Expiration-Day Effects of the All Ordinaries Share Price Index Futures: Empirical Evidence and Alternative Settlement Procedures

by
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Abstract:

Stock index futures were the most successful financial innovation of the 1980s. In spite of their widespread use internationally, they continue to be criticised for causing 'aberrations' in the stock market, particularly on expiration days when futures contracts are cash-settled. This paper examines expiration-day effects of the Sydney Futures Exchange's All Ordinaries Share Price Index (SPI) futures and discusses alternative futures settlement procedures. Our investigations indicate that, while index stock trading volume is abnormally high near the close on expiration days, price movements are not different from those observed on other days. In other words, the SPI futures cash settlement at the close appears to have worked well through our sample period. This study also describes and analyses the two basic alternative cash settlement procedures—a single price settlement and an average price settlement.

Keywords:

STOCK INDEX FUTURES; INDEX ARBITRAGE; PROGRAM TRADING; EXPIRATION-DAY EFFECTS; SETTLEMENT PROCEDURES.

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1. Introduction

Stock index futures contracts were, perhaps, the most successful financial innovation of the 1980s. The first contract was the Chicago Mercantile Exchange's S&P 500 futures, which began trading in the US in April 1982.[1] The contract design quickly spread to almost every major financial futures market worldwide—the Sydney Futures Exchange's Australian All Ordinaries Share Price Index futures first traded in 1983; the London International Financial Futures Exchange's FTSE 100 futures in 1984; the Hong Kong Futures Exchange's Hang Seng Index futures in 1986; the MATIF's CAC-40 index futures in 1988; the Osaka Stock Exchange's Nikkei 225 futures in 1988; and DTB's DAX index futures in 1990.

The primary reason for the success of stock index futures markets is that index futures provide a fast and inexpensive means of changing stock market risk exposures internationally. Suppose, for example, that a stock portfolio manager fears a downturn in the US stock market over the next few weeks and wants to eliminate his market risk exposure. Selling S&P 500 index futures is a quicker and cheaper means of eliminating US stock market risk than selling the portfolio's stocks. Moreover, selling futures allows the manager to maintain his exposure to the idiosyncratic risk of the stocks that he has identified as being 'winners'. Alternatively, suppose that an international fund expects the Japanese stock market to race ahead of other stock markets worldwide. The quickest and easiest way to gain exposure to the Japanese stock market is to buy Nikkei index futures. Over time this long futures position can be replaced with direct investment in Japanese stocks, but the stock market purchases can be made in a slower, less costly, and more orderly fashion.

All stock index futures contracts call for cash settlement on the expiration day. Cash settlement eliminates the cost and difficulty of delivering the many individual stocks in the index. Conversely, final settlement of most other futures contracts is by delivery. Sellers of wheat futures are, for example, obliged to deliver wheat if they have not traded out of their contracts before maturity. By contrast, sellers of stock index futures have no obligation to deliver the underlying stocks. The futures position is closed out at the settlement price determined by the rules of the exchange. Until recently, the Share Price Index (SPI) futures settled at the closing price of the All Ordinaries Share Price Index (AOI) on the expiration day of the futures contract. Beginning with the March 1997 contract, the futures has settled at the prices determined in a special call auction market that occurs fifteen minutes after the stock market close.

Index expirations attract considerable attention, primarily because of the large volume of trading, but also at times because of sharp price changes. In the US, the 'triple witching hour' (ie, the last hour of trading on the third Friday of the quarterly month when index futures, index options, and equity options expire simultaneously) attracted considerable attention from exchanges, regulators, and the general public in the mid 1980s. In Australia, the 29 March 1996 expiration

1. Technically speaking, the S&P 500 futures was the first *successful* index futures contract. The Kansas City Board of Trade introduced a futures contract on the Value Line index in February 1982, two months earlier than the CME's S&P 500 contract. The contract had limited success, however, because the Value Line index was geometrically-weighted, undermining the futures contract's effectiveness as a hedging vehicle.

was quite controversial. According to press reports, large sales of stocks, apparently as part of an index arbitrage unwinding, occurred late in the day, causing the AOI to fall by 21 points. In this study, we analyse this expiration along with other recent expirations.

Stock index expirations have been studied in a number of academic papers. Widely known are a series of studies by Stoll and Whaley (1986, 1987, 1990a, 1991) and Stoll (1988) that examine expiration-day effects of US index derivatives. Across all contract expirations since the inception of index futures, they find that the effects are remarkably consistent: index stock trading volume is abnormally high and observed price movements are small and within the bounds of transaction costs. Karolyi (1996) examines Nikkei 225 futures contract expirations, and, like Stoll and Whaley, concludes that the expiration of the Nikkei 225 futures induces abnormal trading volume but economically insignificant price effects.

Another branch of stock index futures research examines the degree to which the stock index futures price and the stock index level are properly aligned through index arbitrage. Papers in this branch of the academic literature include MacKinlay and Ramaswamy (1988), Stoll and Whaley (1990b), Miller, Muthuswamy and Whaley (1994), and Abhyankar (1995). One reason for a divergence of the stock index futures price and the reported stock index level is that stock indexes are usually computed from the last trade prices of the component stocks.[2] Because stocks do not trade continuously, the reported stock index is always a stale indicator of stock index portfolio value. Stock index futures prices, on the other hand, are always current. A second reason for divergence is that transaction costs limit index arbitrage of small price misalignments.

This paper examines expiration-day effects of the All Ordinaries Share Price Index futures and discusses alternative settlement procedures. First, we provide the background on the Australian Stock Exchange's (ASX) All Ordinaries Share Price Index and its derivatives. In section 3, we describe the potential sources of expiration-day price effects. We summarise prior research on expiration effects in section 4. Our methods for measuring empirically the presence of expiration effects are discussed in section 5. The data are briefly described in section 6. Expiration volume effects are analysed in section 7. Our findings as to price effects of the fourteen expirations of the SPI futures between March 1993 and June 1996 are presented in section 8. Alternative settlement procedures are discussed in section 9. The conclusions and recommendations are presented in section 10.

2. Australian Stock Index Futures

The ASX's All Ordinaries Index underlies the Sydney Futures Exchange's index futures contract. The AOI is a value-weighted index of approximately 320 of the ASX's largest stocks that make up over 95% of the market value of all Australian stocks. The index value began at 500 on 31 December 1979 and stood at about

2. A notable exception to this rule is the FTSE-100 index, which is computed on the basis of bid/ask price midpoints.

2330 in October 1996. The value of the index on day *t* is the prior day's closing index value times the change in the market value of the index, that is

$$I_t = \frac{V_t}{V_t^B} I_{t-1}^C,$$

where I_t is the index value on day *t*, I_{t-1}^C is the closing index value on day *t*–1, V_t is the aggregate market value of the stocks in the index on day *t*, and V_t^B is the base aggregate market value of the stocks for the beginning of day *t*. The base value reflects any overnight changes (between *t*–1 and *t*) in the index composition due to delistings, additions, capital changes, and the like.

Futures and options on the AOI have traded on the Sydney Futures Exchange since February 1983 and June 1985, respectively. Current contract specifications are provided in table 1.

Table 1

Specifications of the Share Price Index (SPI) Futures and Futures Option Contracts Traded on the Sydney Futures Exchange

Futures on the All Ordinaries Share Price Index	
Contract Unit	A$25 times ASX All Ordinaries Share Price Index.
Minimum Tick Size	One index point, except on the last trading day when the minimum is 0.1 index points.
Contract Months	March, June, September, December.
Last Trading Day	Last business day of the contract month.
Trading Hours	9.50 a.m. – 12.30 p.m. and 2.00 p.m. – 4.00 p.m. SYCOM[1]: 4.40 p.m. – 6.00 a.m.
Put and Call Options on the All Ordinaries Share Price Index Futures	
Contract Unit	One All Ordinaries Share Price Index futures contract.
Minimum Tick Size	Option prices are quoted at minimum intervals of 0.1 index points.
Contract Months	March, June, September, December plus serial months.
Last Trading Day	Last business day of the contract month.
Striking Price	Set at intervals of 25 index points.
Exercise	May be exercised on any business day up to and including the expiration day.
Trading Hours	9.50 a.m. – 12.30 p.m. and 2.00 p.m. – 4.00 p.m. SYCOM[1]: 4.40 p.m. – 6.00 a.m.

Note: 1. Sydney Computerised Overnight Market.

The SPI futures has a quarterly expiration cycle (ie, March, June, September, December) and expires on the last business day of the contract month. The current minimum tick size is 1.0 index point except for the expiration month when it is 0.1 index point.[3]

3. Sources of Expiration-Day Effects

Expiration-day price effects may arise from a combination of factors including the existence of index arbitrage opportunities, the cash settlement feature of index options and futures, the stock market procedures for accommodating the unwinding of arbitrage positions in the underlying index stocks, and attempts to purposely manipulate prices. This section discusses each of these possibilities.

3.1 Stock Index Arbitrage

Index arbitrage links the price of the futures or option contract to the level of the underlying index. In the absence of transaction costs, the equilibrium relation between the index futures price, F, and the index level, S, is:

$$F = S(1 + r - d), \tag{1}$$

where r is the riskless rate of interest and d is the dividend yield of the stock index portfolio over the remaining life of the futures.[4] If actual prices deviate from this equilibrium (and the magnitude of the deviation exceeds transaction costs), arbitrageurs buy or sell the component index stocks and take an offsetting position in the index futures. If the futures price exceeds the right side of equation (1), for example, arbitrageurs sell index futures and buy index stocks. The simultaneous purchase of the basket of stocks in the index portfolio is called program trading.

3.2 Cash Settlement

Index arbitrage positions are frequently unwound at the expiration of the futures contract. If an index futures expires at the close, the futures self-liquidates through cash settlement at the closing index level. The stock position, on the other hand, must be liquidated through trades in the marketplace. An arbitrageur who is long the underlying stocks and short the index futures contract must sell the underlying stocks at their closing prices. As long as the stocks are sold at the same prices used in calculating the index value for cash settling the futures contract, the arbitrageur exits his position risklessly, independent of the level of the prices at which the stocks are sold. If many arbitrageurs liquidate positions at the same time and in the same direction, price effects are possible.

3.3 Stock Market Procedures

The severity of price effects on expiration day depends in part on the stock market procedures for accommodating order imbalances that may arise when arbitrage positions are unwound. If the underlying market for the index stocks is deep and

3. The minimum tick size of the SPI futures was increased and the contract denomination reduced in 1993. For an analysis of these changes, see Martini and Dymke (1995).
4. Equation 1 assumes that interest and dividends are paid at the maturity of the futures contracts.

if suppliers of liquidity are quick to respond to selling or buying pressure, the price effects of large arbitrage unwindings will be small. If unjustified price effects were known to occur, knowledgeable investors would stand ready to buy underpriced stocks and sell overpriced stocks—actions that would normally limit price effects to fall within the bounds of transaction costs. If market mechanisms are not well designed to offset sudden imbalances, however, the price effects may be substantial. In the case of index futures contracts that settle at the close, arbitrage positions must be unwound at closing prices. In the US, arbitrageurs place market-on-close (MOC) orders, indicating their desire to trade at the closing price, whatever it may be. If large MOC orders are received late in the day and investors to take the other side are difficult to locate, price effects are possible. Modifications in trading mechanisms such as requiring early placement of MOC orders, can reduce the risk of unexpected imbalances at the close.

3.4 Manipulation

Expiration-day stock price effects may also arise from attempts to manipulate stock prices. Such attempts may occur directly in the way an arbitrage position is unwound or indirectly through arbitrage unwindings that benefit other positions. An index arbitrageur who is long stocks and short futures, for example, may try to profit directly by quietly selling a portion of his stocks prior to expiration and then forcefully selling the remaining position at the prices used to determine the futures settlement price. If the futures settlement price (at which the arbitrageur settles the short position) is successfully driven down to a level lower than the average price at which the long position in stocks is sold, the arbitrageur makes a profit in liquidating the arbitrage position. Many index arbitrageurs attempt to do this, not only at expiration but also on days prior to expiration. The risk in this strategy is self-evident: once stocks have been sold without also liquidating the corresponding amount of futures, arbitrageurs are no longer perfectly hedged, and they face basis risk. If stock prices were to rise and the futures contract to close higher, arbitrageurs would lose. This strategy also reduces the number of shares available for sale at the expiration point, consequently reducing the ability to influence the futures settlement price.

An index arbitrageur might engage in indirect manipulation, not to benefit the arbitrage account but to benefit another account. Suppose, for example, a broker is instructed to buy stocks for one account (an order unrelated to index arbitrage) while, at the same time, is unwinding a long-stock/short-futures arbitrage position for another account. By selling the stocks forcefully at the prices used to determine the futures settlement price, the broker may lower stock prices for the benefit of the buyer. No harm is done to the index arbitrage account because the loss due to the decline in stock prices is offset by gain on the long stock index futures position. A broker confident that prices can be forced lower can also benefit by selling index futures or stocks prior to the expected price decline. The manipulation effort will fail and the effect on stock prices will be limited, however, if other knowledgeable investors are standing ready to buy at bargain prices and thereby keep prices from falling.

4. Prior Evidence on Expiration-Day Effects

In the period before June 1987, all US stock index futures and options cash settled at the closing price. Studies of expiration-day effects during this period found large volume effects and small price effects during the last hour of trading on quarterly expiration days (Stoll & Whaley 1986, 1987). Price effects were smaller when options alone expired. Starting with the June 1987 expiration, the CME's S&P 500 futures contract settled at an index value calculated from the opening prices of the component stocks, while the CBOE's S&P 100 index options continued to settle at the close. Stoll and Whaley (1991) analyse the effect of this change in settlement procedures. They find substantial volume effects and small price effects around the time of expiration.

Table 2 summarises the Stoll and Whaley findings.

Table 2

Volume and Price Effects around Quarterly Expirations of the S&P 500 Futures Contract, January 1985 through June 1989

	Number of Observations	Friday Close	Friday Open
Volume[1] Effects			
Pre June 1987			
Expiration Days	9	20.8%	6.6%
Non-Expiration Days	18	8.5%	8.7%
Post June 1987			
Expiration Days	9	9.4%	26.3%
Non-Expiration Days	17	5.5%	8.5%
Price Effects[2]			
Pre June 1987			
Expiration Days	9	0.366%	0.061%
Non-Expiration Days	18	0.124%	–0.002%
Post June 1987			
Expiration Days	9	0.211%	0.281%
Non-Expiration Days	17	0.056%	0.012%

Notes: 1. Volume is the percentage of two-day volume in index stocks trading in the last half hour before Friday close or in the first half hour of trading on Friday morning.

2. Price effects are the percent portfolio reversal in the half hour after expiration.

Source: Stoll and Whaley (1991), tables II, III, V.

In the period before June 1987, when the S&P 500 futures contract expired at the close, volume in the last half-hour before the close averaged 20.8% of two-day volume on expiration days and 8.5% of two-day volume on non-expiration days. After the change, when the S&P 500 futures contract expired at the open, volume at the open averaged 26.3% of two-day volume on expiration days but only 8.5% on non-expiration days. In summary, the volume effects are extraordinary.

Stoll and Whaley measure price effects by the extent to which the S&P 500 index price reverses after the expiration. In the period before June 1987, when the S&P 500 futures contract expired at the close, the average price of the S&P 500 stocks reversed on Monday after the Friday expiration by 0.366%. A reversal is a price decline (increase) followed by a price increase (decline). The reversal on expiration days compares with a reversal of 0.124 on non-expiration days, a net effect of 0.242%. Stoll and Whaley conclude that this effect is within the bounds of trading costs. For example, the minimum bid-ask spread, which is $0.125, amounts to 0.417% of the typical stock price of $35.00.

Switching the expiration to the opening after June 1987 resulted in an observable, albeit small, price effect at the opening: 0.281% on expiration days versus 0.012% on non-expiration days. A price effect was also observed at Friday close, presumably because certain futures and options contracts continued to expire at the Friday close.

Day and Lewis (1988) calculated implied volatilities from index option prices around index options and futures expirations in the period March 1983 to December 1986. They found a noticeable increase in implied volatility around both quarterly and monthly (non-quarterly) expirations.

In an analysis of the behaviour of individual stocks on quarterly expirations in the period before 1986, Stoll and Whaley (1990a) found that stocks in the index behaved like non-index stocks: all stocks exhibited price reversals, but stocks in the index displayed a greater tendency to reverse in the same direction.

