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Program Trading and Individual Stock Returns: Ingredients of the Triple-Witching Brew*

The price and trading volume behaviors of individual stocks in the Standard and Poor's 500 Stock Index (S&P 500) are analyzed on stock index futures expiration days, a time when the market is known to be subject to heavy program trading. The price behavior of stocks that are subject to program trading is shown to be very similar to stocks that are not. Stocks that decline in price in the last half hour Friday tend to increase in price at the opening on Monday and vice versa. The Monday reversal as a fraction of the Friday price change is only slightly higher for the S&P 500 stocks than for non-S&P 500 stocks, indicating that the price reversals reflect, for the most part, the bid-ask spreads of the individual stocks. Trading volume in the last half hour of expiration days is shown to be substantially higher than normal.

The effect of financial innovations such as stock index futures and options on stock market volatility has received a great deal of attention recently. Many important aspects of this issue have been eloquently analyzed by Merton Miller in a variety of writings and speeches.[1]

One focus of attention has been program trading in the last hour of the day on the quarterly expirations of stock index futures, stock index options, and stock options—the so-called triple witching hour.[2] On expiration days, index arbitrage positions are unwound at the closing of trading by selling (or buying) the index portfolio stocks.[3] This program trading causes abnormal

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1. See, e.g., Miller (1987). Market structure issues are analyzed in Grossman and Miller (1986, 1988).

2. The price and volume effects on expiration days have been analyzed in some detail by Stoll and Whaley (1986, 1987).

3. Stock index futures contracts are settled in cash at the level of the underlying index when the futures contract expires. To unwind an index arbitrage position at expiration therefore requires that the underlying stock portfolio be liquidated with market-on-close orders on the expiration day.

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trading activity in the stock market. Stoll and Whaley (1986, 1987) measure the aggregate price and volume effects of stock index futures and options expirations in the stock market. They find that, although the aggregate volume of stock market trading in the triple witching hour is approximately twice the normal volume of trading during the last hour, the average price effect, as measured by the extent to which the S&P 500 Stock Index reverses in the first half hour on the day after the expiration day, relative to the price change in the last hour of the expiration day, is only 0.38% of the closing index price. While this price effect pales in comparison to price moves like those experienced on recent nonexpiration days (e.g., October 19, 1987), the triple witching hour offers a rare opportunity to study the effects of noninformation events. The price effects on expiration days are due, not to information, but to trading imbalances.

The price and volume effects on triple-witching days reported by Stoll and Whaley apply to market averages. Market averages, in turn, are a brew reflecting the behavior of many individual stocks. In this article, the ingredients of that brew—the behavior of individual stocks on days when the market averages are subject to a trading shock—are analyzed.[4] Such an analysis is important. If the nature and magnitude of price effects in index stocks is the same as that of stocks not in the index, expiration-day price effects may only reflect normal movements between bid and ask prices. The evidence reported here suggests that, in large part, this is the case. While prices of index stocks tend to change in the same direction, the nature and magnitude of the price changes is like that of nonindex stocks and is consistent with the normal price effects of the execution of transactions.

This article focuses on the 11 quarterly expirations of S&P 500 index contracts in the period June 1984–December 1986. During this period all index futures and options settled at the Friday closing index price (as calculated from the prices of the component stocks of the indexes). Prior to this time, index futures and options contracts expired on various days during the contract month and, after this time, expiration procedures were modified so that certain contracts expired at the opening price on Friday. Concern about expiration days has diminished since the move to the Friday opening, but controversy about program trading continues. Expiration days provide an excellent laboratory for assessing the impact of program trading.

This article is organized as follows. In Section I, the data that form the basis of the analysis are described. Price and volume information for individual stock transactions on the New York Stock Exchange

4. Stoll and Whaley (1986) infer the behavior of S&P 500 stocks in comparison to non-S&P 500 stocks from the S&P 500 Stock Index and the NYSE Index, but they do not examine individual stocks.

(NYSE) is used. In Section II, trading-volume data of index and non-index stocks are analyzed. Since expiration effects are most commonly associated with the expiration of the S&P 500 index futures—the most actively traded index futures—and not with the expiration of index options or other index futures, the index/nonindex categorization refers to the stocks of the S&P 500 index and to non-S&P 500 stocks, respectively. Section III contains a description of how price effects are measured. Whether price changes are the result of new information or are due to the transaction-cost frictions of a market is typically measured by the degree to which prices rebound (or reverse) after a transaction. The movement between the bid and ask reflects that rebound, as does the price rebound after a block transaction.[5] In the context of program trading on expiration days, a reversal refers to a change in the direction of the price movements from expiration Friday closing to Monday opening, that is, to the fact that the closing price Friday was temporarily "out of line." Section IV contains the empirical results of the stock reversal measurements. The results indicate that the reversals observed are less than the reversal observed around large block transactions (see Holthausen, Leftwich, and Mayers 1987) and are roughly as large as the bid-ask price effects observed in normal transactions. In addition, the results show that the magnitude of the reversal is not uniform across the stocks within the S&P 500, indicating that program trading is not unilaterally dominating stock market trading during the triple witching hour. In Section V, factors affecting stock reversals are considered. The magnitude of the stock return in the last half hour Friday is shown to have an important effect on the size of the return reversal; however, the magnitude of stock's reversal does not depend on its relative volume of trading at the Friday close. The article concludes in Section VI with a summary.

I. Data

Individual stock transaction prices and volumes for all NYSE stocks during the period 1982 through 1986 were obtained from Francis Emory Fitch. From this file, transactions for all NYSE stocks for the 11 quarterly index-futures-expiration Fridays in the period June 1984–December 1986, as well as for the Mondays immediately after the

5. The literature on transaction-cost-induced price changes and the role of market microstructure in price variability is voluminous. For an overview of the literature and an excellent analysis of the way alternative trading systems provide market liquidity at minimum cost, see Grossman and Miller (1986). For a model of market liquidity and its implication for price reversals as measured by the serial covariance of successive price changes, see Grossman and Miller (1988). Recent years measuring the price reversals of movements between the bid and ask are Roll (1984), Glosten and Harris (1986), and Stoll (1987). Price reversals associated with large transactions are examined in Kraus and Stoll (1972), Scholes (1972), and Holthausen, Leftwich, and Mayers (1987).

expiration days, are taken. In addition, a control group consisting of the transactions for all NYSE stocks on 11 nonexpiration Friday/Mondays are gathered. The 11 Friday/Monday nonexpirations are the 11 weekends 2 weeks prior to the expiration weekends.

In the analyses to follow, NYSE stocks are frequently categorized into S&P 500 and non-S&P 500 subsamples on each of the 11 expiration days and the 11 nonexpiraton days. S&P 500 stocks are identified on each of the 22 days using various issues of the monthly publication *Standard and Poor's "500" Information Bulletin*. Because some stocks in the S&P 500 are not listed on the NYSE, the number of index stocks analyzed is slightly less than 500.

Finally, one exclusionary criterion was applied to the sample data. Because much of the subsequent analysis is carried out using stock returns rather than price changes and because stocks with very low prices tend to produce return outliers, any stock with a Friday closing prices less than $3.00 on the expiration day is excluded from the analysis for that day and the following Monday. The criterion was not particularly restrictive in the sense that only 38 stocks, on average, were eliminated on each of the 22 weekends examined in this study.

