Program Trading and Expiration-Day Effects
Author(s): Hans R. Stoll and Robert E. Whaley
Source: *Financial Analysts Journal*, Vol. 43, No. 2 (Mar. - Apr., 1987), pp. 16-18+20-28
Published by: Taylor & Francis, Ltd.
Stable URL: https://www.jstor.org/stable/4479013
Accessed: 05-11-2019 17:56 UTC

by Hans R. Stoll and Robert E. Whaley

Program Trading and Expiration-Day Effects

The arbitrage between index futures and the underlying cash index and the cash settlement feature of index futures contracts, which requires arbitrageurs to unwind positions in the stock market, are thought to be at the heart of the abnormal stock price movements during the "triple-witching" hour—the last hour of trading on days on which index futures, index options and options on index futures expire simultaneously. During 1984 and 1985, volume was substantially higher than normal in the last hour of trading on those quarterly Fridays. Open interest in the expiring futures contracts on the expiration day amounted to about 40 per cent of the average month-end open interest. The incremental stock market volume, however, was approximately one-third the volume that would be implied if the entire expiration-day open interest were traded in the stock market.

Analysis of stock market price changes in the last hour of expiration days and the first half-hour of the following day indicates that the volatility of price changes was significantly higher on expiration days, with the stock market tending to fall. Stocks not in the S&P 500, however, exhibited no price effects. Price effects seemed also to be associated only with the S&P 500 futures contract expirations; index option expirations themselves did not lead to abnormal market movements. When the magnitude of price effects was measured by the degree of reversal in prices on the morning after the expiration day, the average magnitude of the price effect in the 10 most recent quarterly futures contract expirations examined was about 0.4 per cent of the closing index value at expiration.

The average expiration-day price effect of 0.4 per cent is not large, considering that a price impact of approximately 0.25 per cent of the value of the transaction can be expected on the basis of the bid-ask spread. Once this market impact cost is drawn out, the average expiration day price impact falls to about 0.15 per cent of the value of the transaction, an amount representing the additional cost of liquidity. Furthermore, price impacts in excess of those found on expiration days are frequently encountered in large block transactions, where the cost of providing liquidity also increases. On expiration days, however, transactions in many stocks occur simultaneously, so the market as a whole is affected.

Hans Stoll is the Anne Marie and Thomas B. Walker Professor of Finance at the Owen Graduate School of Management, Vanderbilt University. Robert Whaley is Associate Professor of Finance at The Fuqua School of Business, Duke University.

This article is based on a larger study, Expiration Day Effects of Index Options and Futures, *Monograph Series in Finance and Economics, Monograph No. 1986-3 (New York: New York University, March 1987). The study was carried out at the request of the major option exchanges.*

The authors thank the Chicago Board Options Exchange, the Chicago Board of Trade and the Chicago Mercantile Exchange for providing the data used in the study, and Paul Laux for his capable research assistance. The authors are grateful for useful comments by and discussions with David Emanuel, Richard J. Rendleman, Jr., and their colleagues at Vanderbilt and Duke Universities. Professor Whaley acknowledges the support of the Futures and Options Research Center at Duke University.

FUTURES AND OPTION contracts based on stock indexes were first introduced in 1982 and 1983. Since that time, trading in these contracts has grown dramatically. Today, one contract alone—the S&P 500 futures contract—trades an average of $12 billion worth of equity value each day, an amount substantially in excess of stock market volume. Volume in other index option and futures contracts is also large. In recent months, considerable public attention has focused on these new contracts because of the seemingly dramatic movements in stock market volume and prices on the expiration days of the contracts. This article presents evidence on the magnitude and economic significance of these effects.

Index Futures Arbitrage

Two characteristics of index futures make the arbitrage that links the index futures price to the index cash price different from the corresponding arbitrage in traditional futures contracts. First, the underlying asset is an index that is itself not traded. Arbitrage requires the purchase or sale of the individual stocks that comprise the index. *The purchase or sale of a portfolio of stocks pursuant to a single order is called program trading*. Although program trading is used for a number of reasons unrelated to index futures (by index funds, for example), much of it is associated with the index futures arbitrage process. Second, index futures call for cash settlement at expiration, rather than for delivery of the underlying asset as is typical in traditional futures contracts. This means that arbitrageurs must unwind their positions in the stock market on the expiration day. It is this unwinding process that has been blamed for expiration day price and volume effects.

Futures/Cash Arbitrage Relation

The equilibrium relation between the price of an equity futures contract, F, and the underlying stock index price, S, is given by the cost-of-carry relationship:

$$F = S(1 + r - d), \qquad (1)$$

where r is the riskless rate of interest over the life of the futures contract and d is the rate at which dividend income is expected to accrue on an investment in the underlying index over the same contract life.[1] This relation is driven by the fact that, in an efficiently functioning capital market, a portfolio consisting of a long position in the index, a short position in Treasury bills and a short position in the index futures contract provides a predictable outcome.

More specifically, consider an investment of S in the underlying index, financed with riskless borrowings at interest rate r. Assume that the portfolio also has a short position of one futures contract at price F. Because the futures position involves no investment outlay, the net investment when the portfolio is formed is zero.

Now consider the value of this portfolio when the futures contract expires at time T. The equity position has value $Sd + S_T$, reflecting the dividend income earned on the equity investment, Sd, as well as the new (random) level of price, S_T. The riskless borrowings have accrued interest and are now at a level of $-S(1+r)$. The futures position has a random value $-(S_T - F)$, reflecting settlement at the level of the cash index at the end of the futures contract expiration day. The net value of the portfolio on expiration day is thus certain to be $Sd - S(1+r) - F$. But, because the initial investment in this portfolio is equal to zero, and because the price uncertainty of the long stock position is exactly offset by the short position in the futures contract, the net value of the portfolio must also equal zero at expiration. Setting the terminal value of the portfolio equal to zero provides the pricing relation given by Equation (1).