The interpretation of expiration-day price effects depends on the standard against which the effects are measured. As Roll (1984) and Stoll (1989) have noted, price reversals are to be expected after transactions as prices move between bid and ask levels. Stoll (1988) compared expiration-day effects with various measures of market impact costs and found that '. . . the average expiration-day price effect is roughly of the same magnitude as the price impact observed in a normal transaction'. Nevertheless, policy makers remain concerned about price effects that are substantially in excess of the average.

Expiration-day effects of index futures contracts in other countries have not been studied to the same degree as those in the US. The only exception is a comprehensive investigation of the Nikkei 225 index futures contract by Karolyi (1996). Applying methodology similar to that used by Stoll and Whaley (1991), Karolyi examines abnormal price and volume effects for Japanese stocks during the period May 1988 through November 1991. Consistent with the Stoll-Whaley findings, Karolyi documents abnormally large trading volume at the point of expiration and small but economically insignificant price effects (about 0.20%).[5]

5. Procedure for Measuring Expiration-Day Effects

We measure two aspects of expiration-day effects: abnormal trading volume and abnormal price movements. Abnormal trading volume is measured by the ratio of

5. It is interesting to note that, in spite of Karolyi's evidence, the settlement of the index futures was moved from the close to the open.

the dollar trading volume in the last half-hour on expiration day to total dollar trading volume on that day. Evidence of abnormal trading activity in the stock market during the last half-hour of the futures contract life would be consistent with index arbitrage unwinding. To measure abnormal price movements, we compute (a) the variance of stock returns on expiration days compared to non-expiration days, and (b) the degree to which index arbitrage unwinding drives stock prices away from their equilibrium levels. A larger variance on expiration days than on other days would reflect the presence of larger price changes. If large price changes are attributable only to unwinding activity, prices should rebound in the opposite direction after the futures contract has expired. We compare price reversals after expirations to price reversals after non-expiration days. In this section, we describe our measurement procedures.

5.1 Abnormal Trading Volume

In this study, *trading volume* of an individual stock is defined as the sum of the dollar values of all trades in a particular interval, that is,

$$\textit{Trading volume} = \sum_{i=1}^{\textit{no. of trades}} \textit{price per share}_i \times \textit{no. of shares}_i. \qquad (2)$$

Daily trading volume is the sum of the dollar values of all trades during the day, from market opening at 10.00 a.m. until market close at 4.00 p.m.[6] *Trading volume at the close* is defined as the dollar value of all trades that occur in the last thirty minutes of trading of that stock. If the stock trades right up until the close at 4.00 p.m., this interval is defined as 3.30 p.m. – 4.00 p.m. Where the stock's last trade is before the close, say, 3.45 p.m., the interval is defined as 3.15 p.m. – 3.45 p.m. *Relative trading volume at the close* is then defined as the ratio of trading volume at the close to total daily trading volume. A relative trading volume figure of 10%, for example, means that 10% of the stock's trading volume took place in the last half-hour of the day. If trading took place at a uniform rate throughout the day, the relative trading volume figure should be 8.33% (ie, thirty minutes divided by six hours).

To measure *abnormal trading volume*, a benchmark for what is 'normal' is needed. In this study, *normal trading volume* is defined as relative trading volume at the close on the days exactly one and two weeks prior to the expiration day. For the March 1993 contract expiration on 31 March 1993, for example, the control group measures are computed for 24 March 1993 and 17 March 1993. To measure abnormal trading activity, we test for a meaningful difference between the average relative trading volume on expiration days and the average relative trading volume on non-expiration days for the same set of stocks.

5.2 Variance of Stock Returns

To determine whether stock index expirations bring increased volatility to the stock market, we calculate the variance of the five-minute return in individual

6. During our sample period, the Australian Stock Exchange (ASX) and the Sydney Futures Exchange (SFE) closed early on four (pre-holiday) expiration days: 12/93, 3/94, 12/94 and 12/95.

stocks on expiration days in comparison to non-expiration days. We also measure the variance of the five-minute return in the SPI futures contract price for expiration and non-expiration days. Five-minute returns are calculated on the basis of the last transaction price in each five-minute interval.[7]

5.3 Individual Stock Reversals

Volatility of stock returns could reflect either new information or unwarranted volatility associated with expirations. New information would cause permanent price changes in stocks, whereas unwarranted volatility would cause temporary price changes.

Temporary price effects are measured by the degree to which stock prices reverse after the futures contract expiration. One measure of reversal is the *individual stock reversal*, which is based on individual stock returns around the close. Stock i's return *before* the close, $R_{b,i}$, is defined as the return over the last thirty minutes of the day, that is,

$$R_{b,i} = \frac{P_{close,i} - P_{close-30,i}}{P_{close-30,i}}, \tag{3}$$

where $P_{close-30,i}$ is stock i's price thirty minutes before the market close on expiration day, and $P_{close,i}$ is stock i's price at the close. Stock i's return *after* the close, $R_{a,i}$, is defined as the return from the close until the following morning's open, that is,

$$R_{a,i} = \frac{P_{open,i} - P_{close,i}}{P_{close,i}}, \tag{4}$$

where $P_{open,i}$ is stock i's price at the open on the following morning. Based on these two stock returns, an *individual stock reversal* is defined as:

$$REV_i = \begin{cases} R_{a,i} & \text{if } R_{b,i} < 0 \\ -R_{a,i} & \text{if } R_{b,i} \geq 0 \end{cases}. \tag{5}$$

The stock reversal REV_i is positive when the sign of the stock return after expiration is the opposite of the sign of the return before expiration, and the stock reversal is negative when stock price movement after expiration continues in the same direction as before.

The *abnormal stock reversal* is measured by using the sample of control group dates described earlier. A normal stock reversal is defined as the stock reversal observed on the days exactly one and two weeks prior to the expiration day. Stock reversals can be expected even on normal days as stock prices bounce between the bid and the ask.[8] To measure the abnormal stock reversal, we test for a meaningful difference between the average reversal on expiration days and the

7. If no trade takes place in an interval, the last transaction price from the preceding interval is used.
8. The tick size is smaller in Australia than in the US (one Australian cent versus US 12.5¢). Although average stock prices are also lower (A$7 versus US$35), the percentage tick size is smaller in Australia and consequently the bid-ask bounce can also be expected to be lower.

average reversal on non-expiration days for the same set of stocks. Average stock reversal is computed as:

$$\overline{REV} = \frac{1}{n} \sum_{i=1}^{n} REV_i \,. \tag{6}$$

5.4 Portfolio Reversal

The average stock reversal may overstate the size of any systematic disruption in the stock market since individual stocks may reverse in opposite directions. The average stock reversal can be positive (because of the bid-ask bounce) without there being a common reversal for all stocks. Unwinding of an arbitrage position requires purchases or sales of portfolios of stocks, which could generate a common reversal. To account for this possibility, we calculate a *portfolio reversal*, defined as:

$$REV_p = \begin{cases} R_{a,p} & \text{if } R_{b,p} < 0 \\ -R_{a,p} & \text{if } R_{b,p} \geq 0 \,. \end{cases} \tag{7}$$

where

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

and n is the number of stocks considered. The portfolio reversal would normally be less than the average stock reversal but would equal the average stock reversal when all stocks reverse in the same direction.

6. Data

This study analyses the expiration-day effects of the fourteen SPI futures expirations during the period January 1993 through June 1996. The data used in this study were provided by the Sydney Futures Exchange (SFE) and the Australian Stock Exchange (ASX). Specifically, the SFE provided intraday trade prices for the SPI futures as well as the AOI, and the ASX provided trade-by-trade data for the twenty or so largest market capitalisation stocks in the AOI. A list of the stocks used in our analyses is provided in appendix A.

7. Expiration-Day Volume Effects

The analysis of volume effects is based on data for a sample of the AOI's twenty or so largest stocks. Table 3 summarises the abnormal trading volume results for the fourteen expirations. For the 31 March 1993 expiration, for example, the sample consists of nineteen stocks, which is approximately 50% of the total market value of the AOI. On that day, the average proportion of total dollar trading volume occurring during the last thirty minutes of the day was 35.03%. In

Table 3

Average Proportion of Total Daily Trading Volume Accounted for in the Last Half Hour of Trading on Expiration Days and Non-Expiration Days for Each SPI Futures Contract Expiration in the Period January 1993 through June 1996

Contract Month	Expiration Days: Number of Observations	Expiration Days: Relative Trading Volume	Non-Expiration Days: Number of Observations	Non-Expiration Days: Relative Trading Volume	*t*-ratio
9303	19	35.03%	38	17.89%	5.24
9306	19	30.77%	38	18.22%	3.58
9309	20	21.07%	40	18.71%	0.69
9312	20	28.52%	40	27.36%	0.18
9403	20	28.69%	40	23.33%	1.34
9406	20	20.13%	40	23.14%	–0.72
9409	20	29.58%	40	18.25%	2.84
9412	21	40.47%	42	24.11%	2.53
9503	21	20.43%	42	19.67%	0.22
9506	21	28.74%	42	17.66%	3.44
9509	21	34.11%	42	22.50%	2.94
9512	21	43.54%	42	23.77%	3.07
9603	20	46.51%	40	17.94%	7.02
9606	20	23.31%	40	22.01%	0.35
All	283	30.81%	566	21.07%	8.57

contrast, the average proportion for the non-expiration days, 17 and 24 March 1993, was 17.89%. The *t*-ratio reported in the last column, 5.24, indicates that the difference is significant in a statistical sense. In other words, the trading volume of index stocks at the close on the March 1993 expiration was significantly higher than on non-expiration days.

The *t*-ratios of the other contract expirations indicate that the result is general. On eight of fourteen expirations, trading volume is significantly higher than normal. Of the remaining six, five show higher trading volume at the close, although the difference is not significant in a statistical sense. On one expiration, June 1994, trading volume at the close appears slightly lower than normal. The largest relative volume occurred on the March 1996 expiration which has been the subject of a regulatory inquiry. When all of the relative trading volume data are pooled, the average closing volume on expiration days is 30.81% as compared to 21.07% on non-expiration days. Index unwinding appears to induce abnormally high stock market trading. Whether this trading ‘disrupts’ the stock market is addressed next.

8. Expiration-Day Price Effects

8.1 Expiration-Day Price Behaviour of the Reported Index and the Futures

To provide a general understanding of the price movements during the most recent fourteen SPI futures contracts expirations, five-minute price levels for the AOI and the SPI futures are plotted for each expiration for the period from the open of trading on the day of expiration until noon on the day following expiration. The results are contained in appendix B. In addition, summary index price levels are provided in table 4.

Table 4

Level and Returns of the All Ordinaries Share Price Index at the Expiration of the Nearby SPI Futures Contract

Contract Month	Expiration Day Open	Expiration Day Close	Noon on Day Following Expiration	Open-to-Close Return	Close-to-Noon Return	Portfolio Reversal
9303	1,678.3	1,667.4	1,660.9	–0.65%	–0.39%	–0.39%
9306	1,718.3	1,739.0	1,749.3	1.20%	0.59%	–0.59%
9309	1,952.3	1,963.9	1,958.5	0.59%	–0.27%	0.27%
9312	2,154.6	2,172.8	2,167.9	0.84%	–0.23%	0.23%
9403	2,091.3	2,051.3	2,012.7	–1.91%	–1.88%	–1.88%
9406	1,975.2	1,988.8	1,966.2	0.69%	–1.14%	1.14%
9409	2,030.6	2,028.1	2,028.9	–0.12%	0.04%	0.04%
9412	1,932.7	1,912.8	1,911.8	–1.03%	–0.05%	–0.05%
9503	1,884.8	1,906.5	1,901.9	1.15%	–0.24%	0.24%
9506	2,034.1	2,016.0	2,008.8	–0.89%	–0.36%	–0.36%
9509	2,118.8	2,135.7	2,136.3	0.80%	0.03%	–0.03%
9512	2,199.7	2,200.6	2,222.6	0.04%	1.00%	–1.00%
9603	2,236.8	2,231.4	2,225.6	–0.24%	–0.26%	–0.26%
9606	2,241.9	2,242.1	2,241.7	0.01%	–0.02%	0.02%
				Average		–0.19%

To interpret the figures, consider the March 1993 expiration. On this expiration day, the AOI opened at 10.00 a.m. at a level of 1678.3. It increased slightly and then proceeded to fall steadily throughout the day. Shortly after 2.00 p.m. the index began to rise, and then fell modestly by the close of trading at 4.00 p.m. The SPI futures price series begins before the index because the futures market opens ten minutes earlier (at 9.50 a.m.). The futures price movements are similar to the index during the day, except that no futures prices appear between 12.30 p.m. and 2.00 p.m. because the futures market is closed.[9] The futures market closed at

9. In a normal day of trading, the SPI futures contract does not trade between 12.30 p.m. and 2.00 p.m. On days in which the stock market closes at 1.00 p.m. due to an upcoming holiday, the futures market trades past 12.30 p.m. until 1.10 p.m. and then closes for the day. Four early closures are included in our sample: 12/93, 3/94, 12/94 and 12/95.

4.10 p.m., ten minutes after the stock market. Note that the last reported futures price of the day and the last reported index level are the same, reflecting the current cash settlement procedure for the SPI futures. Note also that no futures prices appear on the day following expiration since the futures contract has expired.

We first calculate the variance of five-minute returns of the SPI futures contract on expiration days and on non-expiration days. To our surprise, as indicated in table 5, the average variance over the fourteen expiration days is less than the average variance over fourteen non-expiration periods.

Table 5

Variance of Five-Minute Returns of the SPI Futures Contract on Expiration Days and Non-Expiration Days in the Period January 1993 through June 1996

	Average Return Variance ($\times 10^{-3}$)	
Contract Month	Expiration Days	Non–Expiration Days
9303	0.000477	0.000770
9306	0.000333	0.000718
9309	0.000239	0.000592
9312	0.000833	0.000606
9403	0.001749	0.001307
9406	0.000608	0.001103
9409	0.000481	0.000519
9412	0.000440	0.001033
9503	0.000691	0.000485
9506	0.001111	0.001192
9509	0.000810	0.000909
9512	0.000326	0.000515
9603	0.000451	0.000924
9606	0.000740	0.000353
Mean	0.000664	0.000788

In ten of the fourteen cases, the within-day variance of five-minute returns is less on expiration days than on non-expiration days. This failure to find expiration-day volatility may reflect the fact that volatility occurs near the close rather than throughout the entire day. Price of individual stocks near the closing is examined later in this study.

To gauge whether the stock market ‘reversed’ as a result of the expiration of the futures, we compare the open-to-close return for the AOI on expiration day with the close-to-noon return on the day following expiration. These data are in table 4. For the March 1993 expiration day, the AOI fell from 1678.3 to 1667.4 for an open-to-close return of –0.65%. From the close on expiration day to noon the following day, the return was –0.039%. Since both returns are negative, the portfolio reversal is negative. For this expiration, the index level did not reverse after expiration, indicating that there were no abnormal effects associated with the expiring futures.

Scanning the portfolio reversals of the AOI reported in table 4, we find that virtually no reversal appears to be of consequence. More reversals are negative than positive (ie, eight of fourteen), and the average reversal across all expirations is negative (ie, –0.19%). Only reversal for June 1994 appears large and positive. The market rose by 0.69% on expiration day, and then fell by 1.14% by noon on the day following the announcement. Examination of the figure for the June 1994 expiration (in appendix B) clarifies the event. The figure shows that the stock market opened higher on the expiration day. Recall that the reported index level is computed on the basis of last trade prices, and the first computation made at the beginning of the day is based primarily on the previous day's closing levels. Within minutes the index began trading at a level of about 1988, and it stayed there most of the day. Attributing this pattern of index movement to the unwinding of stock index arbitrage positions is difficult.

The March 1996 expiration, which has been the subject of a regulatory investigation, shows a continuation rather than a reversal. The sharp price decline at the market's close was not reversed the following Monday. Holding constant other factors, this price pattern implies that the closing price was not an abnormal price. If it had been, market forces would have caused the price to reverse on the Monday after the expiration day. On the other hand, if other factors were not constant—if, for example, bad news arrived that kept prices from rebounding—a reversal may have been obscured. It is difficult to draw conclusions about a single expiration, but taken together the data on all the expirations in our sample show no indication of an expiration effect.