II. Triple-Witching-Hour-Volume Effects

The first examination of triple-witching-hour effects focuses on trading volume. If large stock positions from index arbitrage are being carried into the futures contract expiration day and are being unwound with market-on-close orders, the volume of trading in index portfolio stocks should be abnormally high at the close of trading on expiration days.

To test this proposition, the total trading volume for each stock in the last half hour of expiration Friday and the first half hour of the subsequent Monday morning are computed and expressed as a proportion of the stock's total trading volume on Friday and Monday.[6] The proportions are then averaged across all stocks in the S&P 500 and across all non-S&P 500 stocks for all contract expirations. The results are reported in table 1. Also reported in table 1 are similar values computed for the 11 nonexpiration-day control group, although only the averages across all of the nonexpiration days are shown.[7]

Table 1 documents several interesting aspects of triple-witching-hour trading-volume behavior. First, the volume of trading at the close of expiration day is considerably higher than normal. If trading volume were distributed evenly across Friday and Monday, approximately 4%

6. The emphasis in this article is on the price and volume behavior of individual stocks in the last half hour of the expiration day because Stoll and Whaley (1986) show that most of the abnormal behavior is concentrated in that interval.

7. Day-by-day statistics are available from the authors.

TABLE 1 **Average Proportion of Friday/Monday Dollar Trading Volume Accounted for in the Last Half Hour on Friday and the First Half Hour on Monday for NYSE Stocks on S&P 500 Index Futures Contract Expiration Days June 1984–December 1986**

	S&P 500 Stocks*				Non-S&P 500 Stocks†			
Friday Date	No. of Stocks	Average Trading Volume per Stock‡ (in Thousands of Dollars)	Last Half Hour Friday $\bar{V}_0$§	First Half Hour Monday $\bar{V}_1$§	No. of Stocks	Average Trading Volume per Stock‡ (in Thousands of Dollars)	Last Half Hour Friday $\bar{V}_0$§	First Half Hour Monday $\bar{V}_1$§
Expiration days:‖								
1984:								
June 15	467	9,572	.043	.081	1,010	1,300	.033	.129
September 21	463	12,214	.064	.088	1,022	1,412	.044	.114
December 21	456	8,730	.135	.089	992	1,147	.057	.128
1985:								
March 15	457	11,655	.150	.079	1,008	1,505	.046	.134
June 21	461	13,441	.237	.069	991	1,802	.052	.126
September 20	455	12,451	.165	.124	1,004	1,628	.045	.155
December 20	457	16,914	.202	.058	1,004	2,447	.119	.113
1986:								
March 21	459	22,838	.220	.076	1,021	3,364	.214	.081
June 20	458	18,262	.249	.066	1,009	2,476	.212	.077
September 19	457	18,411	.211	.069	1,002	2,007	.153	.096
December 19	457	27,262	.338	.058	1,034	2,690	.162	.079
Mean	459	15,614	.183	.078	1,009	1,980	.103	.112
Nonexpiration days:#								
Mean	459	14,002	.041	.085	1,010	1,996	.038	.121

* S&P 500 stocks trading on the NYSE on expiration/nonexpiration days.

† Non-S&P 500 stocks trading on the NYSE on expiration/nonexpiration days.

‡ Total dollar trading volume for each stock is defined as the sum of all shares traded on Friday times the closing price Friday and all shares traded on Monday times the opening price Monday.

§ $\bar{V}_0$ is the average proportion of total Friday/Monday trading volume accounted for in the last half hour Friday. $\bar{V}_1$ is the average proportion of total Friday/Monday trading volume accounted for in the first half hour Monday.

‖ The 11 expiration days are the days on which the S&P 500 index futures contract expired at the close of trading on the third Friday of the futures contract month.

\# The 11 nonexpiration days used as the control group are the 11 Fridays, each 2 weeks prior to an expiration Friday.

of the volume would be traded in each half hour.[8] Note that this is the case in the last half hour of trading on nonexpiration Fridays when index stocks trade 4.1% of 2-day volume and nonindex stocks trade 3.8% of 2-day volume. On expiration days, however, S&P 500 stocks averaged 18.3% of their 2-day volume in the last half hour of Friday, over four times the normal level.

Second, for S&P 500 stocks, the average proportion of trading accounted for in the last hour Friday, $\bar{V}_0$, increases dramatically from a normal level of 4.3% for the June 1984 contract expiration to a level of over 33% for the December 1986 expiration. Moreover, over the same time period, the average dollar trading volume per stock for the 2-day period increased from \$9.5 million to over \$27.2 million. Clearly, program trading related to the expiration of the S&P 500 futures contract has had an important impact on the volume of trading of S&P 500 stocks, and the effect has become more pronounced as the level of index arbitrage activity has increased.

Third, index arbitrage activity appears also to have had an impact on the trading activity in non-S&P 500 stocks. Table 1 shows that volume in non-S&P 500 stocks—stocks not subject to S&P 500 index arbitrage trading—was also above normal on the recent expiration days, averaging 10.3% of 2-day volume and ranging from 3.3% at the June 1984 expiration to 21.4% at the March 1986 expiration. This may reflect some program trading activity in the broader-based NYSE and Value Line indexes or, perhaps, portfolio-balancing transactions associated with program trading in S&P 500 stocks.

Finally, the average proportional trading volume in the first half hour Monday morning following the expiration day, $\bar{V}_1$, is not meaningfully different from the trading volume experienced in the first half hour on any Monday. In general, Monday mornings have greater trading volumes than Friday afternoons, as is evidenced by an average 8.5% Monday to 4.1% Friday for S&P 500 index stocks and an average 12.1% Monday to 3.8% Friday nonindex stocks on nonexpiration days, respectively. However, the Monday expiration-day trading volumes are not different from the Monday nonexpiration-day trading volumes in any meaningful way. On the Mondays following the expiration day (nonexpiration day), the S&P 500 stocks had an average trading volume of 7.8% (8.5%) and the non-S&P 500 stocks, 11.2% (12.1%). This suggests that positions assumed in the last half hour on expiration Friday are not liquidated immediately on the following Monday morning.

8. On September 30, 1985, stocks on the NYSE and the equity index futures contracts trading on the various futures exchanges began trading at 9:30 A.M. (EST) as opposed to the traditional 10:00 A.M. As a result of the half-hour increase in the length of the trading day (from 6 to 6.5 hours), the anticipated (uniform) rate of trading volume per half hour dropped from 4.4% to 3.8%.

III. Measuring Price Effects

The trading-volume figures clearly show that abnormal trading activity occurs in the stock market during the triple witching hour. More important than trading-volume effects, however, are price effects. Does the abnormal trading activity lead to abnormal price movements, and is the magnitude of the price changes above the level expected due to transaction costs?