Violation of Equation (1) signals program trading. For example, if the futures price, F, exceeds the index price, S, plus the net cost of carry, $S(r - d)$, a long arbitrage opportunity is indicated; a riskless arbitrage profit is ensured by buying the index stocks (using the proceeds from riskless borrowing) and selling the futures. Institutional investors in low-risk, short-term debt instruments are natural long arbitrageurs. Such investors have ready access to cash and view as their opportunity cost of funds the yield on short-term debt instruments, not the cost of borrowing funds. Such institutions will find long index arbitrage attractive whenever a net return in excess of that on CDs or T-bills can be guaranteed. That return can be significantly less than the return required by an arbitrageur who must borrow new funds for the arbitrage.

If the futures price falls below the level of the index plus the net cost of carry, a short arbitrage opportunity is indicated; again, a costless, riskless arbitrage profit is ensured. In practice, a

1. Footnotes appear at end of article.

short arbitrage position poses a number of difficulties not posed by a long arbitrage position. The most serious of these is the short-sale rule. An arbitrageur attempting to sell short a basket of 200 stocks must wait for an up-tick in each of the 200 stocks. As a result, the arbitrageur may be unable to establish a short position that properly represents the index. This difficulty is not too severe in the Major Market Index, which contains only 20 stocks, but it is quite severe in the S&P 500 or the New York Stock Exchange Composite Index. Difficulties may also arise in borrowing the stocks for short sale, but facilities for borrowing seem to be well developed.

Because of short-selling impediments, arbitrage of a futures price that is too low is frequently undertaken through stock replacement strategies. Institutional investors that already own the index stocks sell those stocks, put the proceeds in debt instruments and replace the stocks with the futures contracts. The new position has the same economic payoff as the initial position, but at a lower cost.

Transaction Costs and Risks

Arbitrage program trading on the basis of the cost-of-carry relationship is not completely costless or riskless. First of all, the arbitrageur faces commissions and the bid-ask spread in both the stock and futures markets. An arbitrage opportunity signaled by last transaction prices may disappear by the time brokers execute the transaction in each stock. This is particularly likely if several arbitrageurs are acting on the same signal. Market practitioners who engage in index arbitrage estimate total proportional round-trip transaction costs from all these factors to be on the order of 0.5 to 0.75 per cent of the underlying value.

For example, the commission to trade 100 S&P 500 futures contracts is approximately $1,250. The commission to trade the corresponding value of underlying stocks (100 times the value of the S&P 500 futures contract, or $10,000,000), assuming a rate of $0.07 per share, is approxiamtely $17,500. Assuming a bid-ask spread of 0.5 per cent, the one-way impact associated with buying and selling the underlying stocks is $25,000.[2] The one-way market impact associated with trading the 100 futures contracts is estimated to be $1,250. If the arbitrage position is held to expiration, market impact costs arise only when the position is established, not when it is unwound. Thus the round-trip transaction cost equals two commissions plus one market impact cost, or $61,250—about 0.6125 per cent of the market value of the underlying stocks.

The position would be unwound before expiration if the incremental profit exceeded the market impact costs of the unwinding. Also, transaction costs may be lower than 0.6125 per cent for brokerage firms that trade on their own accounts. In general, however, traders executing arbitrage transactions must wait until the size of the price violation from the cost-of-carry relationship is sufficiently large to recover transaction costs.

In addition, two types of risk may arise in an arbitrage transaction. First, in Equation (1), d is the anticipated dividend yield on the index portfolio over the futures contract life. To the extent that unexpected dividend increases or decreases occur during the period, the arbitrage trade will be risky. An unexpected increase in dividends will increase profits for the long arbitrageur and decrease profits for the short arbitrageur. An unexpected cut in dividends will have the reverse effects. For the stocks in the S&P 500, however, cash dividends and their timing are very predictable.

Second, if all the stocks in the index are not bought or sold, tracking risk may arise. Many arbitrageurs of the S&P 500, for example, choose to trade a basket of stocks—say, the largest 200—because of the cost and time involved in doing a program trade in 500 stocks. To the extent that the price movements of this subset of stocks are not perfectly correlated with the price movements of the index, there will be the risk that the price of the basket may not converge to the futures price at expiration.

Arbitrage in Practice

Sophisticated arbitrageurs can assess and monitor the transaction cost, dividend yield and tracking risk factors on a continuous basis. In determining whether to undertake arbitrage, for example, sophisticated computer services determine the value of the index based on the bid or ask prices of the component stocks, thereby estimating the market impact cost. These services also provide the dividend yield on the index or any basket of exchange-traded stocks, based on past dividend declaration dates and amounts. Once an arbitrage position is established, the position is continuously monitored to evaluate the tracking risk component.

In order to minimize transaction costs, the arbitrageur must take a minimal dollar position in the underlying index stocks. In practice, arbitrage in the Major Market Index involves a stock program of $3 million. The S&P 500 can be arbitraged using a basket of stocks amounting to $10 million, but an arbitrage using all 500 stocks is said to require about $25 million. Of course, once an arbitrage opportunity is identified, market participants want to assemble as large a program as possible.