8.2 Expiration-Day Price Reversals in Individual Stocks

The figures in appendix B provide an overall view of the behaviour of the index and the index futures price on the expiration day and the day thereafter. A more accurate picture, however, can be obtained by looking at individual stocks. If the unwinding of index arbitrage positions disrupts the stock market, increased volatility and significant price reversals should be observed in individual stocks.

The volatility of five-minute stock returns on expiration days and non-expiration days is first measured for each of the twenty or so stocks in the sample for each of the fourteen expiration days. Table 6 presents the average variance across the stock for each expiration day. The overall average variance on expiration days (0.00062) is nearly twice the overall variance on non-expiration days (0.00034), and the difference is statistically significant on eight of the fourteen days. On two of the remaining days (March and June 1996 expirations), the average variance is less on the expiration day than on the corresponding non-expiration day. Because expiration-day volatility tends to occur near the close, the return volatility of the largest stocks is also examined over the last two hours of expiration days. The results in table 7 are similar to those in table 6. The average variance of five-minute returns in the last two hours of trading is about twice as large on expiration days as on non-expiration days. The difference is statistically significant in nine of fourteen days.

Table 6

Average Five-Minute Stock Return Variance for Largest Stocks in the AOI on Expiration Days and Non-Expiration Days for Each SPI Futures Contract Expiration in the Period January 1993 through June 1996

	Expiration Days		Non-Expiration Days		
Contract Month	Number of Observations	Average Return Variance ($\times 10^{-3}$)	Number of Observations	Average Return Variance ($\times 10^{-3}$)	
9303	19	0.007234	38	0.003342	*
9306	19	0.004254	38	0.002632	
9309	20	0.007586	40	0.003247	*
9312	20	0.006494	40	0.001589	*
9403	20	0.006909	40	0.002807	*
9406	20	0.006950	40	0.004550	
9409	20	0.003226	40	0.002833	
9412	21	0.003921	42	0.001789	*
9503	21	0.010887	42	0.002479	*
9506	21	0.009184	42	0.008902	
9509	21	0.007978	42	0.002412	*
9512	21	0.006099	42	0.002930	*
9603	20	0.002996	40	0.003159	
9606	20	0.002842	40	0.005269	
Mean		0.006183		0.003424	

Note: * = statistically significant.

These results indicate some increased volatility in individual stock returns that is not reflected in the volatility of index futures returns in table 5, presumably because the stock fluctuations are idiosyncratic. The increased volatility in individual stocks could come directly as a result of index expiration or indirectly as a result of the higher level of volume on expiration days.

To assess whether there is a direct effect of the index expiration on stock prices, we next examine if closing prices on expiration days are temporary deviations from equilibrium. Temporary deviations are inferred if the price change at the close is reversed the following morning. If the higher volatility of individual stocks on expiration days is directly attributable to index futures expirations that temporarily drive prices away from equilibrium, we should observe systematic reversals. On the other hand, if the higher volatility is simply the result of greater volume or other factors, systematic reversals would not be observed.

Abnormal price effects are measured by comparing stock price changes in the last thirty minutes of the expiration day to stock price changes from the

Table 7

Average Five-Minute Stock Return Variance for Largest Stocks in the AOI During the Last Two Hours on Expiration Days and Non-Expiration Days for Each SPI Futures Contract Expiration in the Period January 1993 through June 1996

	Expiration Days		Non-Expiration Days		
Contract Month	Number of Observations	Average Return Variance ($\times 10^{-3}$)	Number of Observations	Average Return Variance ($\times 10^{-3}$)	
9303	19	0.007719	38	0.003235	*
9306	19	0.007825	38	0.003379	*
9309	20	0.015922	40	0.002855	*
9312	20	0.004824	40	0.000978	*
9403	20	0.006450	40	0.002653	*
9406	20	0.007407	40	0.005956	
9409	20	0.003106	40	0.002894	
9412	21	0.005127	42	0.001433	*
9503	21	0.017195	42	0.002383	*
9506	21	0.004625	42	0.008619	
9509	21	0.005851	42	0.002923	*
9512	21	0.003574	42	0.001370	*
9603	20	0.005359	40	0.004938	
9606	20	0.003879	40	0.002245	
Mean		0.007062		0.003276	

Note: * = statistically significant.

expiration-day close until the following morning's opening transaction price. A price change between the close and the opening that reverses the price change in the last thirty minutes of the prior day would be evidence of an expiration effect.

Summary results, classified by expiration day, are reported in table 8. To understand how to interpret these results, again consider the March 1993 expiration. On this expiration day, the average reversal for the stocks in the index is 0.24%. This means that the index stocks did reverse, on average, but not by very much. Indeed, this expiration reversal is less than the comparable average stock reversal on the non-expiration days, 0.53%. The *t*-ratio reported in the last column, 1.42, indicates that there is no significant difference between the reversals observed on expiration days and those observed on non-expiration days, at least for the index stocks examined at the March 1993 contract expiration. The interpretation of the results for the other contract expirations is similar. Most of the expiration days and non-expiration days have positive reversals, and the difference between their levels is not meaningful statistically. Across all contracts, the average stock reversal is 0.11% on expiration days, but this value is not significantly different from the average reversal of 0.05% on non-expiration days.

Table 8

Average Stock Reversal for Largest Stocks in the AOI on Expiration Days and Non-Expiration Days for Each SPI Futures Contract Expiration in the Period January 1993 through June 1996

	Expiration Days		Non-Expiration Days		
Contract Month	Number of Observations	Average Stock Reversal	Number of Observations	Average Stock Reversal	*t*–ratio
9303	19	0.24%	38	0.53%	–1.42
9306	19	0.10%	38	0.19%	–0.18
9309	20	0.33%	40	–0.44%	1.01
9312	20	0.28%	40	–0.20%	0.54
9403	20	0.07%	40	0.04%	0.03
9406	20	0.70%	40	0.17%	0.52
9409	20	–0.05%	40	0.04%	–0.09
9412	21	–0.07%	42	–0.08%	0.01
9503	21	0.06%	42	0.06%	0.00
9506	21	–0.06%	42	0.09%	–0.15
9509	21	0.08%	42	0.03%	0.05
9512	21	0.10%	42	0.19%	–0.10
9603	20	–0.33%	40	0.00%	–0.33
9606	20	0.13%	40	0.09%	0.04
All	283	0.11%	566	0.05%	0.68

Aside from the fact that the average stock reversals are no different on expiration days than non-expiration days, the size of the reversals are small in economic terms. Consider, for example, the March 1993 expiration when index stocks had an average reversal of 0.24%. The average share price of the nineteen stocks included in the sample on this day was about $7.00. This means that the size of the reversal is a mere 1.7¢. The average stock reversal across expirations was 0.11%. Using a $7 share price, the typical reversal amounts to less than a penny (0.77¢).

The results in table 8 imply that unwinding of stock index arbitrage positions does not disrupt the stock market, at least insofar as the market is reflected in the price movements of high capitalisation stocks.

8.3 Expiration-Day Portfolio Price Reversals

Return reversals in individual stocks are to be expected as stock prices bounce between the bid and ask sides of the market. Consequently the small reversals found for individual stocks are a surprise. Expiration day price effects can be problematical insofar as all stock reverse in the same direction. If stocks reverse in the same direction, the reversal in the return of a portfolio of stocks would be significant. Since individual stock reversals were not found, a portfolio reversal is unlikely. Nevertheless, for completeness, portfolio return reversals were calculated for the sample of the twenty largest stocks. The data in table 9 confirm that no evidence exists of any systematic portfolio reversals. The average reversal over the fourteen expirations is –0.05%, essentially a zero effect.

Table 9

Average Portfolio Reversal for Largest Stocks in the AOI on Expiration Days and Non-Expiration Days for each SPI Futures Contract Expiration in the Period January 1993 through June 1996

	Expiration Days		Non-Expiration Days	
Contract Month	Number of Observations	Average Portfolio Reversal	Number of Observations	Average Portfolio Reversal
9303	19	0.32%	38	0.50%
9306	19	–0.11%	38	–0.04%
9309	20	0.35%	40	–0.96%
9312	20	0.34%	40	–0.54%
9403	20	–1.02%	40	0.31%
9406	20	0.65%	40	0.01%
9409	20	0.02%	40	0.34%
9412	21	–0.32%	42	0.55%
9503	21	–0.26%	42	0.37%
9506	21	–0.29%	42	0.10%
9509	21	0.00%	42	0.34%
9512	21	–0.25%	42	0.17%
9603	20	–0.33%	40	0.02%
9606	20	0.24%	40	–0.01%
Average		–0.05%		0.08%

8.4 Summary of SPI Expiration-Day Effects

The empirical results provided in this section are consistent with the studies of the US and Japanese markets: trading volume in the stock market at the time of expiration is abnormally high, but the associated price effects are economically insignificant. Indeed, the average price reversal for Australian Stock Exchange index stocks on expiration days is insignificantly different from zero. Based on this evidence, a change in the procedures used to settle the SPI futures contract does not appear to be warranted. Nonetheless, given the SFE's recent change in settlement to a call auction market fifteen minutes after the stock market close, it is worthwhile to consider the merits of alternative settlement procedures.

9. Alternative Settlement Procedures

As noted earlier, index futures expiration-day effects occur primarily because index arbitrage positions are not self-liquidating. While the futures contract settles automatically, the arbitrageur is forced to liquidate his stock position on his own. The process by which stock positions are liquidated can influence stock prices. In turn, the process by which stock positions are liquidated is influenced by the rules for determining the index futures settlement price. The purpose of this section is to describe the merits of alternative settlement procedures in light of the potential for trading abuses.

9.1 Delivery

One method for contract settlement is delivery. In general, delivery contracts are more common than cash settlement contracts. If the underlying stocks were to be delivered by the short to the long, the root cause of potential price effects would be eliminated. An arbitrageur who bought (sold short) stock and sold (bought) futures would simply deliver (take delivery of) the underlying stocks against the futures. Without concentrated demand to buy or sell index stocks from index arbitrage positions, no price effect would be induced.[10]

As a practical matter, delivery is not possible because of the cost and difficulty of transferring a large portfolio of stocks. The AOI contains about 320 stocks. Settlement by delivery would require the delivery of 320 stocks in the same proportions as they exist in the index. While technically feasible, the cost of making such delivery is likely to outweigh the benefit. Consequently, all active stock index futures contracts call for cash settlement.[11]

9.2 Cash Settlement Procedures

Ruling out delivery as a viable means for settling an index futures contract leaves cash settlement. Under cash settlement, the choices are few: whether to use a single price or an average price, whether to settle at the open or at the close, and whether to make other changes in stock market procedures. To begin, the current cash settlement procedures of the world's major index futures contracts are summarised in table 10.

9.2.1 *Single Price* The US, German, and Japanese index futures contracts settle at an index level based on a single price for each of the index stocks. For some contracts, the single price is the opening price for the day; for others, it is the closing price. Ideally, the settlement price should reflect the true condition of the market and should be based on reasonable depth of trading. Typically, the stock market exhibits greater trading volume and depth at the open and the close than at other times of the day, so basing a settlement index level on prices at these times makes sense.

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10. Other delivery problems might arise, however. For example, in a short squeeze (where the shorts have difficulty in acquiring the stock for delivery), stock prices might temporarily be forced up.
11. Karolyi (1996) notes that the Osaka Exchange's Kabusaki fifty index futures contract called for delivery of 1,000 shares of each of the fifty largest stocks in the Nikkei index. The contract was later changed to permit cash settlement.

Table 10

Cash Settlement Procedures for Selected Index Futures and Index Options Contracts

	Settlement Price
Futures Contract	
S & P 500 (Chicago Mercantile Exchange)	Special S & P 500 index value calculated from the opening prices of each of the stocks in the index. If stock fails to trade on the expiration day, the prior day's close is used.
All Ordinaries Share Price Index (Sydney Futures Exchange)	Closing value of the ASX All Ordinaries Share Price Index on the last day of trading calculated to one decimal place from the closing prices of the component stocks.
FTSE 100 (London International Financial Futures Exchange)	Settled at 10.30 a.m. on the basis of the FTSE cash index values averaged over the period 10.10 a.m. – 10.30 a.m.
CAC-40 (MATIF)	Settled at 4.00 p.m. on the basis of the CAC–40 cash index values averaged over the period 3.40 p.m. – 4.00 p.m.
DAX (Deutsche Terminboerse)	DAX cash index value calculated from the opening prices of the index stocks on the Frankfurt Stock Exchange.
Nikkei 225 (Osaka Securities Exchange)	Settled at special opening price calculated from the opening prices of the Nikkei index stocks.
Option Contract	
S & P 100 (Chicago Board Options Exchange)	American-style option exercisable any day at a settlement price calculated from the closing prices of the index stocks.

From a user's standpoint, a single price provides the greatest benefit. The effectiveness of arbitrage and hedging activities depends on convergence between cash and futures prices. With a single settlement price, convergence is ensured. This means that the arbitrageur has no basis risk whatsoever since underlying stock positions are unwound at the stock prices that match the price at which the futures contract settles. A hedger, who may have basis risk arising from imperfect correlation with an underlying position, need not be concerned about additional basis risk arising out of a lack of convergence at settlement.

The decision whether to use the opening or closing price in contract settlement rests on the desire that the buying and selling interest be representative of the market's true condition and not be unduly influenced by the expiration itself. At the close, the sale of stocks as part of large index arbitrage unwindings can put price pressure on stocks because there is insufficient time to locate the other side of the trade. At the opening, however, the sale of stocks can more easily be postponed until the other side can be found. The opening of a stock under selling pressure, for example, can be postponed until sufficient numbers of buyers are located.

Many markets open with an auction procedure that tabulates buy and sell orders and disseminates information on order imbalances to the market in order to attract additional traders. Stoll and Whaley (1991) evaluate the effectiveness of the CME's decision to move from closing prices to opening prices in the settlement of the S&P 500 futures and futures options. They conclude that empirically the change had little effect on the size of the stock reversals. This may be attributable to the role of the specialist and the fact that the opening procedure on the NYSE is not a fully disclosed auction market.

Aside from the market depth consideration, the decision about whether to use opening or closing prices has another element—'perceived' market integrity. The reported index level disseminated throughout the day is based on the last trade prices of the index stocks. If settlement occurs at the close, the settlement price is computed on the basis of the closing prices of each of the stocks and equals the last reported price for the index on that day. Settlement at the open, however, is different. While the index continues to be reported as normal, there is a 'special' index level computed on the basis of the opening price of each stock. Since all stocks do not open at the same time, this settlement price is not available until the last index stock has opened and may be different from any index level reported for the trading day. For the March 1993 S&P 500 futures contract expiration, for example, the settlement price based on the opening prices of each of the stocks was 454.19. The highest reported level of the S&P 500 on that day, however, was about 453. Although hedgers and arbitrageurs are not harmed by this phenomenon, the fact that the settlement price is well away from *any* reported index level for the day may be regarded with suspicion by some market participants.

Stock market procedures affect the possibility of manipulating a single settlement price. So long as mechanisms are available to respond to sudden buying or selling pressure, a single price settlement is no easier to manipulate than are other settlement procedures. Settlement at the opening has the advantage that the opening can be delayed if buying or selling pressure threatens to push a stock's price away from equilibrium; the disadvantage is that the index settlement value will differ from the regularly reported index level. Settlement at the closing price is less confusing for investors because the index settlement value is the same as the closing index level; however, late unannounced buying or selling pressure may be more difficult to deal with. Adjustments in stock market procedures such as early warning of large index unwindings can help overcome some of these drawbacks.

9.2.2 *Average Price* The UK and French index futures settle at an average price of the underlying index calculated over a period of time. The UK price is the average price of the FTSE index calculated over the period 10.10 p.m. – 10.30 a.m. The CAC-40 price is an average of index prices over the period 3.40 p.m. – 4.00 p.m. The average price is used on the grounds that an average is more difficult to influence than a single price. Also an average may be more appropriate where the stock market is a dealer market, as in the UK, because a dealer market is not well suited to arriving at a single auction price that reflects the interests of all market participants.

From the perspective of hedgers and arbitrageurs, an average price is less desirable than a single price because it introduces basis risk. To unwind their positions, index arbitrageurs must buy or sell the proper amount of their stock positions at each of the index prices that are averaged in arriving at the settlement price. This is a difficult and impractical task. Since there is no way of guaranteeing that the stock position will be unwound at the futures contract settlement price, basis risk occurs.