To answer these questions, a measure of price effects is necessary. One way of measuring price effects is to examine whether prices reverse after the event of interest. In this study, reversals are based on returns of NYSE stocks up to and after the futures contract expiration instant on the 11 expiration days. The return up to the expiration instant is defined as the stock's rate of return during the last 30 minutes of the expiration day,

$$R_{0,i} = \frac{P_{\text{close},i} - P_{\text{close}-30,i}}{P_{\text{close}-30,i}}, \tag{1}$$

and the return after expiration is defined as the stock's rate of return from expiration Friday close to Monday morning open,

$$R_{1,i} = \frac{P_{\text{open},i} - P_{\text{close},i}}{P_{\text{close},i}}. \tag{2}$$

The actual prices used in the computation of returns are as follows: $P_{\text{close}-30,i}$ is the first price for stock i on the transaction tape after 3:30 and before 3:45 P.M. of Friday, $P_{\text{close},i}$ is the price of the last transaction after 3:45 P.M. on Friday, and $P_{\text{open},i}$ is the stock i price at the time of the opening transaction on Monday morning. If no price is observed for a stock in either the 3:30–3:45 P.M. or the 3:45–4:00 P.M. time interval, it is excluded from the analysis on that day. Where stock splits or dividends occurred between Friday close and Monday open, the return $R_{1,i}$ is appropriately adjusted. Stocks with a return, $R_{0,i}$ or $R_{1,i}$, less than -0.20 or greater than 0.20 are excluded from all analyses (including table 1).[9]

The returns (1) and (2) form the basis of the reversal measure used in this analysis. The reversal measure, REV_i, is defined as

$$REV_i = \begin{cases} R_{1,i} & \text{if } R_{0,i} < 0.0, \\ -R_{1,i} & \text{if } R_{0,i} \geq 0.0. \end{cases} \tag{3}$$

If the stock price rises (falls) during the last half hour Friday and then opens at a lower (higher) level on Monday morning than at the Friday close, REV_i is positive, indicating a reversal. If REV_i is negative, the

9. Over the 11 expiration days, 10 stocks met this exclusion criterion. Over the 11 nonexpiration days, three stocks met the exclusion criterion.

Monday open was higher (lower) than the Friday close, indicating that the price has continued to rise (fall).

The reversal measure (3) is used both at an individual stock and at a portfolio level. At the individual stock level, stock reversals measured using (3) are averaged arithmetically, that is,

$$\overline{REV} = \frac{1}{n}\sum_{i=1}^{n} REV_i, \tag{4}$$

where n is the number of stocks in the sample on the expiration day, to compute an average stock reversal. This measure examines the degree to which individual stock prices reverse following the triple witching hour, without accounting for the fact that stocks may reverse in the opposite directions. The measure $\overline{REV}$ is particularly useful in assessing how the magnitude of the reversal compares to the relative bid-ask spread in the stock market.

A portfolio reversal, on the other hand, is based on the portfolio returns,

$$R_{0,p} = 1/n \sum_{i=1}^{n} R_{0,i} \text{ and } R_{1,p} = 1/n \sum_{i=1}^{n} R_{1,i},$$

and is computed as

$$REV_p = \begin{cases} R_{1,p} & \text{if } R_{0,p} < 0.0, \\ -R_{1,p} & \text{if } R_{0,p} \geq 0.0. \end{cases} \tag{5}$$

Portfolio reversals are used to assess the magnitude of the reversal insofar as all stocks in the portfolio reverse in unison. For example, individual stocks might each have positive reversals, half in one direction and half in the other. In this case, stocks are not moving together, and, while the average stock reversal is positive, the portfolio reversal is zero. Conversely, if all stocks have positive reversals in the same direction, the portfolio reversal could equal or exceed the average stock reversal.

Stock reversals and portfolio reversals include the effect of market drift. If all stock prices increase on Friday and on Monday, returns will not reverse except relative to the mean returns on Friday and Monday. To account for market drift, index reversals are compared to nonindex reversals on the same days. An alternative procedure is to calculate serial dependence in returns relative to the mean returns, something that is done later in this article.

IV. Triple-Witching-Hour Returns and Reversals

The investigation of triple-witching-hour price effects is divided into three parts. First, to assess the magnitude of price effects, reversals of S&P 500 stocks are calculated and compared to reversals of non-S&P

500 stocks on expiration days and to S&P 500 and non-S&P 500 stocks on nonexpiration days. Second, the degree of uniformity of price changes in S&P 500 stocks is examined. If program trading is the dominant cause of price changes, stocks in the S&P 500 index should exhibit less cross-sectional dispersion of returns than nonindex stocks on expiration days or index stocks on nonexpiration days. Third, since program trading is often said to be concentrated in the high-capitalization stocks, differences in reversal patterns according to the market value of stocks in the S&P 500 index are investigated.

A. *Average Reversals*

Table 2 reports average stock returns during the last half hour of expiration Friday, $R_{0,p}$, and from Friday close to Monday open, $R_{1,p}$.[10] The average returns are based on the number of stocks in the sample on that day. Note that many stocks are excluded because they do not have a transaction in each of the last two 15-minute intervals just before the market closed. Even on expiration days where considerable program trading activity is taking place, an average of 96 stocks (363 in table 2 vs. 459 in table 1) from the S&P 500 are excluded for this reason.

In table 2, the average portfolio reversal (REV_p) calculated over the 11 expiration days, is 0.240% for S&P 500 stocks,[11] and the average portfolio reversal of the non-S&P 500 stocks is 0.066%. Neither of these reversals is significantly different from zero at the 5% probability level, so it is not surprising that the difference in the average reversals for the S&P 500 and the non-S&P 500 stocks, 0.0174%, is not significantly different from zero. The average S&P 500 portfolio reversal on expiration days also exceeds the average S&P 500 portfolio reversal on nonexpiration days (by 0.158%), and the average non-S&P 500 portfolio reversal on nonexpiration days (by 0.188%); but these differences are also not statistically different from zero. The mean difference between the portfolio reversal of S&P 500 and non-S&P 500 stocks on expiration days (0.174%) exceeds the mean difference on nonexpiration days (0.030%) by 0.144%, but the difference is again not statistically significant. The evidence indicates that program trading on

10. The signs of the average returns of S&P 500 stocks correspond to the signs of the returns of the S&P 500 index. The index returns may be found in Stoll and Whaley (1986, 1987) and Stoll (1988). Differences between the index returns and the average stock returns do arise because the index is value-weighted and because table 2 excludes stocks that did not trade between 3:30 and 3:45 P.M. and between 3:45 and 4:00 P.M. For December 20, 1985, slight differences in the period over which returns are measured can lead to different results because on that day index returns over the last hour were negative but were positive over the last half-hour.

11. This value is 0.06 less than the average reversal of the S&P 500 index itself over these same expiration days. The average reversal of the S&P 500 on the 11 expiration days is 0.30%. This value may be calculated from the results in Stoll (1988, table 2).