Arbitrage is most likely to be undertaken by those who can incur the lowest transaction costs and have the lowest opportunity cost of funds. Brokerage firms trading for their own accounts face the lowest transaction costs and are important arbitrageurs for this reason. Two factors may limit their arbitrage potential, however. First, the availability of brokerage firms' capital can be constrained by net capital requirements and the manner in which the "haircut" provisions are applied to positions in futures and stocks as well as the manner in which margin requirements are applied to arbitrage positions. (Since arbitrage is riskless, or nearly riskless, both margin requirements and haircut provisions ought to be minimal.) Second, brokerage firms tend to be net borrowers of funds and may have uses for funds that are more profitable than index arbitrage. The fact that brokerage firms have marketed arbitrage programs to their customers indicates that opportunities in excess of street capital have been available.[3]

Position Unwinding

At expiration, the futures contract is settled at the closing price of the underlying index. As a result, the arbitrageur is unaffected by the manner in which the position in the index stocks is unwound, so long as the closing price on each of the stocks is received. For example, if the process of unwinding a long arbitrage position pushes the value of the index down, the futures contract will also settle at a lower price. Because the arbitrageur is perfectly hedged, the loss on the stocks is offset by the gain on the short futures position.

To assure execution of each index stock at the closing price, the arbitrageur places with the specialist market-on-close orders—i.e., market orders to be executed at the closing price. If many arbitrage programs are being unwound in the same direction late on the expiration day, the result may be an order imbalance that can cause closing prices to move in one direction or the other. In the face of major imbalances, the exchange could impose a trading halt; to date, however, all such orders have been honored.

Volume Effects

One way to measure the potential impact of futures contract expirations is through the open interest that exists in the futures market on the day in which the contract expires. If the open interest is not large, there is no potential for abnormal stock trading volume arising from the unwinding of arbitrage positions.

Index futures are cash settlement contracts; we would expect the fraction of these contracts held to expiration to exceed the fraction of futures contracts calling for delivery. In delivery markets, investors in long positions have a natural reluctance to take delivery from the shorts when there is some uncertainty about quality and time of delivery. For example, the CFTC reported that only 12 per cent of the average monthly open interest in grains was delivered in 1985, as opposed to 38.6 per cent for the S&P 500 Index, 36.6 per cent for the NYSE composite and 55.5 per cent for the Major Market Index.[4]

Table I gives a more detailed picture of the pattern of open interest around eight expiration days of the S&P 500 futures contract in 1984 and 1985. On December 20, 1985, the open interest in the expiring Dec/85 contract was 27,116, which is approximately one-half the open interest in that contract outstanding on the preceding contract expiration day (54,428 on September 20, 1985). In fact, open interest in the second maturity contract grows to its peak level on the day the nearby maturity contract expires. At the same time, because the open interest in the expiring contract remains large, the total open interest in all contracts tends to reach a peak around expiration days. The decline in the open interest of the expiring contract and the increase in the open interest of the next maturity suggests that a substantial portion of the open interest is rolled over into the next contract maturity. Nevertheless, a substantial fraction of the open interest in the expiring contract remains outstanding at expiration.

If the entire open interest at expiration implies stock market trading in the corresponding amount, volume in the stock market would be affected significantly. For example, the open interest in the Dec/85 contract on December 20,

Table I Open Interest in S&P 500 Index Futures Contracts on the Day Before, the Day Of and the Day After Contract Expiration (1984 and 1985)

		Number of Contracts in Open Interest			
*Contract**	*Date (Year, Month, Day)*	*Expiring Contract*	*Next Contract*	*Closing Stock Index Price*	*Market Value of Underlying Equity at Contract Closing*
Mar/84	840314	15,535	23,498		
	840315	14,176	26,472	157.41	$1,115,722,000
	840316	0	26,201		
Jun/84	840614	14,226	26,000		
	840615	13,863	27,871	149.03	1,033,001,400
	840618	0	26,849		
Sep/84	840920	11,413	27,502		
	840921	9,752	30,815	165.67	807,806,900
	840924	0	29,768		
Dec/84	841220	22,216	39,378		
	841221	20,484	42,866	165.53	1,695,358,200
	841224	0	42,678		
Mar/85	850314	27,123	48,815		
	850315	26,989	51,411	176.53	2,382,184,000
	850318	0	52,153		
Jun/85	850620	23,268	52,519		
	850621	23,324	56,587	189.61	2,211,231,800
	850624	0	57,691		
Sep/85	850919	20,522	52,479		
	850920	17,177	54,428	182.05	1,563,536,400
	850923	0	54,131		
Dec/85	851219	27,058	56,627		
	851220	27,116	59,748	210.94	2,859,924,500
	851223	0	59,594		

Source: Chicago Mercantile Exchange.
* The Mar/84 contract was the last S&P 500 futures contract to expire on the third Thursday of the contract. All contracts thereafter expired on the third Friday of the contract month.

1985 represents contracts on $2,860 billion in stock, compared with an average daily volume of trading on the New York Stock Exchange of about $4 billion. The implication for the stock market is unclear, however.

First of all, for every long in the futures market there is a short. It is thus possible that short futures positions may sell stock while long futures positions buy it, so that there is no imbalance. This is possible, for example, if an equal number of long arbitrage and short arbitrage opportunities arose during the life of the contract and were held to expiration. Second, some of the open interest may reflect spreaders who have bought the expiring contract and sold the next maturity because the nearby futures price was depressed at expiration day. The spreader would then buy stocks to replace the long futures position in the expiring contract; this might offset the sales of the stock by the long arbitrageurs. Finally, a portion of the open interest may represent speculators on both the long and short sides of the market; these positions would tend to offset each other.