Some argue that an average price is more difficult to manipulate than a single price, but this is not necessarily the case. If the total potential volume available to determine the single price is the same as the potential volume of the twenty trades determining the average price, influencing each of twenty prices that are used to calculate an average over a twenty-minute interval should be as easy as influencing a single price at the end of twenty minutes.

The average settlement price has the advantage that the evolution of the settlement price can be observed. If index arbitrage unwindings put selling pressure on stock prices, the first of twenty index prices will be lower. Observing this price, value investors who judge the price to be too low can enter buy orders at favourable prices. The same response from value investors is possible, however, in a single price settlement in which opportunity exists to search for more buyers or sellers before the final price is determined. A single price settlement has the advantage of focusing all trading interest at one point such as the open or close. Although a manipulator knows that point, so do all the value traders who wish to take advantage of mispricing. The presence of value traders keeps prices from deviating very much from their equilibrium values.

The average settlement price, like the opening settlement price, may be dramatically different from reported index levels. Suppose the settlement value were based on five index values observed over the last five minutes. Assume those values were 100, 99, 98, 97 and 96. The reported index level at the end of the interval is 96 while the settlement price is 98. This type of discrepancy may cause investor confusion, thereby inducing a perception that markets are not operating fairly.

The average settlement price seems most appropriate when the underlying stock market is a dealer market in which buying and selling interests are not directly exposed. The quotes of a dealer at a moment of time may not reflect the market clearing price that would result if all buyers and sellers decided to trade with that dealer. Quotes are indicated prices, and it may be desirable to collect a sample across dealers and through time of such indications. The need for an average settlement price is less clear in a continuous auction market where all buying and selling interest can be reflected in a single market clearing price.

9.3 Stock Market Procedures

Index settlement procedures are influenced by stock market procedures, and stock market procedures, in turn, affect the viability of alternative index futures settlement procedures. A single price settlement requires a mechanism that allows index arbitrageurs to unwind at that price and, at the same time, provides liquidity for the potentially large volume of trading at the point of index expiration. US markets allow traders to place market-on-close (MOC) orders or market-on-open (MOO) orders. As their names imply, such orders are market orders that are to be traded at the closing price or opening price of the stock. They facilitate the unwinding of an arbitrage position. An issue is whether liquidity to offset arbitrage unwindings is supplied by the stock market. Can a large MOC order to sell placed in the last five minutes of trading, for example, be traded at reasonable prices, or will market prices be depressed?

Stock market mechanisms can be modified to facilitate the provision of liquidity in response to large arbitrage unwindings. For example, it may be desirable to require early disclosure of MOC (or MOO) orders by arbitrageurs. If the rest of the market does not know large sell orders will be placed it may not have sufficient time to respond. A remedy for such a problem might be that MOC or MOO orders will be honoured only if placed thirty minutes in advance. A continuous auction market (such as the NYSE or the ASX) is one in which market orders are executed at resting limit orders.[12] The risk is that a market order placed to unwind an index arbitrage position will overwhelm resting limit orders and cause a temporary price effect. Traders should be given an opportunity to respond to this opportunity to buy at favourable prices.

An alternative to a continuous auction market is a call auction market. A call auction market accumulates orders over some period of time and executes at a single price that maximises the volume of trade. The outcomes of a call auction are sensitive to the design of the auction market. The key to a reasonable outcome is prior disclosure of the likely market clearing price and the opportunity for traders to change their orders. Transparency of the auction is also desirable because it eliminates the possibility that certain participants have private information about the orders submitted to the auction. The opportunity to re-contract gives the market a chance to supply liquidity if the indicated clearing price deviates from equilibrium. Traders may attempt to game call markets, however, by placing false orders and withdrawing them at the last minute, and many traders will wait until the last minute to place their orders. It may therefore be necessary to provide incentives for traders to place orders in a timely fashion and not to withdraw them. The introduction of a call auction at the close would require suspension of the continuous market. Consequently, a call auction mechanism is most natural at the open, and is an argument for using the open rather than the close as a settlement price. In addition at the open, liquidity is provided as traders have the opportunity to accumulate orders overnight. Finally, the design of the auction is complicated by the fact that auctions occur simultaneously in many correlated stocks. These auctions must be designed so that information about the market clearing price in one stock can be used to provide information about the optimal market clearing price in another stock.

Empirical evidence in Amihud and Mendelson (1987) and Stoll and Whaley (1990c) shows that return volatility on the NYSE is greatest around the auction-type opening than at other times. This reflects the difficulty of correctly reflecting in the opening auction price the overnight news in a stock as well as the information conveyed by the opening price of other stocks. Volatility also results from the fact that the auction is usually a one-shot auction with limited transparency and limited pre-opening disclosure. The recently introduced ASX closing auction, which takes place fifteen minutes after the market close, has the advantage that not much new information must be incorporated in the auction price, but it has the disadvantage that volume may be less than it would be in an opening auction.

9.4 Other Issues

Other suggestions have been made to deal with expiration price effects. These include disclosure by index arbitrageurs, telescoping of positions, and changes in

12. For a recent paper on the Australian stock market, see Aitken and Frino (1996).

expiration days. Arbitrageurs might be required to disclose positions so that the market could anticipate the direction of unwindings. Such a requirement, aside from being an administrative nightmare, would be difficult to enforce. How would the reports be made and to whom? Telescoping positions is the reduction of arbitrage positions as expiration is approached. Such a requirement, also an administrative nightmare, would impose basis risk on arbitrageurs who would be forced to unwind positions early. Some have argued that a Friday expiration is particularly troublesome because of the additional uncertainty of the upcoming weekend. The SPI futures do not necessarily expire on Friday (although ten of the fourteen expirations in our sample are on Friday). If settlement is at the opening, traders have the rest of the day to trade out of a position before the weekend.

10. Conclusions and Recommendations

The empirical investigations of the SPI futures contract expirations conducted in this study indicate that, while some expiration-day volume effects are evident in the Australian stock market, there is no evidence of a systematic price effect. The absence of *any* abnormal price movement is inconsistent with the evidence reported for the United States and Japan, where small, economically insignificant, price movements were observed. Abnormal price effects due to an expiration are measured by the extent to which prices reverse—return to normal—after the expiration. The average reversal in a portfolio of the top twenty or so Australian stocks is negligible, reflecting perhaps a lesser degree of index arbitrage activity in Australia or the fact that index arbitrage unwindings occur before the expiration day. In summary, settling the SPI futures at the close appears to have worked satisfactorily.

Beginning with the March 1997 expiration, the SPI futures have cash-settled at the prices of the stocks established in a special call auction market fifteen minutes after the stock market close. Whether this new procedure is the best among the available alternatives is open to debate. This study analyses the two basic alternative cash settlement procedures—a single price settlement and an average price settlement. The single price settlement focuses all buying and selling interest at one known point in time. This leads to depth of trading and reduces the chance that the price will deviate from equilibrium. Settlement at a single price also eliminates basis risk because hedgers can guarantee that the unwinding of the stock position and futures contract position takes place at the same price.

The average price settlement tends to be used where the underlying market is a dealer market. In view of the fact that the Australian stock market is a computerised continuous auction market, the single price settlement appears more appropriate than the average price settlement. The average price procedure also has the disadvantage that it introduces basis risk.

Single price settlement can take place either at the opening or at the close. Each approach has its benefits and costs. The benefit of a special index opening price as the settlement price is that the opening can be postponed until supply and demand are in balance. The disadvantage is possible confusion among investors because the regular index value differs from the special index value used to settle futures contracts. The closing price has the disadvantage that buying or selling pressures may be difficult to handle when little time is left at the end of the trading day. It has the advantage that the index settlement value and the regularly disseminated index are the same. Both procedures seem to work reasonably well according to experience in the United States.

A single price settlement can be facilitated by using a call auction mechanism for trading the stocks underlying the index. A call auction aggregates orders over time and executes orders at a single price that maximises volume of trade. A call auction is most natural at the open, at which time overnight orders have also accumulated. The outcome of the call auction is, however, sensitive to its design. Care should be taken to give market participants an opportunity to observe the likely clearing price and to re-contract. Traders also need incentives to place orders in a timely fashion and not to withdraw them.

Markets are remarkably adaptive. If expiration-day price effects were to occur, value traders looking for favourable prices would be ready to provide liquidity. Critical to successful settlement is that stock market mechanisms be designed to make it easy for traders to respond quickly if large volume pushes prices away from equilibrium.

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Appendix A

All Ordinaries Share Price Index Stocks Used the Analyses of Abnormal Trading Volume and Price Behaviour

			Contract Months													
Ticker	Stock	Weight	1993				1994				1995				1996	
		(%)	M	J	S	D	M	J	S	D	M	J	S	D	M	J
AMC	AMCOR Ltd	1.506	×	×	×	×	×	×	×	×	×	×	×	×	×	×
ANZ	Australia and New Zealand Bank	2.981	×	×	×	×	×	×	×	×	×	×	×	×	×	×
BHP	Broken Hill Properties	10.570	×	×	×	×	×	×	×	×	×	×	×	×	×	×
BIL	Brambles Industries	1.273	×	×	×	×	×	×	×	×	×	×	×	×	×	×
BOR	Boral Ltd	1.041	×	×	×	×	×	×	×	×	×	×	×	×	×	×
CBA	Commonwealth Bank Australia	1.660	×	×	×	×	×	×	×	×	×	×	×	×	×	×
CCL	Coca-Cola Amatil	2.554	×	×	×	×	×	×	×	×	×	×	×	×	×	×
CML	Coles Myer Ltd	1.472	×	×	×	×	×	×	×	×	×	×	×	×	×	×
CRA	CRA Ltd	3.836	×	×	×	×	×	×	×	×	×	×	×	×	×	×
CSR	CSR Ltd	1.342	×	×	×	×	×	×	×	×	×	×	×	×	×	×
FBG	Fosters Brewing	1.398	×	×	×	×	×	×	×	×	×	×	×	×	×	×
FLC	Fletcher CHA	0.982	×	×	×	×	×	×	×	×	×	×	×	×		
LLC	Lend Lease Corp	1.519	×	×	×	×	×	×	×	×	×	×	×	×	×	×
NAB	National Australia Bank	5.508	×	×	×	×	×	×	×	×	×	×	×	×	×	×
NCP	News Corp Ltd	3.969	×	×	×	×	×	×	×	×	×	×	×	×	×	×
NCPDP	News Corp–Pref	1.650								×	×	×	×	×	×	×
PDP	PAC Dunlop Ltd	0.853	×	×	×	×	×	×	×	×	×	×	×	×	×	×
WBC	Westpac Banking	3.453	×	×	×	×	×	×	×	×	×	×	×	×	×	×
WMC	WMC Ltd	3.038	×	×	×	×	×	×	×	×	×	×	×	×	×	×
WOW	Woolworths Ltd	0.962			×	×	×	×	×	×	×	×	×	×	×	×
WPL	Woodside Petroleum	1.561	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	Total	53.128	19	19	20	20	20	20	20	21	21	21	21	21	20	20

Appendix B

Plots of SPI Futures Prices and AOI Levels on Expiration Days During the Period, March 1993 through June 1996

Prices are at five-minute intervals from the open on the expiration day to noon on the day following expiration. The AOI levels are plotted as a solid bold line, and the SPI futures prices are plotted as a light line.