TABLE 2 **Cross-sectional Average Returns and Average Reversals for NYSE Stocks on S&P 500 Index Futures Contract Expiration Days, during the Period June 1984–December 1986**

Friday Date	No. of Stocks	Average Percentage Return $R_{0,p}$*	$R_{1,p}$*	Portfolio Reversal REV_p†	Average Stock Reversal $\overline{REV}$‡
Expiration days, S&P 500 stocks:§					
1984:					
June 15	276	−.246	−.212	−.212	−.046
September 21	317	−.300	−.110	−.110	.060
December 21	371	.323	.184	−.184	.048
1985:					
March 15	374	−.340	.080	.080	.220
June 21	384	.970	−.570	.570	.420
September 20	290	−.520	1.100	1.100	.970
December 20	402	.570	−.031	.310	.130
1986:					
March 21	363	−.560	.260	.260	.500
June 20	402	.980	−.360	.360	.330
September 19	368	.460	.100	−.100	.150
December 19	448	1.670	−.570	.570	.570
Mean	363	.273	−.012	.240	.305
Standard error	. . .	. . .	. . .	.122	.089
Expiration days, non-S&P 500 stocks:§					
Mean	351	.227	−.019	.066	.216
Standard error	. . .	. . .	. . .	.084	.041
Mean difference‖	. . .	. . .	. . .	.174	.089
Standard error of difference¶	. . .	. . .	. . .	.157	.073
Nonexpiration days, S&P 500 stocks:#					

Mean	305	.140	−.113	.082	−.019
Standard error	...	...	...	.103	.039
Nonexpiration days, non-S&P 500 stocks:#					
Mean	299	.146	−.054	.052	.113
Standard error	...	...	...	.082	.028
Mean difference‖	...			.030	−.131
Standard error of difference‖	...	...	...	.047	.053

* Percentage stocks returns are defined as

$$R_{0,i} = \frac{P_{close,i} - P_{close-30,i}}{P_{close-30,i}}, \quad \text{and} \quad R_{1,i} = \frac{P_{close,i} - P_{close,i}}{P_{close,i}},$$

where $P_{close-30,i}$ is the stock price 30 minutes before market close on Friday, $P_{close,i}$ is the stock price at the close Friday, and $P_{open,i}$ is the stock price at the open Monday morning. The average stock (or portfolio) returns $R_{0,p}$ and $R_{1,p}$ are equal weighted averages of the stocks returns.

† The portfolio reversal REV_p is defined as

$$REV_p = \begin{cases} R_{1,p} & \text{if } R_{0,p} < 0.0, \\ -R_{1,p} & \text{if } R_{0,p} \geq 0.0, \end{cases}$$

where

$$R_{0,p} = \frac{1}{n}\sum_{i=1}^{n} R_{0,i}, \quad \text{and} \quad R_{1,p} = \frac{1}{n}\sum_{i=1}^{n} R_{1,i},$$

and where n is the number of stocks in the portfolio.

‡ Average stock reversal is defined as

$$\overline{REV} = \frac{1}{n}\sum_{i=1}^{n} REV_i,$$

where

$$REV_i = \begin{cases} R_{1,i} & \text{if } R_{0,i} < 0.0, \\ -R_{1,i} & \text{if } R_{0,i} \geq 0.0. \end{cases}$$

§ S&P 500/non S&P 500 stocks trading on the NYSE on expiration days.

‖ Mean and standard error are based on the distribution of the 11 expiration-day average returns or return differences.

\# S&P 500/non-S&P 500 stocks trading on the NYSE on nonexpiration days.

expiration days induces a relatively small and statistically insignificant portfolio reversal for the S&P 500 index stocks.

Much can be hidden in the computation of a portfolio reversal, however. As noted earlier, if stocks reverse after the expiration instant, but not all in the same direction, the portfolio reversal may be small while the average stock reversal may be large. The average stock reversal, $\overline{REV}$, for S&P 500 stocks on expiration days is 0.305% and is significantly greater than zero. The mean stock reversal for non-S&P 500 stocks on expiration days is 0.216 and is also significantly different from zero. The fact that the average stock reversal for S&P 500 stocks across expiration days, 0.305%, is greater than the average portfolio reversal, 0.240%, indicates that the S&P 500 stocks did not display uniform price change behavior at the futures contract expiration—an issue to be examined more closely later in this section. The mean difference in reversals is 0.089%, which compares with a "normal" difference of −0.131% on nonexpiration days.[12] The difference in the differences is 0.220%, indicating that the average S&P 500 stock reversal exceeds that of non-S&P 500 stocks by 0.220% more on expiration days than on nonexpiration days.

Both the S&P 500 portfolio reversal of 0.240% on expiration days and the average S&P stock reversal of 0.305% are small when compared to the normal price effects of stock transactions. Roll (1984) estimates a realized spread of 0.51% for an equally weighted portfolio of NYSE stocks, and Stoll (1989) estimates a realized spread of 0.39% from NYSE specialist income data (which implicitly value weights stocks).[13] Both of these estimates exceed the observed reversals during the investigation period. Moreover, the average expiration-day reversals are considerably less than the reversals of large block transactions—about 0.65%, according to Holthausen, Leftwich, and Mayers (1987).

In summary, the average index reversal is clearly quite modest and falls within the bands of normal transaction costs. On occasion, however, substantial portfolio reversals are observed. For example, the December 1986 futures expiration had an S&P 500 portfolio reversal of 1.670, well outside normal transaction cost bands. Price effects deserve closer scrutiny.

12. An average stock reversal is not observed for the sample of nonexpiration days because of a strong positive market trend on one of the weekends. On June 1, 1984, $R_{0,p}$ is 0.68% and $R_{1,p}$ is 0.69%, a strong upward drift that obscures reversals relative to the drift. By comparing index reversals to nonindex reversals, we abstract from the general market drift.

13. Quoted spreads are, of course, higher than realized spreads, with the result that average expiration-day price effects would look small by comparison to quoted spreads. The appropriate comparison is with realized spreads, i.e., the amount actually earned by the specialist. See Stoll (1987).

B. Uniformity of Price Change

Program trading has raised concerns that individual stocks are being traded like undifferentiated bushels of wheat without regard to the earnings prospects and other characteristics that distinguish one stock from another. If program trading of index stocks dominates trading based on idiosyncratic stock characteristics, the cross-sectional variability of returns ought to be less for S&P 500 stocks than for non-S&P 500 stocks and less for S&P 500 stocks on expiration days than on nonexpiration days. The last half hour of expiration Fridays is a time during which program trading is said to dominate the market, as the volume evidence presented earlier suggests, and therefore is an ideal period over which to test whether index stocks exhibit greater than normal uniformity of behavior.

Table 3 contains the cross-sectional variances of stock returns, $R_{0,i}$ and $R_{1,i}$, on expiration days and on nonexpiration days for S&P 500 and non-S&P 500 stocks. The variance estimates indicate that expiration days and program trading do not reduce cross-sectional variability of returns; in fact, surprisingly, cross-sectional variability appears to increase. The cross-sectional variance of returns in the last half hour on expiration days exceeds the corresponding variance on nonexpiration days by a factor of 2.945 in the case of S&P 500 stocks and by a factor of 1.629 in the case of non-S&P 500 stocks. The null hypothesis that the cross-sectional variance of returns during the last half hour Friday is constant across days is clearly refuted. Moreover, the ratio of Friday return variance of S&P 500 stocks to Friday return variance of non-S&P 500 stocks is considerably higher on expiration days, 0.810, than on nonexpiration days, 0.447. Together, these pieces of evidence indicate that price changes of S&P 500 stocks on expiration days are far from uniform.

The lack of uniformity in the price movements of S&P 500 stocks in the triple witching hour can be seen in other ways. In table 4, average stock returns and reversals are reported for extreme deciles of returns during the last half hour of Friday. Several points are worth noting. First, note that the difference between the highest and lowest return deciles for S&P 500 stocks is substantial. The average stock return in the last half hour Friday for the decile of stocks with the highest absolute returns is the opposite sign of the average stock return of the decile at the other extreme for every expiration date. For non-S&P 500 stocks, the difference is even greater, with an average Friday return of 1.500% for the highest decile stocks and an average return of −0.565% for the lowest decile stocks. The effect of program trading is clearly not uniform.