Nevertheless, a large open interest on expiration day could portend a large unwinding of arbitrage positions in the stock market. As open interest figures are public, the stock market can predict the potential source of volume generated by expiring futures contracts. However, the degree of imbalance between buyers and sellers of stocks remains uncertain.

Stock Market Volume

The evidence in Tables II and III makes it clear that stock market volume has been affected by index futures contract expirations and, to some degree, by option expirations. Table II presents data on block transactions and reported share volumes for weeks in which neither the S&P 100 options nor the S&P 500 futures expired on a Friday, for weeks in which only the options expired on Friday, and for weeks in which both the options and the futures expired on Friday. Table III presents summary data for ratios of Friday volume to average daily volume in the week and for ratios of the last hour's volume on Friday to the average hourly volume on Friday.

Table II NYSE Trading Volume Classified by Type of Expiration (December 30, 1983 to December 27, 1985)

	Number of Blocks[b]		*Share Volume in Thousands*		
Type of Friday[a]	*Per Week*	*On Friday*	*Per Week*	*On Friday*	*Last Hour*
Nonexpiration Day					
Mean	9,204	1,924	474,896	99,049	15,959
Std. Deviation	2,358	589	110,124	27,158	5,011
No. of Obs.	81	81	81	81	81
Options-Only Expiration Day					
Mean	9,707	1,997	493,404	101,483	17,891
Std. Deviation	2,246	597	105,051	28,870	5,073
No. of Obs.	17	17	17	17	17
Futures and Options Expiration Day					
Mean	10,036	2,134	536,999	115,660	31,156
Std. Deviation	2,459	486	118,880	27,490	11,612
No. of Obs.	7	7	7	7	7

Source: Barron's.
a. Expiration type is based on the S&P 500 index futures and the S&P 100 index options. The Mar/84 S&P 500 futures contract expired on the third Thursday of the contract and is not included here. All contracts reported expire on the third Friday of the contract month.
b. Blocks are transactions of 10,000 shares or more.

Table III is appropriate for evaluating abnormal volume of trading because it controls for variations in the number of trading days per week and for the seasonal fluctuations in weekly volume. It is evident from this table that volume of trading in the last hour of Friday is significantly higher when futures and options expire than on other Fridays. On quarterly Friday expirations, volume in the last hour is 58 per cent higher than in other hours of that Friday. On nonexpiration Fridays, last-hour volume is typically somewhat less than the average hourly volume during the rest of the day. Furthermore, because volume on quarterly expiration Fridays exceeds average daily volume by 8 per cent, the absolute volume during the last hour exceeds the absolute volume on nonexpiration Fridays by considerably more than 58 per cent. Indeed, Table II indicates that the average last-hour volume on quarterly expiration Fridays is about twice the average absolute volume on nonexpiration Fridays. While the stock market volume on option expirations is higher than on nonexpirations, the effect is small when compared with the quarterly expirations when both options and futures expire.

The highest volume Friday does not necessarily occur on expiration days. If one ranks all

Table III Relative NYSE Trading Volume Classified by Type of Expiration (December 30, 1983 to December 27, 1985)

Type of Friday[a]	*Number of Blocks on Friday as a Fraction of the Average Number of Blocks per Day in the Week[b]*	*Share Volume on Friday as a Fraction of the Average Share Volume per Day in the Week*	*Share Volume in the Last Hour on Friday as a Fraction of the Average Share Volume per Hour on Friday*
Nonexpiration Day			
Mean	1.004	1.002	0.972
Std. Error	0.0189	0.0174	0.0194
No. of Obs.	81	81	81
Options-Only Expiration Day			
Mean	1.020	1.018	1.080
Std. Error	0.0483	0.0463	0.0100
No. of Obs.	17	17	17
Futures and Options Expiration Day			
Mean	1.072	1.080	1.584
Std. Error	0.0486	0.0470	0.0253
No. of Obs.	7	7	7

Source: Barron's.
a. Expiration type is based on the S&P 500 index futures and the S&P 100 index options. The Mar/84 S&P 500 futures contract expired on the third Thursday of the contract and is not included here. All contracts reported expire on the third Friday of the contract month.
b. Blocks are transactions of 10,000 shares or more.

Table IV Mean and Standard Deviation of the Percentage Rates of Return in the Last Hour of Expiration Day by Index Type and Expiration Type (July 1, 1983 through December 27, 1985)[a]

	Expiration Type		
Index Type	*Futures and Options Expiration*	*Options-Only Expiration*	*Non-expiration*
S&P 500 Index			
Mean	−0.352[b]	0.026	0.061
Std. Deviation	0.641[b]	0.261	0.211
No. of Obs.	10	16	97
S&P 100 Index			
Mean	−0.452[b]	−0.007	0.033
Std. Deviation	0.699[b]	0.401[b]	0.252
No. of Obs.	10	16	97
Non-S&P 500 Stocks[c]			
Mean	0.064	0.079	0.077
Std. Deviation	0.230	0.211	0.264
No. of Obs.	10	16	97
Non-S&P 100 Stocks[c]			
Mean	−0.168	0.059	0.079
Std. Deviation	0.423[b]	0.202	0.160
No. of Obs.	10	16	97

a. The database contains hourly price observations from closing the day before expiration to 10:30 a.m. on the first day after expiration.
b. The null hypothesis of equal means (t-test) or equal standard deviation (F-test) is rejected at the 5 per cent probability level.
c. The rate of return for the value-weighted index of non-S&P 500 stocks, R_X, is computed from the following equation:

$$R_{NYSE} = kR_I + (1-k)R_X,$$

where R_{NYSE} is the rate of return on the NYSE composite index, R_I is the rate of return on the S&P 500 or S&P 100 index, and k is the fraction of the NYSE index in the S&P 500 or S&P 100. For the S&P 500, k is 0.79; for the S&P 100, k is 0.34.