Figure B1

March 1993

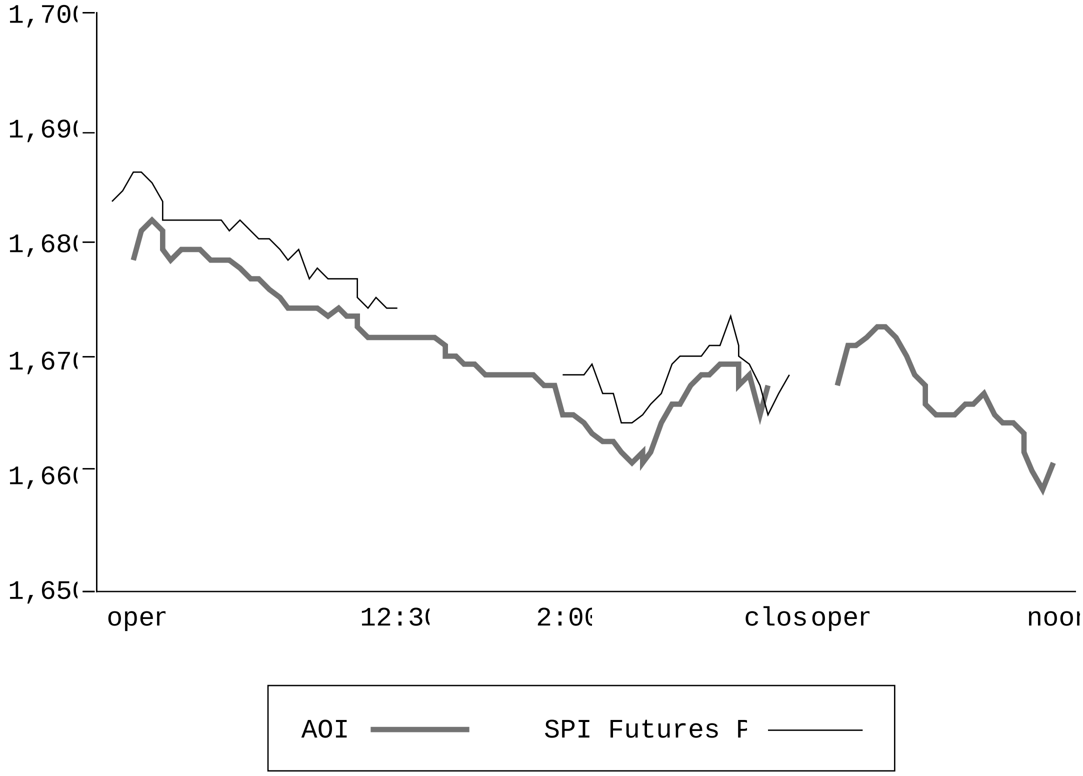


Figure B2
June 1993

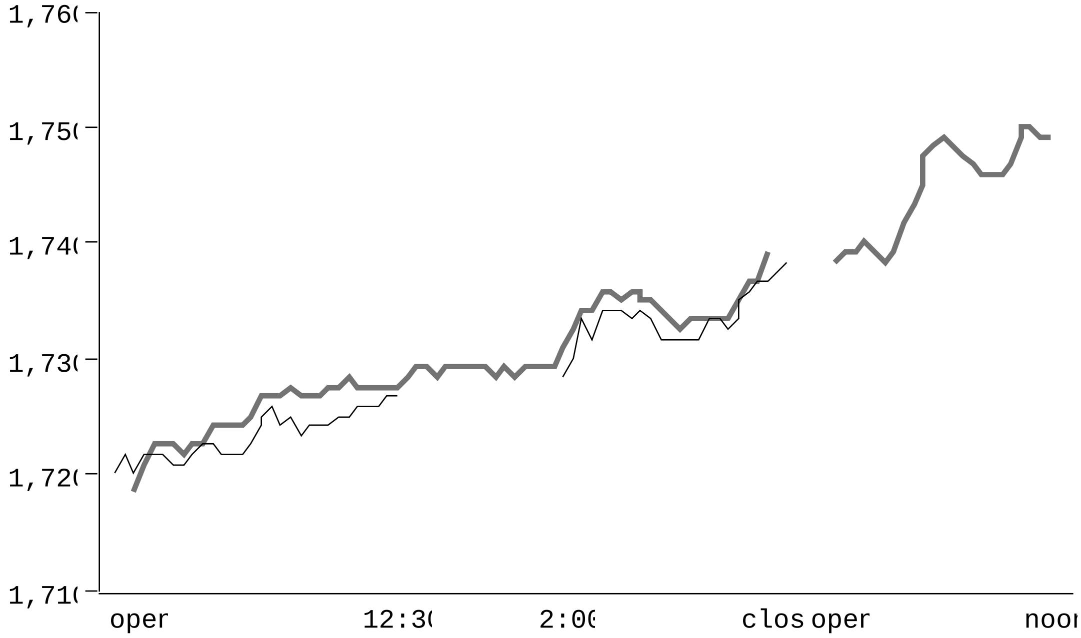


Figure B3
September 1993

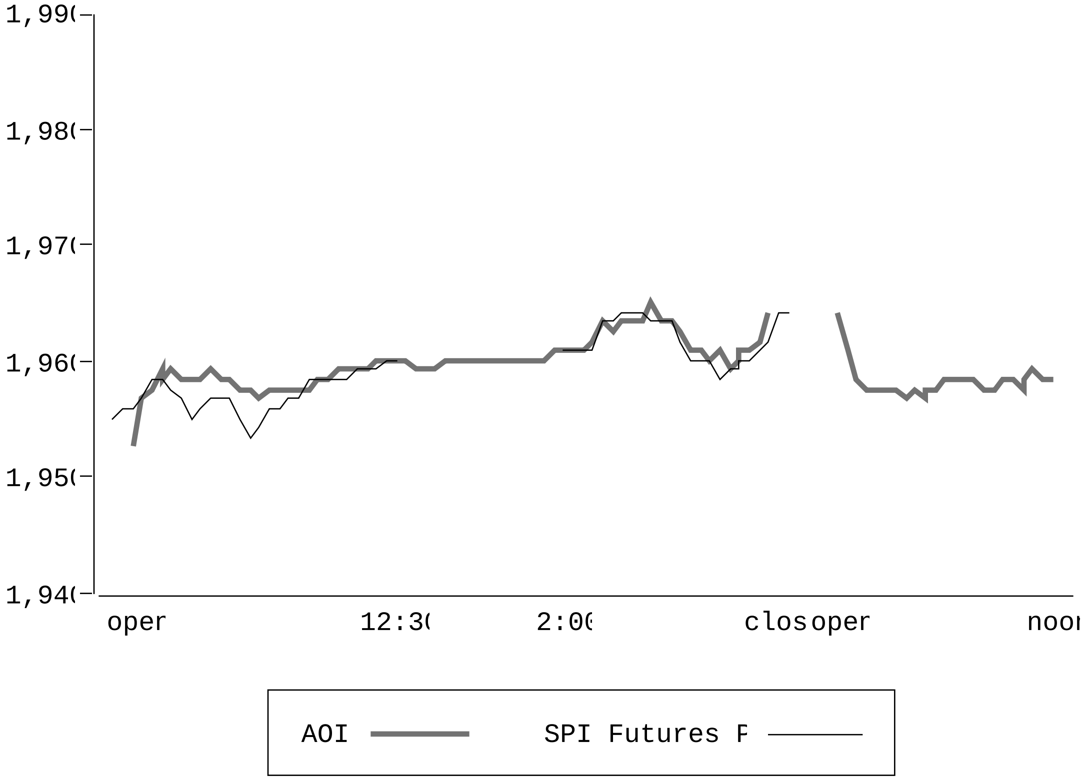


Figure B4

December 1993

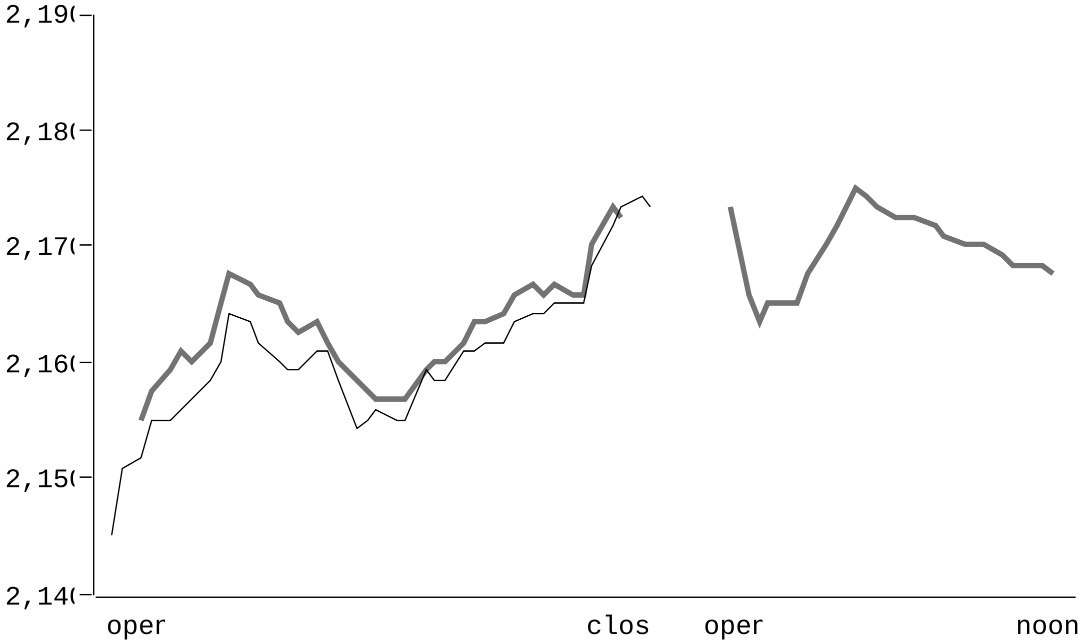


Figure B5

March 1994

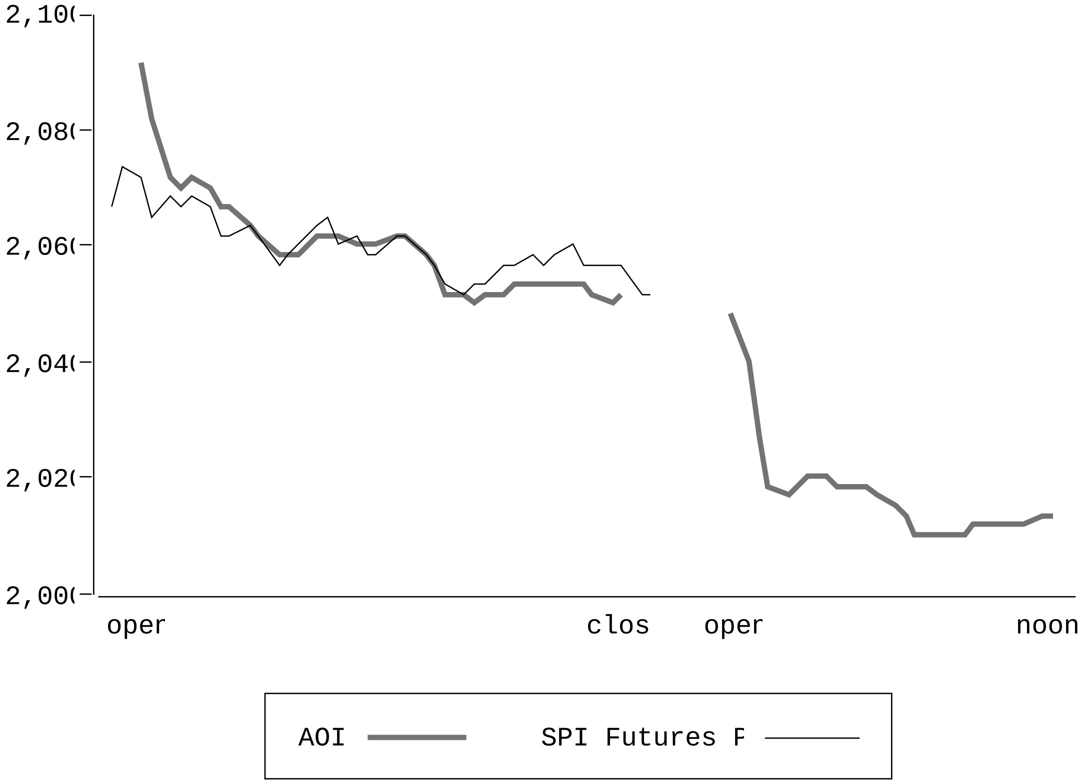


Figure B6
June 1994

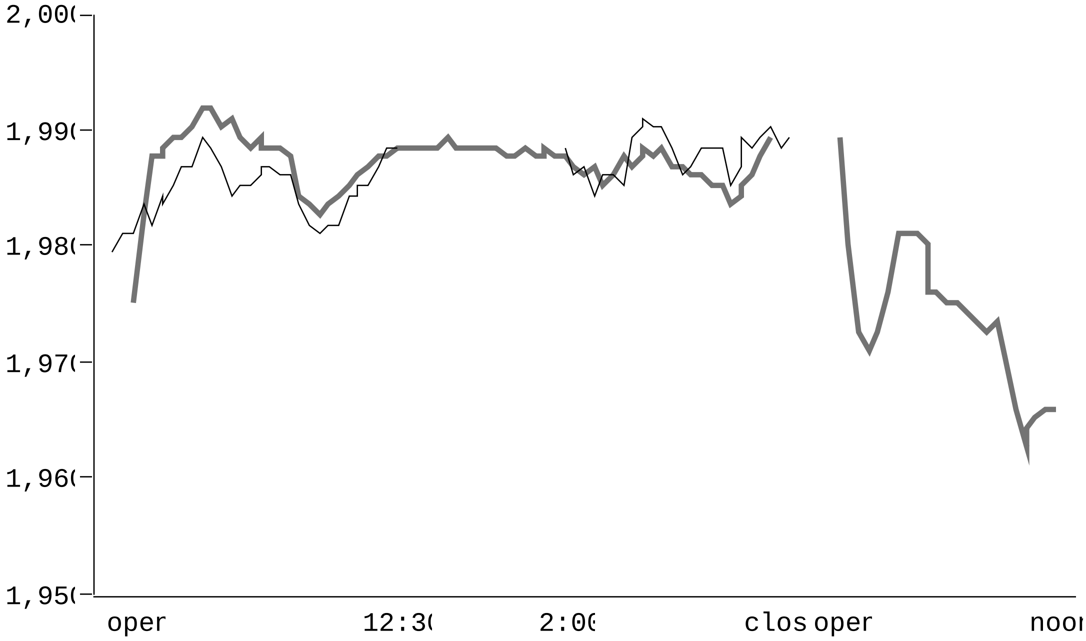


Figure B7
September 1994

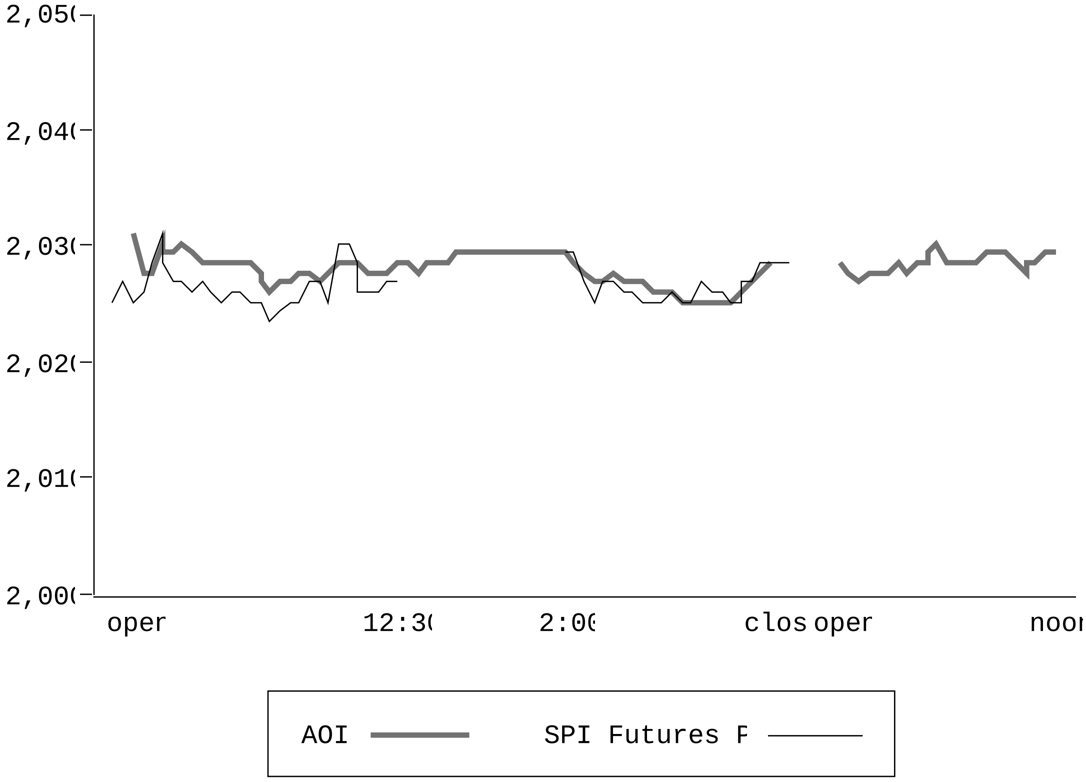


Figure B8

December 1994

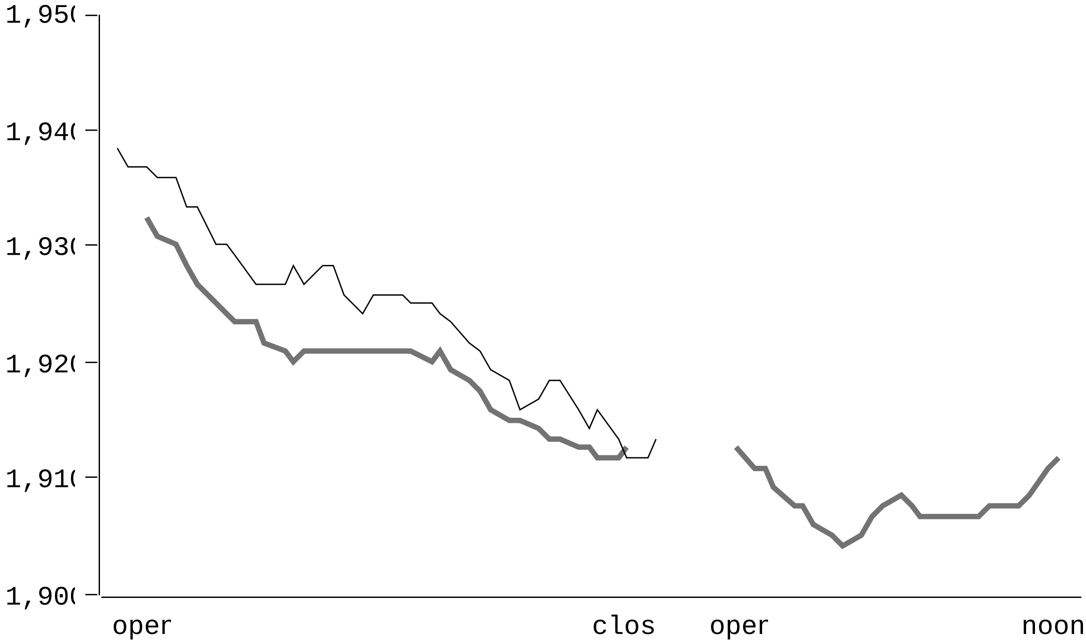


Figure B9

March 1995

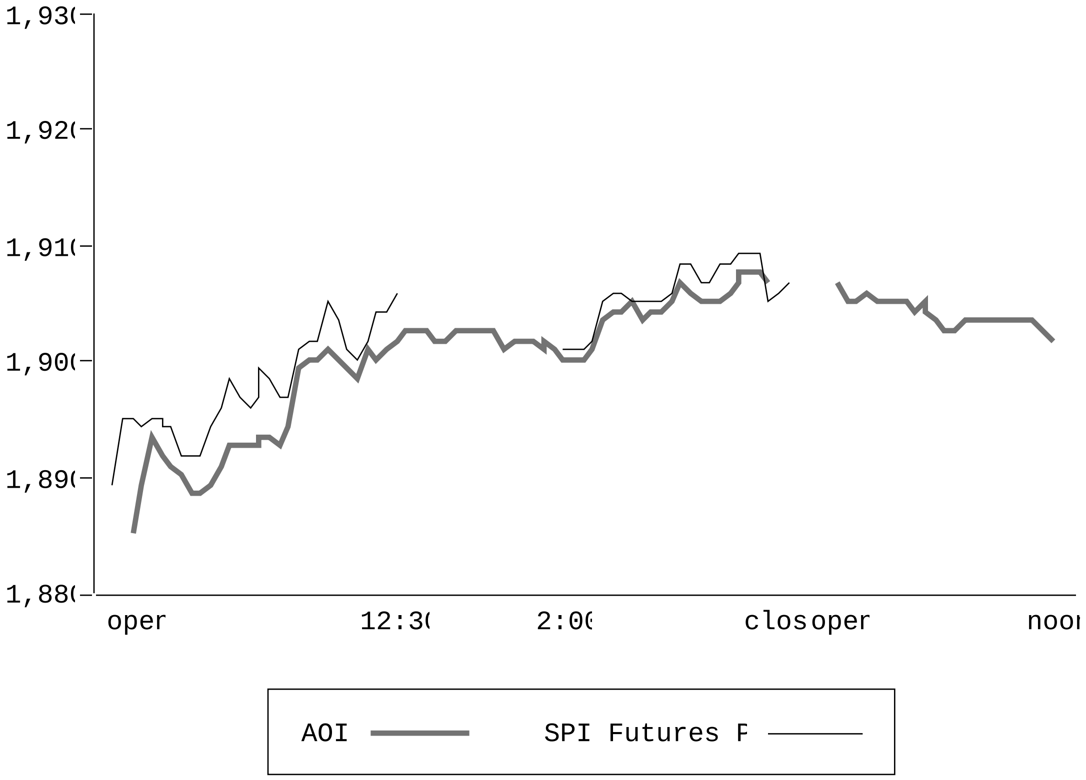


Figure B10

June 1995

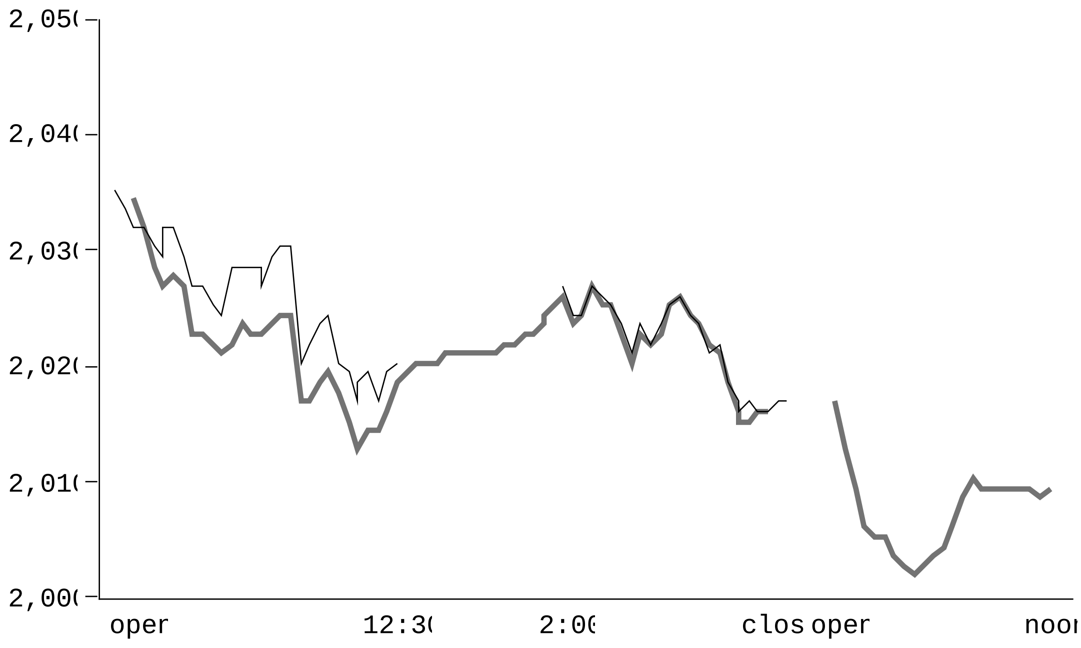
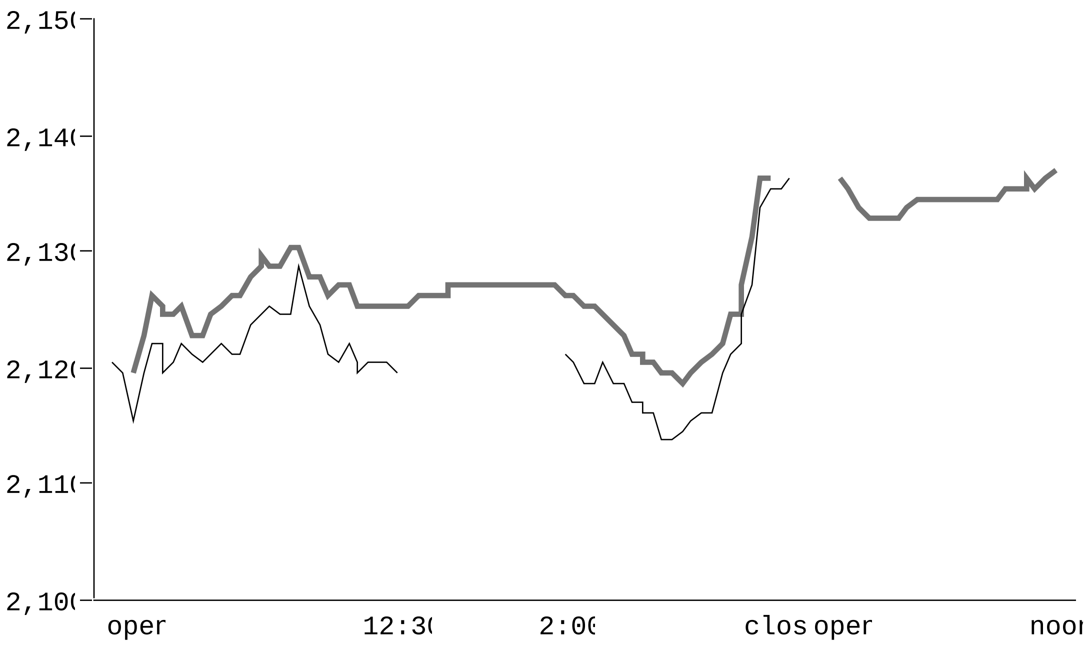


Figure B11

September 1995



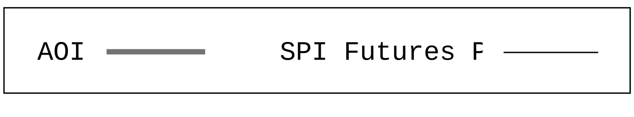


Figure B12
December 1995

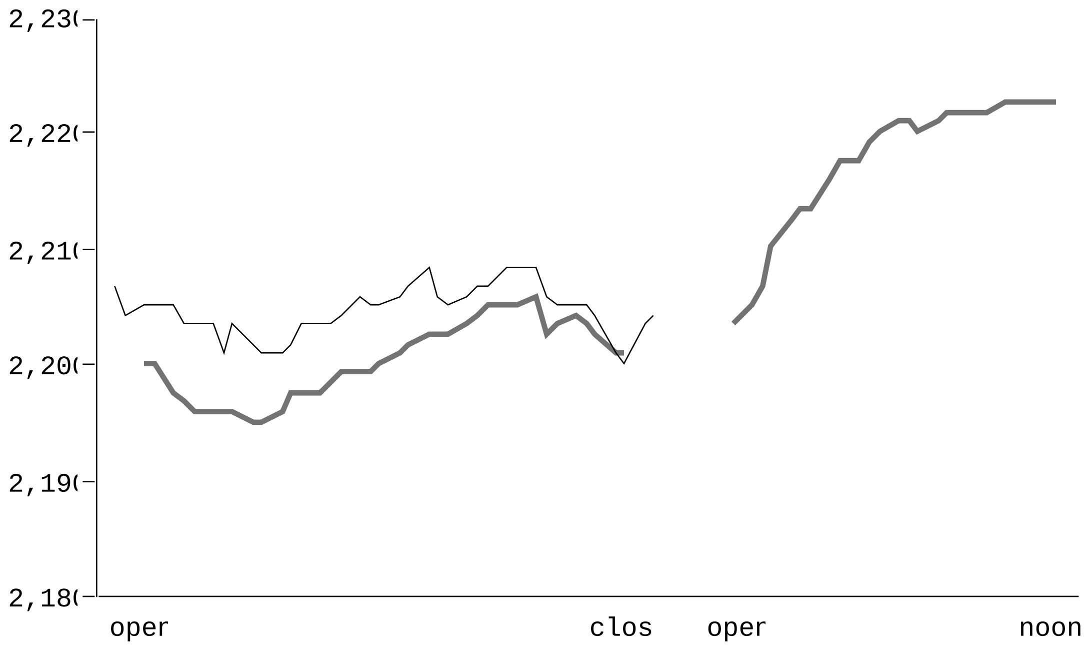


Figure B13
March 1996

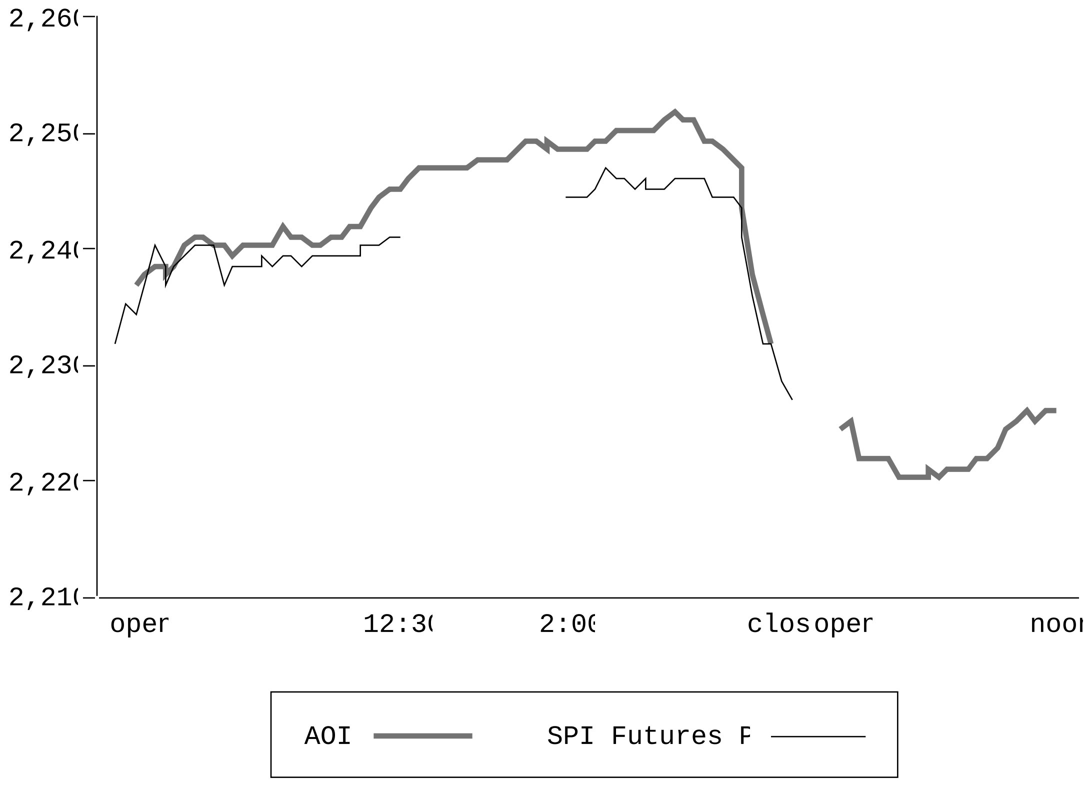
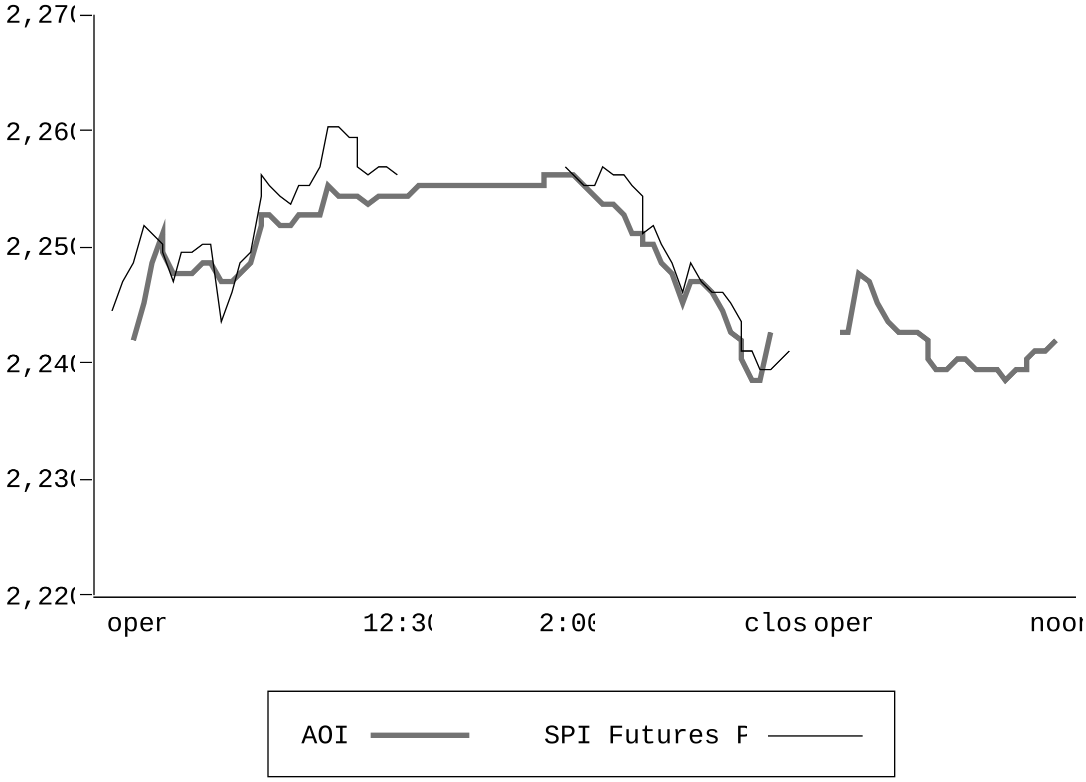


Figure B14
June 1996



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Expiration day effects on European trading volumes

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Abstract
This study investigates the effect of periodic events, such as the stock index futures and options expiration days and the Morgan Stanley Capital International (MSCI) quarterly index reviews, on the trading volume in the pan-European equity markets. The motivation of this study stems from anecdotal evidence of increased trading volume in the equity markets during the run-up to the index options and futures expiration days and MSCI rebalances. This study investigates this phenomenon in more detail and analyses the trading volumes of seven European stock indices and the MSCI International Pan-Euro Price Index. The analysis features a multi-step ahead volume forecast, which is important for practitioners in order to plan multi-day trades while looking to minimise the market impact. The results confirm higher trading activity on the futures and options expiration days, as well as on the MSCI rebalance day. We report a clear futures and options expiration day effect, which accounts for the Friday effect in terms of larger trading volumes. The MSCI rebalance trading volume is significantly different from the volume of the adjacent months with no MSCI reviews, but they cannot explain the end-of-month effect entirely.