Second, stocks with larger Friday returns have larger Monday reversals. The portfolio of the decile of S&P 500 stocks with the highest

TABLE 3 **Cross-sectional Variance of Returns for NYSE Stocks on S&P 500 Index Futures Contract Expiration Days during the Period June 1984–December 1986**

	S&P 500 Stocks*			Non-S&P 500 Stocks†		
		Variance			Variance	
Friday Date	No. of Stocks	R_0‡	R_1‡	No. of Stocks	R_0‡	R_1‡
Expiration days:§						
1984:						
June 15	276	.066	.071	209	.115	.123
September 21	317	.071	.067	303	.093	.129
December 21	371	.102	.166	301	.138	.143
1985:						
March 15	374	.092	.058	254	.087	.106
June 21	384	.135	.077	320	.077	.086
September 20	290	.052	.132	228	.098	.134
December 20	402	.146	.053	447	.131	.089
1986:						
March 21	363	.222	.156	425	.369	.164
June 20	402	.094	.061	304	.137	.085
September 19	368	.081	.064	320	.113	.101
December 19	448	.240	.079	750	.180	.116
Pooled	3,995	.124	.089	3,861	.153	.116
Nonexpiration days:‖						
1984:						
June 1	267	.052	.085	240	.143	.167
September 7	252	.042	.076	217	.094	.140
December 7	255	.036	.052	241	.125	.233
1985:						
March 1	359	.036	.114	356	.097	.120
June 7	284	.037	.048	300	.072	.085
September 6	270	.045	.046	254	.059	.241
December 6	336	.036	.098	284	.098	.216
1986:						
March 7	359	.058	.041	372	.114	.150
June 6	300	.034	.042	304	.090	.232
September 5	355	.037	.046	350	.096	.119
December 5	320	.045	.050	368	.074	.106
Pooled	3,357	.042	.062	3,268	.094	.158
Ratio of variances	. . .	2.945	1.438	. . .	1.629	.735

* S&P 500 stocks trading on the NYSE on expiration/nonexpiration days.
† Non-S&P 500 stocks trading on the NYSE on expiration/nonexpiration days.
‡ Variance of the cross-sectional returns of the stocks times 1,000.
§ The 11 expiration days are the days on which the S&P 500 index futures contract expired at the close of trading on the third Friday of the futures contract month.
‖ The 11 nonexpiration days used as the control group are the 11 Fridays, each 2 weeks prior to an expiration Friday.

absolute Friday returns has an average portfolio reversal across expiration days of 0.753%. The corresponding extreme portfolio of nonindex stocks has an average portfolio reversal of 0.528%. Neither that difference of 0.225% in extreme portfolio reversals on expiration days nor the corresponding difference of −0.079% on nonexpiration days is statistically significant. In other words, index stocks and nonindex stocks exhibit very similar price patterns. The magnitude of the reversal in extreme deciles in both cases corresponds to the magnitudes observed in large block transactions.

Third, the difference between S&P 500 and non-S&P 500 stocks is reflected in the asymmetric character of the reversals in the top and bottom deciles. Nonindex stocks are symmetric—the bottom decile, like the top decile, exhibits a large price reversal. Index stocks are not symmetric to the same degree. The average reversal in the bottom decile is only 0.236% on expiration days. On expiration days the reversal in the top decile of index stocks (0.753) exceeds the reversal in the top decile of nonindex stocks (0.528), whereas the reverse is true on nonexpiration days. These comparisons imply that index stocks do have a greater tendency to move in the same direction than nonindex stocks (while at the same time the cross-sectional variability remains high).

Taken together, the results in tables 3 and 4 imply that program trading has a surprisingly uneven impact on S&P 500 stocks. While there appears some tendency for S&P 500 stocks to move together on expiration days, the price movements are far from uniform. Cross-sectional variability of returns is higher than normal on expiration days for both S&P 500 and non-S&P 500 stocks, and relatively higher for S&P 500 stocks than for non-S&P 500 stocks.

C. *Price Reversals of Index Stocks Classified by Market Value*

Program trading is sometimes carried out using a basket of stocks from the index—most typically the stocks with the largest market capitalizations. It is possible, therefore, that stocks within the index exhibit different price effects according to the market values of their outstanding stock. Table 5 reports portfolio reversals of four equally weighted portfolios of 10 stocks categorized by market value of the stock's outstanding shares on March 31, 1987. The largest five stocks are grouped as a fifth equally weighted portfolio. Other size categories were also examined but are not reported in the table because the results are qualitatively similar.

The results in table 5 indicate that firm size has little relation to the magnitude of reversals. In the table, each size category exhibits an average portfolio reversal (0.312, 0.248, 0.197, 0.322, 0.207) that is approximately the same size as the reversal for the portfolio of all S&P 500 stocks (0.240 in table 2). Conversely, the market-value stratifica-

TABLE 4 Cross-sectional Average Returns and Average Reversals of Extreme Rate-of-Return Deciles* for NYSE Stocks on S&P 500 Index Futures Contract Expiration Days during the Period June 1984–December 1986

	Highest			Lowest		
	Average Percentage Return			Average Percentage Return		
Friday Date	$R_{0,p}$	$R_{1,p}$*	Portfolio Reversal REV_p	$R_{0,p}$	$R_{1,p}$*	Portfolio Reversal REV_p†
Expiration days, S&P 500 stocks:‡						
1984:						
June 15	−1.680	.210	.210	1.194	−.612	.612
September 21	−2.030	.400	.400	.990	−.606	.606
December 21	2.201	−.109	.109	−1.509	.425	.425
1985:						
March 15	2.110	.380	.380	1.390	−.368	.368
June 21	3.480	1.110	1.110	−.750	.040	−.040
September 20	2.064	1.834	1.834	.530	.700	.700
December 20	3.185	−.537	.537	−1.010	.130	−.130
1986:						
March 21	3.220	1.250	1.250	2.250	−.586	.586
June 20	3.040	−.830	.830	−.739	.220	.220
September 19	2.284	.213	.213	−1.070	.680	.680
December 19	5.070	−1.410	1.410	−.210	−.030	.030
Mean	.741	−.012	.753	.097	−.032	.236
Standard error	. . .	.	.173	. . .	. . .	.128
Expiration days, non-S&P 500 stocks:‡						
Mean	1.500	−.191	.528	.565	.331	.568
Standard error	. . .	. . .	.152	. . .	. .	.117
Mean difference§	. .	. . .	.225	. . .	. .	−.331
Standard error of difference§	. . .	. .	.219	. .	. . .	.217

Nonexpiration days, S&P 500 stocks:‡						
Mean	1.036	−.239	.358	−.498	.003	.058
Standard error	. . .	. . .	.120	. . .	. . .	.117
Nonexpiration days, non-S&P 500 stocks:‡						
Mean	2.110	−.437	.437	−1.468	.349	.349
Standard error	. . .	. . .	.163	. . .	. . .	.204
Mean difference§	. . .	. . .	−.079	. . .	. . .	−.291
Standard error of difference§	. . .	. . .	.128	. . .	. . .	.132

NOTE.—To form the highest and lowest extreme rate of return deciles, stocks are ranked from highest to lowest according to the half hour return on Friday. The 10% of the stocks with the highest absolute returns form the "Highest" decile. The 10% of the stocks with returns at the opposite extreme form the "Lowest" decile.