Fridays on share volume, only one quarterly expiration is in the top 10 and only two quarterly expirations are in the top 20. But volume in the last hour of Friday is greatest on the quarterly Friday expirations.

Although the volume of trading on expiration Fridays is large, it does not exceed nonexpiration Friday volume by as much as would be implied by the expiration-day open interest in Table I. For the years 1984 and 1985, average Friday stock market volume on quarterly expirations was 115,600,000 shares, or about $4,088 billion, while average volume on nonexpiration Fridays was 99,049,012 shares or $3,467 billion. This difference is about one-third the amount that would be implied if the average open interest of 19,815 contracts, about $1,783 billion, existing on expiration Friday were traded in the stock market.

Price Effects

The fact that the volume of trading is abnormally high during the last hour of expiration days turns our attention to the percentage rates of return on the indexes in that period.[5]

Last-Hour Price Effects

Our primary interest is in the volatility of returns in the last hour of expiration days as compared with nonexpiration days. Table IV shows that the standard deviations of the S&P 500 and S&P 100 are significantly higher in the last hour of quarterly expiration days when futures and options expire together than on nonexpiration days. Option contract expirations appear to cause a somewhat higher than normal volatility for the S&P 100, but not for the S&P 500.

Table IV also examines the behavior of NYSE stocks not included in the S&P 500 or S&P 100 by subtracting the index returns from the NYSE composite return (properly adjusting for the weighting of each index). The volatility of the NYSE stocks not in the S&P 500 is no different on expiration days than on nonexpiration days. In other words, the expiration day effect seems to be associated with those stocks that might be part of position unwinding, not with stocks that would not be a part of an arbitrage position. NYSE stocks not in the S&P 100 exhibit a somewhat higher standard deviation of return on quarterly expiration days than on normal days, but this is presumably because many of these stocks are in the S&P 500.

The sign of the price change during the last hour of trading on the 26 expiration days is difficult to predict, because the unwinding of arbitrage positions could put either upward or downward pressure on prices. In comparison

Table V Mean Reversal and Correlation of Percentage Rates of Return During the Last Hour of Trading on Expiration Day and the First Half-Hour of the Next Trading Day by Index Type and Expiration Type (July 1, 1983 through December 27, 1985)[a]

	Expiration Type[b]		
Index Type	*Futures and Options Expiration*	*Options-Only Expiration*	*Non-expiration*
S&P 500 Index			
Reversal	0.380	0.098	−0.004
Correlation (R_t, R_{t+1})	−0.343	−0.015	0.099
S&P 100 Index			
Reversal	0.532	0.182	0.240
Correlation (R_t, R_{t+1})	−0.326	−0.329	0.045
Non-S&P 500 Stocks[c]			
Reversal	−0.610	0.059	0.078
Correlation (R_t, R_{t+1})	−0.071	−0.012	0.023
Non-S&P 100 Stocks[c]			
Reversal	0.463	−0.005	0.029
Correlation (R_t, R_{t+1})	−0.247	0.284	0.217

a. The database contains hourly price observations from closing the day before expiration to the first half-hour of the first day after expiration.
b. A positive sign indicates a reversal; a negative sign indicates that the price change continued in the same direction on the morning of day t + 1.
c. The rate of return for the value-weighted index of non-S&P 500 stocks is computed from the equation given in Table IV.

with nonexpiration days, however, there is a significantly negative average return on the S&P 500 and S&P 100 over the 10 quarterly expirations when futures and options expire together; no similar effect is observed for stocks not in these indexes. This suggests that arbitrageurs tended to be long stocks and short futures during this period.

A better measure of the price effect is the degree to which prices reverse on the morning after the expiration day. If the price change on the expiration day is abnormal, the price would tend to return to a normal level on the following day. If the price does not return, the initial price change is assumed to be the result of new information, not the result of arbitrage position unwindings. More formally, we define a reversal, REV_{0t}, as follows:

$$REV_{0t} = R_{t+1} \text{ if } R_t < 0,$$

$$REV_{0t} = -R_{t+1} \text{ if } R_t \geqq 0.$$

A positive value for REV_0 indicates a reversal, a negative value a continuation.

Table V reports average values of REV_{0t}, where R_t is calculated over the last hour on the expiration day and R_{t+1} is calculated over the first half-hour on the following day. The average reversal calculated over all futures expirations is 0.380 per cent for the S&P 500 and 0.532 per cent for the S&P 100. The serial correlation of returns is also negative. Stocks not in the S&P 500 exhibit no reversal, while stocks not in the S&P 100 exhibit a reversal of 0.463 per cent. Small reversals are observed when CBOE options (not futures) expire, but the largest of these—for the S&P 100—is smaller than the reversal on days when nothing expires (0.182 per cent, versus 0.240 per cent).