Keywords Trading volume · Expiration day effect · Behavioural finance · European stock market · Feature selection

JEL Classification C32 · C52 · C58 · G12 · G15 · G17

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1 Introduction

This study investigates the increased trading volume associated with recurring special events, namely the stock index futures and options expiration days and the MSCI quarterly index reviews; this is known as 'the expiration day effect' in the literature. We analyse a number of aspects related to the expiration dates, such as the existence of an anticipatory/reactive expiration day effect (i.e. whether the volumes are higher during the days leading up to and following the MSCI rebalances and the stock index options and futures expiration days) and the identification of the principal volume drivers of this phenomenon. The study aims to distinguish between the index options and futures expiration day effects being examined in this study and well-established calendar effects, such as the Friday effect or the end-of-month effect. We discriminate between the Friday effect and the stock index options and futures expiration days, and between the end-of-month effect and the MSCI quarterly reviews in order to identify the primary drivers of increased trading activity.

Typically, financial markets are in a steady state, but they start fluctuating when certain events occur, e.g. company annual reports and announcements, news events, or other (periodic) calendar events, such as the subject of this study (i.e. the expiration days and rebalances). We explore activity surges around the stock index options and futures expiration days and MSCI quarterly reviews.

The contribution of this study is threefold: first, the expiration day effect has been scarcely investigated in the literature, and, out of this small proportion, there is a very small number of papers employing data from the European markets; second, the majority of this specialised literature focuses on returns, while the volume dimension is mostly ignored; and third, planning multi-day trades is important to practitioners and we propose a multi-step ahead prediction model for the expiration day effect. As far as we are aware, this is the first pan-European study on index options and futures expiration days and MSCI rebalances, while employing the most recent 15 years of daily market data.