* The percentage stocks returns are defined as

$$R_{0,i} = \frac{P_{close,i} - P_{close-30,i}}{P_{close-30,i}},$$

and

$$R_{1,i} = \frac{P_{close,i} - P_{close,i}}{P_{close,i}},$$

where $P_{close-30,i}$ is the stock price 30 minutes before market close on Friday, $P_{close,i}$ is the stock price at the close Friday, and $P_{open,i}$ is the stock price at the open Monday morning. The average stock (or portfolio) returns $R_{0,p}$ and $R_{1,p}$ are equal weighted averages of the stocks returns.

† The portfolio reversal REV_p is defined as

$$REV_p = \begin{cases} R_{1,p} & \text{if } R_{0,p} < 0.0, \\ -R_{1,p} & \text{if } R_{0,p} \geq 0.0, \end{cases}$$

where

$$R_{0,p} = \frac{1}{n}\sum_{i=1}^{n} R_{0,i}, \quad \text{and} \quad R_{1,p} = \frac{1}{n}\sum_{i=1}^{n} R_{1,i},$$

and where n is the number of stocks in the portfolio.

‡ The S&P 500/non-S&P 500 stocks trading on the NYSE on expiration/nonexpiration days.

§ The mean and standard error are based on the distribution of the 11 expiration-day average returns or return differences.

TABLE 5 Cross-sectional Average Returns and Average Reversals for Portfolios Formed on the Basis of Market Value of Stock on S&P 500 Index Futures Contract Expiration Days during the Period June 1984–December 1986

	Largest Five		51–60		101–110		251–260		351–360	
Friday Date	$R_{0,p}$	$R_{1,p}$	$R_{0,p}$	$R_{1,p}$	$R_{0,p}$	$R_{1,p}$	$R_{0,p}$	$R_{1,p}$	$R_{0,p}$	$R_{1,p}$
1984:										
June 15	−.445	.493	−.389	−.125	−.024	−.432	.106	−.338	−.339	.501
September 21	−.445	.169	−.532	−.260	−.135	−.225	.000	−.361	−.074	−.386
December 21	.530	.011	−.579	.250	.369	.536	.360	.296	.319	.082
1985:										
March 15	−1.183	.567	−.888	.224	−.576	.054	−.070	−.029	.370	.110
June 21	.430	−.871	1.368	.760	.688	−.401	1.119	−.467	1.303	−.400
September 20	−.425	1.659	−.450	1.224	−.827	1.089	−.306	.789	.457	.882
December 20	.229	−.229	−.218	−.365	−.064	−.135	−.430	−.453	.540	−.106
1986:										
March 21	−1.237	−.498	−1.656	.367	−.845	.512	−.378	.191	1.001	−.286
June 20	1.322	.671	1.404	−.893	.881	−.225	.764	−.277	1.024	−.349
September 19	−.830	.509	.409	.767	.390	.204	.188	−.139	.877	.131
December 19	.710	−.220	1.723	−.524	1.697	−.661	1.417	−.851	1.500	−.466

Mean	−.164	−.006	.017	−.009	.146	.019	.330	−.149	.551	−.026
Mean reversal*	. . .	.312	. . .	.248	. . .	.197	. . .	.322	. . .	.207
Standard error†	. . .	.202	. . .	.188	. . .	.150	. . .	.105	. . .	.115

NOTE.—Categories are derived from ranking the S&P 500 stocks from highest to lowest using their market capitalizations on March 31, 1987. The "Largest Five" category contains the five stocks with the largest market values of stock outstanding; the "51 to 60" category has the 10 stocks with capitalizations ranked 51 through 60; and so on through the remaining categories. The average stock (or portfolio) returns $R_{0,p}$ and $R_{1,p}$ are equal weighted averages of the stocks returns. The percentage stocks returns are defined as follows:

$$R_{0,i} = \frac{P_{close,i} - P_{close-30,i}}{P_{close-30,i}}, \quad \text{and} \quad R_{1,i} = \frac{P_{close,i} - P_{close,i}}{P_{close,i}},$$

where $P_{close-30,i}$ is the stock price 30 minutes before market close on Friday, $P_{close,i}$ is the stock price at the close Friday, and $P_{open,i}$ is the stock price at the open Monday morning.

* The average portfolio reversal across all expiration days, where the portfolio reversal is defined as

$$REV_p = \begin{cases} R_{1,p} & \text{if } R_{0,p} < 0.0, \\ -R_{1,p} & \text{if } R_{0,p} \geq 0.0, \end{cases}$$

where

$$R_{0,p} = \frac{1}{n}\sum_{i=1}^{n} R_{0,i}, \quad \text{and} \quad R_{1,p} = \frac{1}{n}\sum_{i=1}^{n} R_{1,i},$$

and where n is the number of stocks in the portfolio.

† The standard error of the portfolio reversals across expiration days.

tion monotonically orders the average stock returns during the last half hour Friday. The largest five stocks have an average return across expiration days of −0.164% while the stocks ranked 351 to 360 in size have an average return of 0.551%. These results imply that large (small) stocks tend to move together on expiration days; however, the argument that the larger stocks are more severely affected by program trading does not appear to have empirical content.

V. Factors Affecting Reversals

Section IV documents that S&P 500 stocks experience reversals from expiration Friday close to Monday morning open. The magnitudes of the reversals are not large and are not uniform across stocks. Furthermore, the magnitude of the reversal appears to be unrelated to firm size. In this section, the reversal is examined more closely within a regression analysis framework to determine its systematic relation to the magnitude of the return and the volume of trading during the last half hour on expiration Friday.

A. *Serial Dependence in Transaction Returns*

Negative first-order serial dependence in stock returns arises naturally from stock prices moving randomly between bid and ask levels. On expiration days, this negative dependence may increase for the S&P 500 stocks because S&P 500 stock transactions tend to be one side of the market, driving their prices temporarily out of line. To assess the magnitude of the difference in the negative serial covariance, the weekend stock returns, $R_{1,i}$, are regressed on the returns during the last half hour Friday, $R_{0,i}$, that is,

$$R_{1,i} = \alpha_0 + \alpha_1 D_i + \alpha_2 R_{0,i} + \alpha_3 D_i R_{0,i} + \epsilon_i. \quad (6)$$

Note that the regression also includes a dummy variable D_i set equal to one for S&P 500 stocks and zero otherwise. The coefficient α_2 tests whether individual stocks exhibit negative serial dependence in transaction returns, and the coefficient α_3, whether S&P 500 stocks exhibit different negative serial dependence than non-S&P 500 stocks. Separate regressions on nonexpiration days examine whether negative serial dependence is different on expiration days than nonexpiration days. The regression results are reported in table 6.

The results in table 6 are striking. All stocks exhibit strong negative serial dependence that is virtually identical on expiration and nonexpiration days. The average values of the slope coefficient α_2 in the expiration day sample is −0.2306 and in the nonexpiration day sample is −0.2375, with both values being significantly less than zero. In other words, about 23% of the return in the last half hour of Friday tends to be reversed on the following Monday. Stocks with larger Friday returns experience larger Monday reversals, a result that is consistent with the finding that extreme deciles of Friday returns result in larger Monday reversals. Return reversals are a characteristic of markets, independent of futures contract expirations and program trading.