Minute-by-Minute Price Data

Minute-by-minute data for the S&P 500 are used to analyze each expiration day separately. Table VI summarizes the findings on daily volatility of the S&P 500 on expiration days and nonexpiration days. The average standard deviation reported in the table is the average of the daily standard deviations calculated over 12 15-minute returns in the three hours ending 4 p.m. (EST). Volatility is significantly greater on Friday expirations of futures—that is, when futures and options expire together. In the earlier period, when futures expire on Thursday, no effect on volatility is observed. Volatility is somewhat higher than normal when options expire alone, but the difference from normal volatility is not statistically significant. Comparable results are obtained if one-minute returns

Table VI Average of the Standard Deviations of 15-Minute Percentage Rates of Return (×24) in the S&P 500 in the Last Three Hours of Expiration Day by Type of Expiration Day

Type of Expiration	*Average Standard Deviation*	*Number of Days*
S&P 500 Index Futures Expiring Thursday		
Expiration Thursday	2.3555	8
Nonexpiration Thursday	2.6555	90
S&P 500 Index Futures Expiring Friday		
Expiration Friday	3.1521*	7
Nonexpiration Friday	1.7438	71
S&P 100 Index Options Only Expiring		
Expiration Friday	2.1211	14
Nonexpiration Friday	1.7438	71

Source: Stoll and Whaley, *Expiration Day Effects of Index Options and Futures*, Monograph Series in Finance and Economics, Monograph No. 1986-3 (New York: New York University, March 1987).
* Expiration day standard deviation is significantly different from the corresponding nonexpiration day standard deviation at the 5 per cent probability level.

Table VII Rates of Return on the S&P 500 During the Last Minutes of S&P 500 Index Futures Contract Expiration Day and the Opening Minutes of the Day after Expiration (April 21, 1982 through December 31, 1985)

		Index Level				*Rates of Return*			
Exp. Date (t)	*Day After (t + 1)*	*Close −30 Minutes*	*Close*	*Open*	*Open +30 Minutes*	*Last 30 t*	*First 30 t + 1*	*Last 15 t*	*First 15 t + 1*
820617	820618	107.77	107.60	107.60	107.37	−0.158	−0.214	−0.009	−0.139
820916	820917	123.85	123.77	123.76	123.27	−0.065	−0.396	0.081	−0.242
821215	821216	135.43	135.24	135.22	135.69	−0.140	0.348	0.044	0.259
830317	830318	149.54	149.59	149.59	149.86	0.033	0.180	0.027	0.074
830616	830617	169.31	169.14	169.11	168.94	−0.100	−0.101	−0.100	−0.089
830915	830916	164.92	164.38	164.39	164.50	−0.327	0.067	−0.231	0.024
831215	831216	162.25	161.66	161.66	161.96	−0.364	0.186	−0.210	0.136
840315	840316	157.84	157.41	157.46	160.10	−0.272	1.677	−0.241	0.845
840615	840618	149.57	149.03	149.02	148.81	−0.361	−0.141	−0.268	−0.268
840921	840924	166.40	165.67	165.67	165.99	−0.439	0.193	−0.072	0.109
841221	841224	164.65	165.53	165.50	165.98	0.534	0.290	0.133	0.290
850315	850318	177.97	176.53	176.53	177.03	−0.809	0.283	−0.563	0.317
850621	850624	188.02	189.61	189.50	187.93	0.846	−0.828	0.021	−0.649
850920	850923	182.96	182.05	182.12	184.60	−0.497	1.362	−0.328	1.065
851220	851223	210.60	210.94	210.94	210.00	0.161	−0.446	0.200	−0.465

are examined in the hour ending 4 p.m. and in the 15 minutes ending 4 p.m.

Tables VII and VIII provide data on the S&P 500 level 30 minutes before the close, at the close, at the next day's open and 30 minutes after the next day's open for each index futures and index option expiration day. Corresponding 30-minute returns and 15-minute returns are calculated. Some of the percentage price changes are substantial in the last 30 minutes of some of the more recent S&P 500 futures expirations. For example, the Mar/85 and Jun/85 contract expirations saw the S&P 500 change by −0.809 per cent and 0.846 per cent, respectively. However, earlier futures and option expirations are less dramatic. Furthermore, not all the expiration-day price changes are reversed the following day, which suggests that information is responsible for some of the price changes observed.

The data in Tables VII and VIII are used to estimate the magnitude of reversals in Table IX. We first use the measure REV_0, defined above. Over the first eight S&P 500 futures expirations, the average reversal as measured by REV_0 is 0.173 per cent. Over the seven more recent futures expirations, the average reversal is 0.383 per cent, which is nearly identical to the average last-hour reversal reported in Table V for the most recent 10 futures expiration days. (This is a

Table VIII Rates of Return on the S&P 500 Index During the Last Minutes of S&P 100 Index Option Contract Expiration Day and the Opening Minutes of the Day after Expiration (March 18, 1984 through December 31, 1985)

		Index Level				*Rates of Return*			
Exp. Date (t)	*Day After (t + 1)*	*Close −30 Minutes*	*Close*	*Open*	*Open +30 Minutes*	*Last 30 t*	*First 30 t + 1*	*Last 15 t*	*First 15 t + 1*
840419	840423	157.83	158.02	158.02	158.02	0.120	0.000	0.184	−0.057
840518	840521	155.30	155.77	155.80	155.99	0.303	0.122	0.225	0.019
840720	840723	149.15	149.55	149.55	147.91	0.268	−1.097	0.268	−0.822
840817	840820	164.11	164.14	164.14	163.90	0.018	−0.146	0.091	−0.085
841019	841022	167.60	167.96	167.96	167.46	0.215	−0.298	0.305	−0.363
841116	841119	164.51	164.10	164.17	164.23	−0.249	0.037	−0.110	0.085
850118	850121	171.00	171.32	171.31	171.74	0.187	0.251	0.216	0.152
850215	850219	181.63	181.60	181.61	181.10	−0.017	−0.281	0.177	−0.270
850419	850422	180.83	181.11	181.11	180.98	0.155	−0.072	0.094	0.050
850517	850520	187.90	187.42	187.50	189.33	−0.255	0.976	−0.181	0.779
850719	850722	194.65	195.13	195.13	194.48	0.247	−0.333	0.221	−0.323
850816	850819	186.76	186.12	186.14	186.46	−0.343	0.172	−0.118	0.134
851018	851021	187.19	187.04	186.98	187.08	−0.080	0.053	0.016	0.021
851115	851118	198.01	198.11	198.11	198.16	0.051	0.025	0.056	−0.056