The aim of this study is to provide a trading volume in-sample analysis while considering aspects such as the futures and options expiration days and the MSCI quarterly index reviews. The expiration days are an instance of a sparse event and we investigate the futures and options expiration days for 7 of the most liquid European stock indices. The study deals with a set of data analysis challenges and investigates a phenomenon whose scope is new. We propose a novel methodological approach in finance by manually constructing the expiration day calendar data set for the most liquid European indices, retrieving the daily market data for the historical constituents for a 15-year period, rigorously testing the existence of the expiration day effect, and ultimately applying stepwise regression. We inspect anticipatory and reactive effects of the index expiration days and review dates by analysing the previous and following five business days relative to the expiration days. The expiration days consist of all dates when the index options and futures stop trading for a given index.

The study proceeds as follows: Sect. 2 surveys the relevant literature on calendar effects, including the expiration day effect, the Friday effect, and the end-of-month effect, along with a succinct review of the volume-price relation, the stock index futures and options expiration days, and MSCI rebalances; Sect. 3 describes the data sample being investigated, such as the stock universe and the calendar data, while also providing summary statistics on the magnitude of the expiration day effect one week before and after the expiration day and the quarterly review date; Sect. 4 introduces our analytical approach, and the methodology of this experiment; Sect. 5 explores a potential relationship between trading volume and index options and futures expiration days and MSCI rebalances based on OLS descriptive models; following this exploratory analysis, Sect. 6 tests the existence of the investigated effects by conducting randomisation tests, while Sect. 7 introduces and explains the results of the stepwise regression predictive models fit for the index expiration day and MSCI rebalance analyses; finally, Sect. 8 concludes the study with a discussion on the main findings.

2 Background

This section starts with a survey of some of the relevant calendar effects, in order to understand the seasonal market dynamics that have been empirically identified as potential drivers of volume or price returns. This is followed by a short review of the relation between trading volume and price returns, and an introduction to stock index futures and options, potential mechanisms behind the increased trading volume around the futures and options expiration days, and MSCI index reviews.

2.1 Calendar effects

The majority of the literature on calendar effects looks at the relation between calendar anomalies and price returns, while the relation with the trading volume is barely covered. We start by reviewing the relevant calendar effects and then we outline the empirical findings on the connection between volume and price, in order to infer the calendar effects and their impact on trading volume.

Calendar effects are essentially anomalies in the financial markets that are associated with the calendar seasonality. The literature on calendar effects (and on behavioural finance, in general) is highly contentious and its empirical findings are usually inconclusive. One of the reasons is that each calendar effect is usually investigated in isolation, while a full universe of calendar effects would diminish the effect size of the calendar anomalies (Sullivan et al. 2001). It is worth mentioning that the calendar effects have always been identified ex post due to their dependence on empirical evidence from the past time series supporting their existence. The dynamics of some calendar effects is also known to change or reverse over time (Dimson and Marsh 1999; Schwert 2003; Hansen et al. 2005; Pearce 1996), while other calendar effects tend to persist through time, as reported by Lakonishok and Smidt (1988), Barone (1990), Agrawal and Tandon (1994), and Mills and Coutts (1995). The following review of calendar effects outlines some of the event-driven irregularities markets experience.

2.1.1 Weekend effect and the Friday effect

The weekend effect consists of a negative weekend return, implying that the Friday returns are greater than the returns on the following Monday. This calendar anomaly has been widely studied in the literature by authors such as French (1980), Gibbons and Hess (1981), Jaffe and Westerfield (1985), Pettengill (2003), or Cross (1973). Based on the correlation between price and volume that will be introduced in this section, we investigate the 'Friday effect' in conjunction with the expiration day effect because the stock index futures and options expiration days typically fall on the third Friday of the expiration months, and both effects are associated with increased trading volume.

2.1.2 Expiration day effect

The expiration day anomaly consists of higher trading volume and abnormal volatility near the close on expiration days (Stoll and Whaley 1997; Sukumar and Cimino 2012; Chow et al. 2003; Sadath and Kamaiah 2011). This is particularly of interest to this research, as we investigate the trading volume's relationship to the MSCI rebalances and index options and futures expiration days. Pope and Yadav (1992) found an immediate increase in trading volume before the options expiration day on London Stock Exchange, followed by an immediate decrease after the expiration day. Using Indian financial data, Vipul (2005) observed an abnormally high trading volume, which starts to increase on the previous day of the expiration day and continues into the next day for stocks with relatively high volume of derivatives. Chakrabarti et al. (2005) investigate the effects of changes in MSCI indices and find that the trading volume increases significantly and remains high after the change date for the stocks added to the index. Furthermore, Chiang (2009) observed trading volume peaks occurring on the third Friday of each month; this effect is driven by the option expiration day, since it appears only among optionable stocks, with options expiring on the third Friday of the month.

2.1.3 Turn-of-the-month and end-of-month effects

Another popular effect is the turn-of-the-month effect or end-of-month effect, including other similar effects such as the intra-month, the week-of-the-month and the monthly effects. The intra-month effect consists of positive returns in the first half of the month (and more specifically in the early days of the calendar months) only (Ariel 1987; Rosenberg 2004). The turn-of-the-month effect (Cadsby and Ratner 1992) has been typically defined as the stock price surge on the last day of one month and the first three days of the next month. The four-day turn-of-month period represents 87% of the average monthly return (Kunkel et al. 2003). A plausible explanation is the standardisation of payments at the turn of the month (Ogden 1990). Investigating thinly traded Finnish stocks, Nikkinen et al. (2009) found that the release of major US macroeconomic news is driving the turn-of-the-month and intra-month anomalies. Moreover, the higher returns at the turn-of-the-month are associated with a surge in trading volume, which is potentially caused by the buying pressure at the end of the month (Booth et al. 2001). Strong effects on volume are found in the last trading week of the month in the Finish stock index futures, options, and cash markets (Martikainen et al. 1995).

2.2 The volume-price relation

The empirical evidence from the literature broadly supports the positive correlation between volume and price changes (Harris and Raviv 1993; Hong and Stein 2007). The articles on the price–volume relation reported two forms of price indicators that are correlated with trading volume: first, the magnitude (or absolute value) of the price change, i.e. $|\Delta p|$ (Assogbavi and Osagie 2006); second, the price change per se (or the raw price change value), i.e. Δp (Karpoff 1987). The price change can be either the log-price difference or the percentage price change.

2.3 Stock index futures expiration

Stock index futures were introduced in 1982 and are the second most widely traded futures markets by investors, after interest rates (CME Group 2013). They consist of a prediction of where the underlying index cash market will be and introduced the concept of a cash settlement mechanism in order to address the problem of logistical difficulties regarding the delivery of the actual stocks associated with a particular stock index. A stock index tracks the changes in value of a hypothetical portfolio of stocks. More precisely, a stock's weight in the portfolio represents the proportion of the portfolio that is invested in the stock (Hull 2002). When investors engage in a futures contract, they buy the exposure. Entering a futures contract is done synthetically; people are not buying or trading the underlying basket of stocks. Therefore, a future contract can be regarded as a financial position, where buyers and sellers settle in the currency associated with the investment, since the index comprises of stocks from many companies and their ownership cannot be transitioned at settlement.

The futures expiration days represent the dates when the futures contracts stop trading and when the final price settlement occurs. The expiration days for the investigated European stock index futures occur on the third Friday of the expiration month or the previous day in case this is a bank holiday. The indices' futures contracts are traded either on a quarterly basis, i.e. March, June, September and December (e.g. FTSE 100 and DAX 30), or monthly (e.g. CAC 40, FTSE MIB, IBEX, Amsterdam Exchange, and OMX Stockholm 30). There are two broad categories of players in the futures market, namely hedgers, who are protecting against price risks, and speculators, who seek profits from the price changes that hedgers are protecting against.

2.4 Stock index options expiration

Index options are financial derivatives giving the holder the right, but not the obligation, to buy or sell the value of an underlying index, such as the FTSE 100, at the stated exercise price on the expiration day of the option for the European style index options or at any time before the expiration day for American style index options. There are no actual stocks being bought or sold; index options are always cash-settled. Chicago Board Options Exchange (CBOE) has been offering cash-settled options on stock indices since 1983 (CBOE 2015).

Apart from potentially profiting from general index level movements, index options can be employed to diversify a portfolio when an investor prefers not to invest directly in the underlying stocks of the index. Index options can also be used in multiple ways in order to hedge specific risks in a portfolio.

The delta of an option is the option price rate of change relative to the price of the underlying asset; it is the slope of the curve relating the option price to the underlying asset price (Hull 2002). Delta hedging is an option strategy aiming to hedge the risk associated with price fluctuations in the underlying asset of the options contract by offsetting long and short positions. The investor's position remains delta hedged (or delta neutral) only for a relatively short period of time since delta changes. Therefore, the hedge has to be adjusted periodically, which is known as rebalancing.

2.5 Possible mechanisms behind increased trading activity around expiration dates

The effect of volume surges around index options and futures expiration days and MSCI rebalances can be driven by a number of potential mechanisms, such as the roll forward procedure or the rebalancing of delta hedges.

A potential explanation of the larger trading volumes before the stock index futures expiration day consists of investors wanting to roll their futures contracts. Index options and futures expire and need to be rolled into the new expiration. Investors are going to maintain the position beyond the date and they have to exchange their contract for the next contract (i.e. rolling the position) when the contract expires by placing a trade in another futures or options contract with an expiration day that is further in the future. A roll forward enables traders to maintain their position beyond the initial expiration of the options or futures contract. The roll forward is usually carried out shortly before the expiration day of the initial contract and requires the settlement of any gains or losses on the original contract. Most of the futures contracts are not held until the expiration day. Typically, short-term traders exit their futures positions before their expiration day in order to avoid physically buying or selling the underlying product. However, some close their positions in the run-up to the expiration. There are also mechanisms such as ETFs (i.e. exchange-traded funds) that are tracking indices.

Generally, volume surges in the run-up to expiration days, which leads to an increase in volatility, which then spills over to the equity markets (temporary departures from the fair value of the index futures and options than the actual basket of stocks).

Exchange-based trading of options was introduced on the Chicago Board Options Exchange (CBOE) in the USA in 1973, initially as a pilot program. The main reason for this incremental adoption of option trading was the concern that underlying stock prices could be affected by the exchange-listed option trading. However, little evidence has been published to validate the impact of option trading on underlying stock prices until CBOE (1975) publishes an early report concluding that there is no evidence of abnormal price behaviour in the run-up to the option expiration day.

More recently, Ni et al. (2005) provide evidence that option trading impacts the prices of underlying stocks and that the closing prices of optionable stocks cluster at option strike prices on expiration dates. The average alteration of the returns of stocks with listed options is at least 16.5 basis points per expiration date. According to Ni, Pearson and Poteshman, the key drivers of stock price clustering are delta-hedge rebalancing by option market makers with net purchased option positions, described by Avellaneda and Lipkin (2003), and stock price manipulation by option writers, who write options in the week leading up to the option expiration.

Option pinning is the tendency of stock prices to finish near a strike price on the option expiration days. It involves two markets (i.e. the option market and the underlying asset market), while extending to many other interrelated derivative markets for a given index, e.g. futures on the index, options on the futures, options on the index etc. This phenomenon has been studied by Golez and Jackwerth (2012), who argue that index options induce pinning in the market for index futures. The economic mechanism driving the index futures pinning consist of the interplay of market makers, who rebalance their delta hedge as a result of the time decay of those hedges and as a response to reselling and early exercise of in the money (ITM) options by individual investors.

All in all, option market makers absorb excess demand as options are in zero-net supply and market makers typically hedge their exposure by trading the underlying asset. When options are approaching the expiration day, delta can rapidly change and trigger frequent adjustment of delta hedges, leading to an increased volume in the underlying asset.

2.6 MSCI quarterly index review

The Morgan Stanley Capital International (MSCI) indices group is an investment decision support provider and its indices have been tracked closely by international fund managers since 1969. Approximately $8 trillion are estimated to be benchmarked to the MSCI indices worldwide (MSCI 2014) and 97 of the top 100 largest asset managers are served by MSCI (MSCI 2015). Any stock addition or deletion in any MSCI index attracts significant investor attention across the world. In order to reflect the evolving market, the MSCI indices constituent list changes on a quarterly basis, in February, May, August and November, close to the last trading day of these four rebalancing months. The MSCI national indices' changes are announced two weeks prior to the effective date, allowing the investors to react to the MSCI announcements.

The main objective of index funds is to replicate the performance of a given benchmark. Fund managers need to provide the lowest costs and high transparency to their clients, i.e. equity investors, and are more likely to minimise the benchmark tracking error than to take risks for increasing the returns. MSCI index rebalancing revision schedules are publicly released well before the effective revision date, giving rise to speculations. There are clear abnormal returns around the announcement and implementation dates of the MSCI reviews, with a high concentration in the preceding trading days to implementation. This is followed by reversal after the implementation date. Most importantly, the MSCI abnormal returns were correlated with the trading volume, concluding that the majority of fund managers re-adjust their portfolios at the last minute in order to minimise the tracking error. For the additions and deletions of the MSCI review, the trading volume was on average four times higher on the implementation day than on normal trading days (The Trade 2007).

3 Data set

The sample data set covers 7 liquid European indices and the MSCI International Pan Euro Price Index, between 1st January 2000 and 10th May 2015. The stock universe includes a sample of 506 unique stocks, out of which 408 are members of the indices considered for the stock index expiration day analysis and 344 are constituents of the MSCI International Pan Euro Price Index. The daily market data is complemented by a series of special events, which are potentially associated with non-stationarity. We manually collected expiration dates for the stock index futures and options across 7 European indices and the MSCI quarterly reviews. These were supplemented by the historical list of additions and deletions for each index, which allowed us to generate the point-in-time list of constituents of each index.

3.1 Market data acquisition and processing

Table 1 includes the indices' RIC (Reuters Identification Codes) and the total number of constituents as of 11th May 2015 (i.e. 'current constituents') and the number of previous constituents across the entire study period (i.e. 'historical constituents'). There are 45,912 observations for the stock index expiration day analysis, and 10,298 observations for the MSCI rebalance analysis. We retrieved the historical index additions and deletions in order to generate point-in-time snapshots of each index's list of constituents for each unique expiration day. This process starts with the current

Table 1 Market data European indices for the futures and options expiration day analysis and MSCI rebalance analysis

Analysis type	Index RIC	Index name	Current constituents	Historical constituents	Location
Expiration day	.AEX	Amsterdam Exchange Index	25	37	Netherlands
	.FCHI	CAC 40 Index	40	58	France
	.FTMIB	FTSE MIB Index	40	51	Italy
	.FTSE	FTSE 100 Index	100	152	UK
	.GDAXI	Deutsche Boerse DAX Index	30	38	Germany
	.IBEX	IBEX 35 Index	35	44	Spain
	.OMXS30	OMX Stockholm 30 Index	30	34	Sweden
MSCI rebalance	.MSPE	MSCI International Pan Euro Price Index EUR Real Time	204	344	Europe

Table 2 MSCI constituents—country breakdown

Country code	Country name	Historical constituent count	Historical constituent percentage	Current constituent count	Current constituent percentage
AT	Austria	6	1.74	2	0.98
BE	Belgium	10	2.91	4	1.96
CH	Switzerland	26	7.56	18	8.82
DE	Germany	39	11.34	33	16.18
DK	Denmark	8	2.33	6	2.94
ES	Spain	17	4.94	12	5.88
FI	Finland	8	2.33	4	1.96
FR	France	55	15.99	35	17.16
GB	UK	90	26.16	43	21.08
GR	Greece	6	1.74	0	0.00
IE	(Republic of) Ireland	5	1.45	1	0.49
IT	Italy	23	6.69	13	6.37
NL	Netherlands	17	4.94	13	6.37
NO	Norway	8	2.33	4	1.96
PT	Portugal	3	0.87	2	0.98
SE	Sweden	23	6.69	14	6.86

constituent list (i.e. as of 11th May 2015), and then iterates the historical log of index additions and deletions by going backwards in time.