For the expiration day sample, the average α_3 coefficient is -0.0490, indicating that the negative serial dependence in returns is greater for S&P 500 stocks than for non-S&P 500 stocks. However, although the coefficient is negative, it is not significantly different from zero, implying that there is no difference in the first-order serial correlation of the S&P 500 and non-S&P 500 stock returns.

For the nonexpiration day sample, the α_3 coefficient is 0.0550. On nonexpiration days, S&P 500 stocks appear to have less negative serial dependence than other NYSE stocks, perhaps reflecting the fact that S&P 500 stocks have smaller relative bid-ask spreads than other NYSE stocks. But again, the α_3 coefficient is not significantly different from zero, so meaningful interpretation of the coefficient is tenuous at best.

The results for expiration and nonexpiration days can be viewed together. Assuming nonexpiration days characterize the normal relation between $R_{1,i}$ and $R_{0,i}$, the difference in the means of the mean α_3 coefficients, -0.1040, can be viewed as the extraordinary serial dependence of S&P 500 stocks on expiration days. Although the value is negative, the null hypothesis that the serial dependence in S&P 500 stock returns on expiration days is no different from other days cannot be refuted at the 10% probability level.

The intercept terms in table 6 capture effects on Monday returns that are independent of Friday returns—owing to new information or new trading pressures affecting all stocks. In addition, it is possible that the intercept term captures a reversal not captured by the slope term because of a lack of cross-sectional variation in $R_{0,i}$. If that were the case, the intercept for S&P 500 stocks should have a sign opposite the sign of the market return in the last half hour of Friday. In other words, if S&P 500 stocks declined on Friday, they should increase on Monday. To check that possibility, an adjusted mean intercept (and corresponding standard error) is calculated from values of the intercept terms—α_0 and α_1—multiplied by the direction of the market on Friday. The direction of the market is given by the average value of $R_{0,i}$ for S&P 500 stocks (table 2). A negative value would indicate the existence of an additional reversal effect that is common to all stocks. In table 6, the adjusted mean value of α_0, 0.0003, is not significantly different from zero, which implies that non-S&P stocks do not reverse as a group. On expiration days, the adjusted mean value of α_1 is -0.0009 and is statistically significant, which implies the existence of a common reversal S&P 500 stocks.

In summary, all stocks show a tendency to reverse whether or not index futures expire or program trading occurs. On expiration days,

TABLE 6 **Cross-sectional Regressions of Weekend Stock Returns on Returns in the Last Half Hour Friday for S&P 500 Index Futures Contract Expirations during the Period June 1984–December 1986***

$R_{1i} = \alpha_0 + \alpha_1 D_i + \alpha_2 R_{0i} + \alpha_3 D_i R_{0i} + \epsilon_i$

		Parameter Estimates								
Friday Date	No. of Stocks	$\hat{\alpha}_0$	$t(\hat{\alpha}_0)$	$\hat{\alpha}_1$	$t(\hat{\alpha}_1)$	$\hat{\alpha}_2$	$t(\hat{\alpha}_2)$	$\hat{\alpha}_3$	$t(\hat{\alpha}_3)$	$\bar{R}^2$
Expiration days:†										
1984:										
June 15	485	−.0023	−3.70	.0004	.44	−.3961	−6.68	.1497	1.66	.1018
September 21	620	−.0016	2.87	−.0006	.81	.1457	2.56	−.2413	−2.81	.0612
December 21	672	.0025	3.18	−.0004	−.36	−.1745	−2.86	.0967	1.09	.0099
1985:										
March 15	628	.0009	−1.66	.0007	.97	−.1747	−3.06	.1298	−1.77	.0801
June 21	704	−.0018	−3.68	−.0011	1.45	−.2111	−3.86	−.0745	−1.12	.1193
September 20	518	.0051	7.16	.0031	2.89	−.3965	5.42	−.1179	−1.02	.1623
December 20	849	−.0001	−.18	−.0024	−3.57	.0144	.41	−.1246	−2.52	.0413
1986:										
March 21	788	.0008	−1.30	.0011	1.28	−.2628	−9.09	.1358	−2.75	.2188
June 20	706	.0008	1.73	−.0016	2.21	.3183	−8.33	.0363	.65	.2210
September 19	688	.0030	5.97	−.0010	−1.33	.2130	−4.61	−.0156	−.23	.0721
December 19	1,198	−.0021	5.09	.0004	.54	−.2578	−9.97	.0176	.45	.1243

Mean	...	.0002	...	−.0002	...	−.2306	−5.09	−.0490	−.76	.1102
Standard error	...	...	...	...	...	.0355	...	.0351	...	...
Adjusted mean‡		.0003	...	−.0009	...	...	...	...	...	...
Adjusted standard error‡		.0007	...	−.0004	...	...	...	...	...	...
Nonexpiration days:§										
Mean		−.0001		−.0009		−.2375	−3.83	.0550	.41	.0340
Standard error		...		...		.0327	...	.0493	...	...
Adjusted mean‡		−.0002		−.0004		...	...	...	...	...
Adjusted standard error‡		.0009		.0004		...	...	...	...	...
Difference of means‖		...		...		...	...	−.1040	...	...
Standard error of difference‖		...		...		...	...	.0605	...	...

* In the cross-sectional regression, $R_{1,i}$ is the weekend return of stock i, and $R_{0,i}$ is the stock return in the last half hour Friday. Term D_i is a dummy variable equal to one for S&P 500 stocks and zero, otherwise.

† The 11 expiration days are the days on which the S&P 500 index futures contract expired at the close of trading on the third Friday of the futures contract month.

‡ The adjusted mean and adjusted standard error are calculated from the 11 estimated values $\hat{\alpha}_0$ and $\hat{\alpha}_1$ multiplied by the sign of the average return on Friday.

§ The 11 nonexpiration days used as the control group are the 11 Fridays each 2 weeks prior to an expiration Friday.

‖ The mean and standard error are based on the distribution of the 11 expiration-day average returns or return differences.

S&P 500 stocks tend to have slightly larger negative serial correlation than normal, and on nonexpiration days, slightly less. But, neither of these results is statistically meaningful at the 5% probability level.

B. Implied Bid-Ask Spreads

The first-order serial covariances implied by the slope coefficient estimates in table 6 can be used to infer average bid-ask spreads (see Roll 1984 or Stoll 1989). Under the assumption of informationally efficient markets, Stoll shows that the first-order serial covariance in return is

$$\text{cov} = S^2[\delta^2(1 - 2\pi) - \pi^2(1 - 2\delta)], \qquad (7)$$

where S is the proportional bid-ask spread, π is the probability of a price reversal, and $1 - \delta$ is the fraction of the proportional spread by which the price reverses, conditional on a reversal. When $\delta = 0.0$ and $\pi = 0.5$, expression (7) becomes the Roll measure of the implicit bid-ask spread $S = 2\sqrt{-\text{cov}}$.