Table IX Percentage Rate of Return Reversals in the First 30 Minutes of the Day Following Expiration Day as Compared with the Last 30 Minutes of Expiration Day (using the S&P 500 price levels from June 17, 1982 through December 20, 1985)

Type of Expiration Day	*Number of Days*	*Number of Reversals*	*Average Type 0 Reversal, REV_0*	*Average Type 1 Reversal, REV_1*	*Average Type 2 Reversal, REV_2*	*Number of Type 1 Reversals Greater than 0.25%*
S&P 500 Futures Expiring on Thursday	8	4	0.173	0.285	0.276	2
S&P 500 Futures Expiring on Friday	7	5	0.383	0.445	0.550	4
S&P 100 Options Only Expiring	14	9	0.179	0.227	0.203	4

coincidence, because different time periods and different data sets are used.)

The average reversal for option expirations is 0.179 per cent, which is 0.08 per cent greater than the corresponding number reported in Table V. This may be attributable to the use of returns defined over the last half-hour, rather than the last hour, and to the difference in the number of observations (14 rather than 16). It should also be noted that most option reversals result from price increases at the end of the day on Friday followed by price decreases at the beginning of the day on Monday (see Table VIII). This pattern is typical of all Fridays and Mondays and amounts to a reversal of about 0.10 per cent.[6] Net of this "normal" effect, the reversal associated with option contract expirations is insignificant. In the case of futures contract expirations, however, reversals tend to be associated with price declines on Friday and price recoveries on Monday—the opposite of the "normal" pattern (see Table VII).

The number of reversals and two other measures of reversal are also presented in Table IX. We define a Type 1 reversal as follows:

$$REV_{1t} = |R_{t+1}| \quad \text{if } \text{sign}(R_t) \neq \text{sign}(R_{t+1}),$$

$$REV_{1t} = 0 \text{ otherwise.}$$

As in the case of REV_0, the magnitude of the reversal is based on the second-day return. However, if R_t and R_{t+1} are of the same sign (i.e., if no reversal has occurred), REV_1 is assigned the value zero, whereas REV_0 would have a negative value. REV_1 overstates the price effect somewhat, because price reversals due to new information (unrelated to the expiration) are fully reflected, whereas the failure of prices to reverse because of new information is not reflected.

Suppose, for example, that the return in the last half-hour of day t is -0.4 per cent and that the return in the first half-hour of day $t+1$ is 0.9 per cent—0.4 per cent being a price reversal and 0.5 per cent being new information. The reversal is measured as 0.9 per cent by REV_0 and REV_1. But what if the return on day $t+1$ is -0.1 per cent, 0.4 per cent being a reversal and -0.5 per cent reflecting new information. The reversal is measured as -0.1 per cent (a continuation) by REV_0 and as zero by REV_1.

The average values of REV_0 and REV_1 respectively are 0.40 per cent and 0.45 per cent. If the average value of new information arriving in the second period is zero, and if the variance of returns due to new information is not too large, REV_0 and REV_1 each provide an accurate measure of the price effect; if the variance of returns due to new information on day $t+1$ is large, REV_1 will overstate the effect relative to REV_0.

We define a Type 2 reversal as follows:

$$REV_{2t} = |R_t| \quad \text{if } \text{sign}(R_t) \neq \text{sign}(R_{t+1}),$$

$$REV_{2t} = 0 \text{ otherwise.}$$

Conditional on a reversal, this measure uses the first-period price change rather than the second-period price change used for the Type 1 reversal. It has some of the same drawbacks as the Type 1 reversal. If the price change on the first day conveys information, this measure tends to overstate the amount of a price pressure effect as distinguished from an information effect. But it does convey information about the price change on the expiration day.[7]

Table IX presents average values of REV_0, REV_1 and REV_2 based on the data in Tables VII and VIII. The average values of REV_1 and REV_2 are similar in magnitude and, as expected, exceed somewhat the average value of REV_0. The Type 1 reversal averages 0.445 per cent over the seven Friday expirations. Four of the seven

Friday futures expirations experience Type 1 reversals in excess of 0.25 per cent (approximately one-half the bid-ask spread on the underlying index). Only two Thursday futures expiration reversals are this large, and only four of 14 options-only expiration reversals are as large.

Economic Significance

The economic significance of the price effect as reflected in the reversal must be evaluated against some standard and ultimately against the cost of eliminating the effect. The bid-ask spread on the index is approximately 0.5 per cent. On a normal day, one might expect half the stocks in the index to be trading at the bid and half the stocks to be trading at the ask, so that the index price represents a price midway between the bid and the ask. If an arbitrage unwinding necessitates the simultaneous sale of the stocks in the index, all the stocks will sell at the bid price on the floor of the stock exchange. This price would be approximately 0.25 per cent below the previous transaction price and would therefore imply a price effect of 0.25 per cent. Thus a substantial portion of the average price reversal of about 0.4 per cent observed in quarterly Friday expirations can be explained by the normal price impact of trading. Traders unwinding positions before maturity, when a greater incentive exists to minimize price effects, expect to induce price effects of this magnitude.

