficient.

Table 5 helps answer this question. The table 5 data are estimates of the length of the lagged relationship between current and past cash market price changes for October 16, 19 and 20. The estimates were obtained by regressing the contemporaneous minute-to-minute price change on the 15 previous minute-to-minute price changes. Initially, this specification was identified as the unrestricted model. To determine whether the esti-

[34]The same result was obtained when data for October 15 and 21–23 were examined.

[35]This puzzling result for the first 90 minutes of trading on October 19 may be due to the fact that many stocks had not yet opened for trading on the NYSE and the rumors at that time that the SEC would call a trading halt. See Miller, Hawke, Malkiel and Scholes (1987), wire report summary.

Table 5
Estimated Lag Lengths in the Cash Market

Panel A: October 16, 1987 (9:30 a.m. – 4:00 p.m. EST)

$$\Delta LNC_t = -.003 + .401\Delta LNC_{t-1} + .343\Delta LNC_{t-2}$$

(1.19) (7.80)* (6.51)*

$\bar{R}^2 = .41$
DW = 2.00

Panel B: October 19, 1987 (9:30 a.m. – 4:00 p.m. EST)

$$\Delta LNC_t = -.016 + .123\Delta LNC_{t-1} + .228\Delta LNC_{t-2} + .242\Delta LNC_{t-3} + .112\Delta LNC_{t-4}$$

(2.46)* (2.20)* (4.14)* (4.39)* (1.99)*

$\bar{R}^2 = .26$
DW = 2.01

Panel C: October 20, 1987 (9:30 a.m. – 4:00 p.m. EST)

$$\Delta LNC_t = -.001 + .107\Delta LNC_{t-1} + .173\Delta LNC_{t-2} + .258\Delta LNC_{t-3} + .174\Delta LNC_{t-4} + .153\Delta LNC_{t-5}$$

(.132) (1.82) (2.98)* (4.52)* (2.99)* (2.60)*

$\bar{R}^2 = .48$
DW = 2.02

*Statistically significant at the 5 percent level

mated coefficients are sensitive to the lag length and to identify statistically redundant lags, the lag structure was successively shortened by one lag. At each stage, the t-statistic for the coefficient of the most distant lag was examined. If the test indicated the coefficient was statistically insignificant, that lag was dropped and the equation was reestimated with one less lag. This process was repeated until the test rejected the hypothesis that the estimated coefficient of the most distant remaining lag was zero.[36]

The estimates shown in table 5 indicate that the lags ranged from about two minutes on October 16 to five minutes on October 20.[37] It requires about two minutes to execute a trade on the NYSE under normal trading conditions. During the panic, execution times ranged from about 10 to 75 minutes at times.[38] In view of this, the lags estimated in table 5 do not appear to be long enough to reject the efficient markets hypothesis; also, since they varied over the period, it is doubtful that past price changes contained information that could be exploited by traders.

Did Stock Price Changes Reinforce Each Other Across Markets?

The central feature of the cascade theory can be tested by determining whether past price changes in the futures market help explain current price changes in the cash market and conversely. This is done by regressing the change in cash prices on past changes in cash prices; then, past changes in futures prices are added to the estimated regression equation to see if they improve the equation's explanatory power. An F-test is conducted to determine whether the addition of the futures market data significantly increases the cash price equation's coefficient of determination (R^2). The

[36]See Anderson (1971), pp. 223 and 275–76. It is possible that this test may reject some lags that are, in fact, significant if taken as a group. To control for this, F-tests were run with the lag length in the unrestricted model set at 15. The number of lags in the restricted model was set at 12 to determine if the three omitted lags were significant. The lags in the restricted model was then reduced to nine and the test repeated, etc.

[37]The lag had declined to about three minutes by October 23. The method used in this paper to estimate lag length has the problem that the probability of rejecting the null hypothesis (the estimated coefficient is zero) when it is true rises as the lag length is reduced. Consequently, the true lag lengths may be shorter than those estimated in table 5. See Batten and Thornton (1983), pp. 22–23, and Anderson (1971), pp. 30–43.

[38]U.S. Government Accounting Office (1988), p. 73.

Table 6
Granger Tests

Day	Lags	F-statistic Futures → Cash	F-statistic Cash → Futures
October 16	2	17.61*	.76
October 19	4	4.46*	1.57
October 20	5	2.59*	.67

*Statistically significant at the 5 percent level

test is then reversed, with the change in futures prices as the dependent variable.

The results of this test are presented in table 6 for each of the trading days examined in this paper. The lag length employed on each day is the one identified by the table 5 test.[39] The results for cash market prices show that the addition of past changes in futures prices improve the regression estimates; this suggests that price changes in the futures market preceded those in the cash market. This result is consistent with both the cascade theory and the efficient markets hypothesis. Furthermore, it is not unique to the panic; it has been observed for intra-day price data during other periods as well.[40]

Other table 6 results, however, are inconsistent with the cascade theory. The inclusion of past changes in cash prices in the regressions that estimate the change in futures prices does not significantly improve the estimates. This rejects the notion that past changes in cash prices help explain changes in futures prices. This finding is inconsistent with the central feature of the cascade theory, which suggests the panic was caused by declines in cash and futures prices that became larger as they tumbled over each other on the way down.

CONCLUSION

This paper has examined the cascade theory, which has been advanced as an explanation of the October 1987 stock market panic. The theory relies on the notion that stock traders behave "mechanically," are "insensitive to price," and execute transactions in markets without regard to transaction costs. These assertions are inconsistent with the behavior of wealth-maximizing individuals. Not only are the theoretical underpinnings of the cascade theory weak, the data do not support the theory. Instead, the observed relationships that do exist between the markets are not unique to the crash and can be explained by a theory that relies on wealth maximizing behavior.

Almost 60 years later, the cause of the "Great Crash" in October 1929 is still being debated. Those with even longer memories know that there is little agreement about what caused the stock market panic in 1907. Although financial reforms followed each of these panics, history indicates that the reforms have done little to reduce the frequency or severity of panics. Without a reliable theoretical guide to the mechanics of a panic, any reform is no more than a "shot in the dark." The evidence presented in this paper suggests that the reforms advanced by proponents of the cascade theory are unlikely to alter this historical pattern.

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[39]Hsiao (1981) uses a similar method. These lag lengths apply to the cash market. Analysis of the futures market suggests that the appropriate lag for this market is zero.

[40]See Kawaller, Koch and Koch (1987).

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