For each day, $\text{cov}(R_1, R_0)$ is computed cross-sectionally for the sample of S&P stocks and the sample of non-S&P stocks.[14] Next, the Roll measure of the implicit spread is calculated, and the resulting figures are averaged across expiration and nonexpiration days. The implied percentage spreads are as follows:

	Expiration Days	Nonexpiration Days
S&P 500	1.076	.537
Non-S&P 500	1.023	.933

These percentage spreads represent the return to a dealer who bought the sample stocks at the bid price at the Friday close (or sold them at the ask price) and reversed his position at the Monday open. Alternatively, they represent the market impact costs to the investor on the other side. The Roll model assumes a 50% chance that positions are reversed at a profit to the dealer ($\pi = .5$). If the probability of a price reversal is greater on expiration days, the implied spread is reduced. If, for example, $\pi = 1.0$, $S = \sqrt{-\text{cov}}$, which is one-half the Roll measure. Since the implied spreads calculated according to the Roll measure are large relative to the data reported in Roll (1984) and relative to the average reversals reported earlier in this article, it appears reasonable to assume that the probability of reversal is higher on expiration days than on other days.

Whether or not the implied spreads are adjusted downward, they indicate that, on expiration days, the market impact costs of trading index stocks are about the same as the market impact costs of trading

14. For the 44 samples (22 days and two stock categories) 43 out of the 44 covariances were negative.

nonindex stocks. But that implies that expiration days impose temporary price impacts because on nonexpiration days the cost of trading index stocks is nearly half the cost of trading nonindex stocks.

C. Volume Effects

The results of table 6 indicate that the weekend stock return is strongly negatively correlated with the stock return in the last half hour Friday, with the degree of correlation being only slightly, if at all, sensitive to whether or not the stock is a member of the S&P 500. Although membership in the S&P 500 cannot distinguish the degree of negative first-order serial dependence in stock returns, perhaps the relative trading volume of the stock in the triple witching hour can.

To test this proposition, the regression model (7) is modified to exclude the dummies for S&P 500 membership and to include the relative trading volume. The regression model tested is

$$R_{1,i} = \gamma_0 + \gamma_1 R_{0,i} + \gamma_2 R_{0,i} V_{0,i} + \epsilon_i, \tag{8}$$

where $V_{0,i}$ is the proportion of the Friday/Monday trading volume accounted for in the last half hour Friday. If concentrated volume in the triple witching hour accentuates price reversals, one would expect a negative value for the coefficient γ_2. Table 7 contains the regression results.

The results in table 7 show that γ_2 is, in general, positive and has an average value of 0.5381 across all expiration days. Although this value is not significantly different from zero at the 5% level, it appears that high volume leads to better markets and lower price reversals. Alternatively, it is possible that this result would be changed by a more careful analysis of the sequence of volumes, including at opening. Hasbrouck and Ho (1987), for example, emphasize a more complex model of trading behavior that includes longer-term dependencies in prices and volumes than is considered here.

VI. Summary and Conclusions

In this article, the behavior of individual stocks in the S&P 500 index is analyzed on stock index futures expiration days, a time when the market is known to be subject to heavy program trading. Results are compared to results for the same set of stocks on a corresponding number of nonexpiration days. Volume of trading in the last half hour of expiration days is substantially above normal.

The most striking finding is the similarity between the price behavior of stocks that are subject to program trading and of the stocks that are not. All stocks exhibit price reversals that reflect the cost of trading. Stocks that decline in price in the last half hour Friday tend to recover at the opening on Monday. The Monday reversal as a fraction of the

TABLE 7 **Cross-sectional Regressions of Weekend Stock Returns on Returns in the Last Half Hour Friday and the Product of Friday's Return and Trading Volume for S&P 500 Index Futures Contract Expirations during the Period June 1984–December 1986***

$R_{1,i} = \gamma_0 + \gamma_1 R_{0,i} - \gamma_2 R_{0,i} V_{0,i} + \epsilon_i$

		Parameter Estimates						
Friday Date	No. of Stocks	$\hat{\gamma}_0$	$t(\hat{\gamma}_0)$	$\hat{\gamma}_1$	$t(\hat{\gamma}_1)$	$\hat{\gamma}_2$	$t(\hat{\gamma}_2)$	$\bar{R}^2$
Expiration days:								
S&P 500 stocks:†								
1984:								
June 15	276	−.0027	−5.27	−.3211	−3.16	1.2897	.92	.053
September 21	317	−.0022	−4.87	−.5210	−5.90	1.1625	1.85	.159
December 21	371	.0021	2.97	.0129	.09	−.4994	−.70	.000
1985:								
March 15	374	−.0002	−.49	−.3307	−5.25	.1186	0.52	.141
June 21	384	−.0026	−4.96	−.6619	−9.88	1.2119	6.52	.224
September 20	290	.0081	10.39	−.9861	−6.03	2.4543	3.42	.133
December 20	402	−.0025	−6.23	−.1145	−1.66	.0159	.07	.028
1986:								
March 21	363	.0003	.56	−.4835	−4.75	.3562	.90	.225

June 20	402	−.0009	−1.64	−.2264	−2.74	−.1804	−.76	.121
September 19	368	.0020	4.45	−.1301	−1.20	−.4103	−1.00	.064
December 19	448	−.0014	−2.33	−.4086	−5.57	.4000	2.44	.181
Mean	. . .	. . .	. . .	−.3792	−4.19	.5381	1.29	.121
Standard error	. . .	. . .	. . .	.0850	. . .	.2709	. . .	. . .
Expiration days, non-S&P 500 stocks:†								
Mean	. . .	. . .	. . .	−.2274	−2.79	.0108	−.07	.073
Standard error	. . .	. . .	. . .	.0396	. . .	.1653	. . .	. . .
Nonexpiration days, S&P 500 stocks:†								
Mean	. . .	. . .	. . .	−.2110	−2.35	.2189	.58	.026
Standard error	. . .	. . .	. . .	.0246	. . .	.3803	. . .	. . .
Nonexpiration days, non-S&P 500 stocks:†								
Mean	. . .	. . .	. . .	−.2624	−2.69	.2812	.41	.041
Standard error	. . .	. . .	. . .	.0410	. . .	.2830	. . .	. . .

* In the cross-sectional regression, $R_{1,i}$ is the weekend return of stock i, and $R_{0,i}$ is the stock return in the last half hour Friday. $V_{0,i}$ is proportion of the Friday/Monday trading volume accounted for in the last half hour Friday.

† The S&P 500/non-S&P 500 stocks trading on the NYSE on expiration/nonexpiration days.

Friday price change is only slightly higher for the S&P 500 stocks than for non-S&P 500 stocks. Stocks with larger returns in the last half hour of Friday tend to have larger reversals on Monday for both index and nonindex stocks.

The effects of program trading on S&P 500 stocks are apparent in the sample. S&P 500 stocks exhibit an average common reversal of 0.240% following the expiration day, while non-S&P 500 stocks exhibit a common reversal of 0.066 percent. Non-S&P 500 stocks do not move in unison because reversals in one direction for some stocks are offset by reversals in the other direction for other stocks.

That is not to say S&P 500 stocks move in unison during the triple witching hour. Substantial differences in the price behavior of index stocks is observed. When the S&P 500 index declines in price the last half hour of Friday, not all stocks decline; some experience substantial price increases, others decline by more than the index. This reflects the importance of idiosyncratic factors in a stock's return as well as differences in the market-making capacity of different specialists.

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