Price reversals in excess of those on futures expiration days are frequently observed in block transactions. Kraus and Stoll find an average price reversal of 0.71 per cent in block sales in excess of $1 million in the period 1968–69.[8] Holthausen, Leftwich and Mayers find a comparable effect for the largest block sales on each of 228 trading days in 1982.[9] Large blocks are defined in terms of normal volume, company size or absolute dollar value. When the largest block on each day is chosen on the basis of size relative to normal daily volume in the stock, an average price reversal of 1.11 per cent is observed. However, block transactions do not necessarily occur simultaneously in many stocks, other than on expiration days. What is different about expiration days is that price pressure in the same direction occurs in a large number of stocks and is therefore reflected in the index.

Neither the price effects on expiration days nor the price effects of block transactions are desirable. They reflect the cost of trading large amounts of stock quickly—a cost that might be avoided in an operationally more efficient market. Unknowing investors might be adversely affected by temporary price changes associated with block transactions or futures expirations if they sell at a temporary trough or buy at a temporary peak. Most temporary price moves tend to be brief, however. Furthermore, expiration days, in contrast to block transactions, have the advantage of being predictable.

Implications

The price effects associated with expiration days are undesirable (as are the price effects associated with block trades), but the seriousness of the price effects must be evaluated in terms of who is hurt by the effect and what the cost of some alternative solution would be. The empirical evidence indicates that the effect is concentrated in a very short period of time, sometimes in the last 15 minutes of trading. Unknowing traders who appear with market orders to sell when an expiration is pushing prices down, or who arrive with market orders to buy when an expiration is pushing prices up, may be hurt. The expiration day phenomenon has the advantage of occurring at a predictable time, giving investors the option of staying away.

Unfortunately, predictability of the expiration has not been accompanied by predictability of the direction and magnitude of order imbalances on the expiration day. Current efforts by the Securities and Exchange Commission and the exchanges to find cost-effective operational procedures for handling unexpected order imbalances on the stock market are desirable. ■

Footnotes

1. A number of papers have examined the relation between index futures and the underlying index. See, for example, B. Cornell and K. French, "Taxes and the Pricing of Stock Index Futures," *The Journal of Finance*, June 1983; S. Figlewski, "Explaining the Early Discounts on Stock Index Futures: The Case for Disequilibrium," *Financial Analysts Journal*, July/August 1984. A corresponding relation exists for index options. In the case of American options that can be exercised before maturity, only upper and lower arbitrage bounds can be established. Index futures, rather than index options, are emphasized in this article be-

cause most arbitrage activity and most price effects are associated with the index futures. See the complete study, H.R. Stoll and R.E. Whaley, *Expiration Day Effects of Index Options and Futures*, Monograph Series in Finance and Economics, Monograph No. 1986-3 (New York: New York University, March 1987).

2. The assumed 0.5 per cent relative bid-ask spread likely understates the market impact cost of trading the entire S&P 500 index portfolio. In "Transaction Costs and the Small Firm Effect," *Journal of Financial Economics*, June 1983, H.R. Stoll and R.E. Whaley reported that, when firms on the New York Stock Exchange were arranged from largest to smallest according to the market value of common equity, the average relative bid-ask spread for the decile of largest firms was 0.69 per cent during the period 1960 through 1979 and that the average relative bid-ask spread increased monotonically as firm size decreased. Considering that the decile of largest firms on the NYSE comprises about 40 per cent of the S&P index and that the remaining 60 per cent are smaller firms listed on the NYSE, it is likely that the relative bid-ask spread for the S&P 500 index portfolio is on the order of 0.69 per cent or higher.
3. See, for example, Goldman Sachs, "The Handbook of Stock Index Arbitrage," and Morgan Stanley, "Trading Strategies for Stock Index Products."
4. See Commodity Futures Trading Commission, *Annual Report*, 1985.
5. We also examined daily rates of return based on closing prices and rates of return earlier in the day, but it became clear that those effects that existed were to be observed in the last hour of the day.
6. See L. Harris, "A Transaction Data Study of Weekly and Intradaily Patterns in Stock Returns," *Journal of Financial Economics*, May 1986.
7. The reader is free to construct alternative measures of reversal. Two additional measures might be constructed. The first is:

   $REV_{3t} = \min(|R_t|, |R_{t+1}|)$ if $\text{sign}(R_t) \neq \text{sign}(R_{t+1})$,

   $REV_{3t} = 0$ otherwise.

   This measure takes account of the fact that a reversal in excess of the initial price change may reflect new information, not merely price impact. This measure is downward-biased because offsetting new information in the second period may limit a reversal that might otherwise have been observed. The second measure is:

   $REV_{4t} = \max(|R_t|, |R_{t+1}|)$ if $\text{sign}(R_t) \neq \text{sign}(R_{t+1})$,

   $REV_{4t} = 0$ otherwise.

   This measure is upward-biased because new information that may exaggerate a price change in the first or second period is treated as part of the reversal.
8. See A. Kraus and H.R. Stoll, "Price Impacts of Block Trading in the NYSE," *Journal of Finance*, June 1972.
9. See R. Holthausen, R. Leftwich and D. Mayers, "Block Trades of Securities and the Price Pressure Hypothesis" (Working paper, Graduate School of Business, University of Chicago, October 1985).