Based on the union of current and past constituents, daily market data containing OHLC (open, high, low, close) prices and end-of-day volume is retrieved for each stock. The daily data was extracted with an automated script from Thomson Reuters. We substituted the trading volume of a stock's primary RIC for its consolidated volume, which was computed as the sum of a stock's main exchange trading volume and its volume on MTFs (multilateral trading facilities). The consolidated volume is used throughout this study since it provides a better picture of a stock's real liquidity and this resulting consolidated volume is referenced simply as 'volume' hereafter.

Data pre-processing and cleansing involved filtering stocks with at least 100 days of available daily market data, and appending metadata to each stock, including information such as exchange location and currency.

Table 2 shows the country distribution for the MSCI Pan-European Index, where the two-letter country codes are represented using standard ISO 3166-1 alpha-2. Each stock is associated with a country based on its exchange country; for example, a Spanish stock's country code is GB if this stock is trading on the London Stock Exchange.

3.2 Calendar data taxonomy

We manually constructed the stock index futures and options expiration day calendar for 7 European indices and the rebalance calendar for the MSCI quarterly reviews, which provide a representative illustration of the main expiration days in Europe for the most liquid indices. A total number of 1042 futures expiration days (with 32,512 observations of daily trading data), 1288 options expiration days (with 46,103 observations of daily trading data), and 49 MSCI rebalance days (with 10,301 observations of daily trading data) are included in the calendar data.

The futures expiration days fall on the third Friday of the expiration month, which occurs either monthly or quarterly (i.e. it follows the quarterly cycle of December, March, June and September). The options expiration days also fall on the third Friday, but they always occur on a monthly basis. When the third Friday is a non-trading day, the stock index futures expiration day is substituted by the previous working day. We did not include the Euro STOXX 50 index since its constituent list overlaps with the blue-chip companies included in the 7 indices listed below. We retrieved each country's non-trading calendar in order to determine if the expiration day for a given index falls on the third Friday of the expiration month or on the previous trading day if the expiration day falls on a bank holiday. The futures contract specifications were retrieved from Euronext (AEX and CAC 40), Eurex Exchange (DAX 30), London Stock Exchange (FTSE 100), Borsa Italiana (FTSE MIB), Bolsas y Mercados Españoles (IBEX 35) and NASDAQ OMX (OMXS30); the options contract expiration days were collected from Bloomberg. The stock index futures and options expiration day calendar covers the following 7 indices, where only FTSE 100 and DAX have quarterly futures expiration days:

- FTSE 100 Index Futures and Options;
- CAC 40 Index Futures and Options;
- DAX 30 Index Futures and Options;
- FTSE MIB Index Futures and Options;
- IBEX 35 Index Futures and Options;
- Amsterdam Exchange (AEX) Index Futures and Options;
- OMX Stockholm 30 (OMXS30) Index Futures and Options.

With the exception of the two quarterly futures expiration indices (i.e. FTSE 100 and DAX 30), where the futures expiration day overlaps with the options expiration day only once every 3 months per quarter, the options and futures expiration days fall exactly on the same date.

The MSCI rebalances are typically implemented on the last trading day of the following quarterly cycle: February, May, August, and November. However, there are very few exceptions when the MSCI quarterly review date falls a few days before the end of the month. When the rebalance day falls on a trading holiday in a given market, then the relevant trading date of MSCI rebalance is the closest previous trading day. The machine-generated review dates were checked against the quarterly index review documents from www.msci.com and span from February 2003 until May 2015.

3.3 Trading volume summary statistics

Figures 1 and 2 illustrate the surges in trading volume on index options and futures expiration days and MSCI quarterly reviews, respectively. In these figures, the trading volume is normalised as the mean daily volume percentage of the cumulative monthly vol-

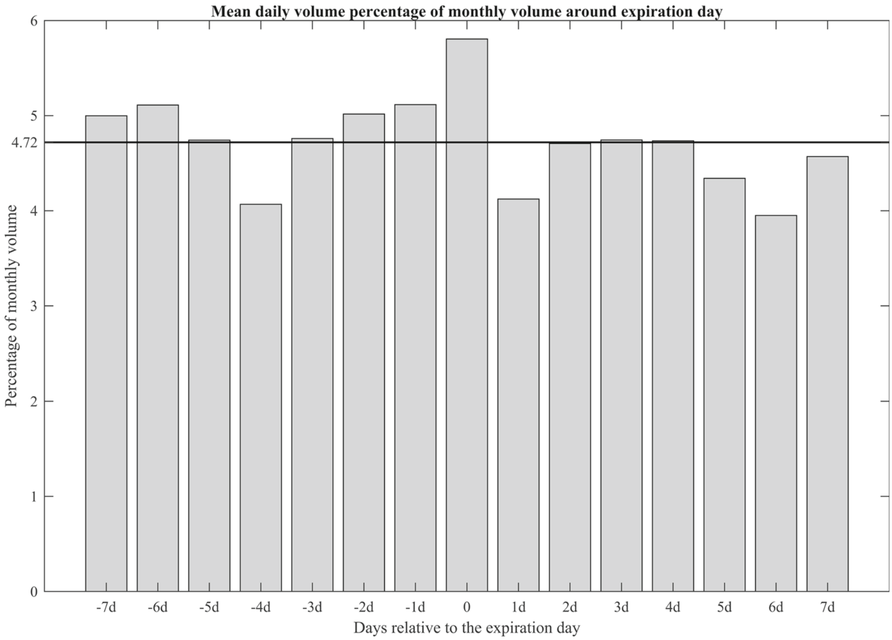

Fig. 1 Mean daily volume percentage of monthly volume around expiration days

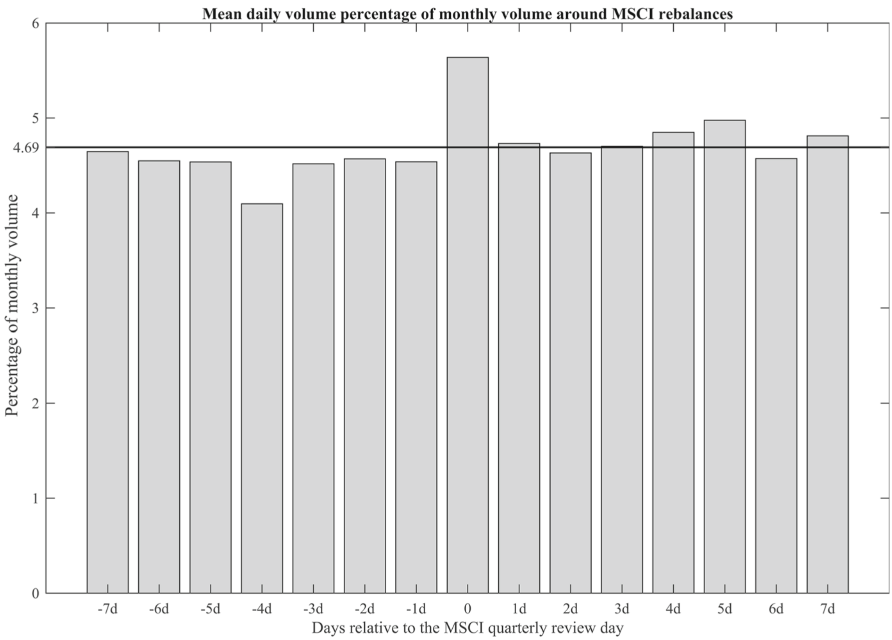

Fig. 2 Mean daily volume percentage of monthly volume around MSCI rebalances

ume. The normalised volumes on index options and futures expiration days and MSCI rebalances are significantly higher than the trading volumes during the 7 trading days in the run-up to the expiration day or MSCI rebalance or during the 7 trading days following these events. Both of these histograms include a horizontal line representing the average across all bins. Figure 1 is based on 66,471 observations of monthly volume for the 403 relevant stocks having minimum 15 daily market data observations per month.

Figure 2 shows the mean daily volume percentage of monthly volume around MSCI rebalances of 59,083 observations of monthly trading volume for the 338 relevant stocks having at least 15 observations of daily market data per month.

4 Analysis approach

This section describes the analytical approach for the index expiration day and MSCI rebalance models. The study commences by validating the existence of the investigated phenomena (i.e. the index options and futures expiration day and the MSCI rebalance, and their relation with an increase in trading activity) by exploring a linear regression model and then employing randomisation tests. Once the existence of these effects is confirmed in the European equity markets as being statistically significant, we build a predictive model, by fitting a number of stepwise regression model (i.e. linear regression models, followed by sequential feature selection) for the index options and futures expiration day, and MSCI rebalance.

The volume on a special date (also called ‘target date’ or t_0, i.e. futures and options expiration days, or MSCI rebalances) is compared with the volume of a benchmark period, which was defined as the median of the 20 trading days prior to a given future expiration day or MSCI rebalance. We chose the median as a measure of central tendency because median is robust to outliers. The study involves data that are periodic, but sparse. There is a number of expiration days and rebalances and we normalise the analysis data in order to identify effects that are common to some stocks and a particular target date, either index options and futures expiration day or MSCI rebalance.

The study also considers a multi-step ahead prediction, up to a step size of 6 trading days. For instance, a 6-step ahead analysis would compute the benchmark volume for the previous 20 trading days for a given date in order to predict the volume impact in 6 days’ time. The default analyses in this study consider one-step ahead forecasting, although the default step size of $n = 1$ day can be lagged and therefore the step ahead lag is defined as $lag = n - 1$. Based on this notation, we define the relative volume for a given expiration or rebalance as the log-ratio between the volume on expiration/rebalance day and its benchmark volume, computed as the median of the previous 20 trading days, as shown in Eq. (1). The target variable in all regression models in this study is the relative volume.

$$V_{\text{rel}} = \log \frac{V_{t0}}{\text{median}\left(V_{t-\text{lag}-1}, V_{t-\text{lag}-2}, \ldots, V_{t-\text{lag}-20}\right)} \tag{1}$$

The index expiration day and MSCI rebalance analyses investigated an anterior or posterior effect in the trading volumes, and therefore, it allowed for offsets relative to the target date, ranging from − 5 days to + 5 days. For example, for an offset of − 3 days, we compute the target date by subtracting 3 trading days from the main target date (i.e. the expiration or rebalance day). A zero-offset analysis considers the expiration day or rebalance day itself. Consequently, we could analyse when the trading volume starts increasing and when it returns to the normal level.

The analysis models are classified into expiration day models and rebalance models, and are fit on different data sets (i.e. different indices). Since we allow for target date offsets, both model classes are fit with and without indicator variables for the number of days relative to the expiration/rebalance day, resulting in 11 additional predictors (ranging from − 5 days to + 5 days).

5 Descriptive modelling

Before validating this paper's hypotheses by conducting a series of randomisation tests and exploring the predictive models in Sect. 7, we provide an OLS descriptive model to explore the positive relationship between the predictors and the target variable, i.e. the trading volume. To this end, we fit two OLS models, one for the index futures and options expiration day and one for the MSCI rebalance, respectively, based on the observed market data of the stocks that were a point-in-time constituent of the analysed indices.

The first OLS model, outlined in Eq. (2), fits the trading volume as a linear function of the indicator variable D_t^{Exp} indicating whether that day is an expiration day (either options or futures expiration day), and two control variables for the day-of-the-week effect, consisting of an indicator variable D_t^{Thu} flagging whether that observation falls on a Thursday and D_t^{Fri} flagging whether it is a Friday. These two day-of-the-week dummy variables were chosen based on the distribution of expiration days, as outlined in Table 4. The high coefficient of the expiration day predictor in Table 3 suggests a positive effect on trading volume when the observation is an index options and futures expiration day. The regression design matrix is constructed on 967,278 observations, out of which 45,743 observations fall on expiration days.

$$V_t = \alpha + \beta_{\text{Exp}} D_t^{\text{Exp}} + \beta_{\text{Thu}} D_t^{\text{Thu}} + \beta_{\text{Fri}} D_t^{\text{Fri}} + \epsilon_t \tag{2}$$

The OLS in Eq. (3) regresses the trading volume on two predictors: the indicator variable D_t^{Reb} flagging whether the observation is an MSCI rebalance day and the indicator variable D_t^{EoM}, which is '1' if the observation falls at least on the 25th day

Table 3 Index expiration day OLS coefficients

Predictor	Coefficient estimate	t statistic	p value
Constant term	− 0.02115	− 33.872	2.43E−251
Expiration day	0.20759	82.171	0
Thursday	0.09108	73.269	0
Friday	0.01918	13.877	8.82E−44

Table 4 Index options and futures expiration day: day-of-the-week distribution

Value	Count	Percentage
1	0	0.00
2	0	0.00
3	29	0.06
4	1179	2.58
5	44,535	97.36

Table 5 Day-of-the-month distribution of MSCI rebalances

Value	Count	Percentage
1–24	0	0.00
25	415	4.04
26	573	5.58
27	610	5.94
28	1911	18.60
29	1212	11.80
30	2535	24.67
31	3018	29.38

Table 6 MSCI rebalance OLS coefficients

Predictor	Coefficient estimate	*t* statistic	*p* value
Constant term	0.02497	38.9340841	0
Rebalance day	0.24803	52.2687882	0
End of month	− 0.09117	− 62.476414	0

of the month and ‘0’ otherwise. This end-of-month dummy variable splits the month on the 25th day of the month based on the distribution outlined in Table 5, where all MSCI quarterly review dates are falling on or after the 25th day of the month. The OLS design matrix has 654,229 observations, with 10,274 being MSCI rebalance days. Table 6 includes the coefficients of the regression model; the high rebalance day coefficient suggests a positive impact on the trading volume when the observation falls on an MSCI quarterly review day.

$$V_t = \alpha + \beta_{\mathrm{Re}b} D_t^{\mathrm{Re}b} + \beta_{\mathrm{EoM}} D_t^{\mathrm{EoM}} + \epsilon_t \tag{3}$$

6 Randomisation analysis

The following randomisation tests address the existence of higher trading activity on the expiration and rebalance days. We test the futures and options expiration day effect against the Friday effect, and the MSCI rebalance effect against the end-of-month effect with regard to higher trading activity. Their control dates account for the day-of-the-week effect and maintain the same proportion of days of the week as the target dates.

The existence of potential structural breaks is analysed in the following randomisation tests in order to allow us to assume structural homogeneity. For this reason, the sample period is divided in two halves (i.e. 1st January 2000–31st December 2007 and 1st January 2008–10th May 2015), and each of these subsamples is analysed, along with the entire sample period. The rationale of dividing the sample on 1st January 2008 is twofold: first, this is an approximate midpoint for our entire sample period; and, second, this coincides with the financial crisis of 2007–2008, whose peak was reached when Lehman Brothers collapsed on 15th September 2008.

The randomisation test generally checks whether two data vectors are significantly different. The difference between these vectors' means is the observed statistic. We randomise the two vectors' labels 1000 times and we compute the newly reshuffled vectors' mean difference. Eventually we test whether the randomised differences are more extreme than the observed difference, resulting in an empirical p value, which is calculated as the percentage of randomisations where the observed difference is larger (for the right-tailed or two-tailed tests) or smaller (for the left-tailed test) than the randomised differences. The p value represents the probability of observing a test statistic at least as extreme as the observed value under the null hypothesis, and if it is small then the validity of the null hypothesis is considered uncertain. When the empirical p value is below the chosen significance level ($\alpha = 5\%$), we reject the null hypothesis.

All of the following randomisation tests are pairwise, and, for each target date, a particular control date is chosen, which is conditioned on the target date. Therefore, the labels are reshuffled on a pairwise basis, flipping a coin for each element in order to decide whether to interchange the target date and the control date.

6.1 Index options and futures expiration days versus control dates

The target dates for the randomisation test between index expiration days and control dates consist of all futures and options expiration dates. There are 32,408 observations of trading days when there are both an index options expiration day and an index futures expiration day. For each target date, we choose the closest control date that falls exactly one or 2 weeks before or after the expiration day. Therefore, the control date falls on the same day of the week as the target date. The test is conducted for each target date offset. When the offset is positive, we do not allow the control date to fall 1 week before the target date, as it would overlap with the critical days around the expiration day. Similarly, when the offset is negative, the control date cannot fall 1 week after the target date. There is a two-tailed test and a right-tailed test. The null hypothesis of the two-tailed test is that the difference between the relative trading volume on the (offset) index options and futures expiration days and the relative trading volume of the control dates comes from a distribution with zero mean, whereas the alternative hypothesis of the right-tailed test is that the mean of the index options and futures expiration day relative volumes is less than the mean of the control date relative volumes.

Table 7 Randomisation tests between index options and futures expiration days and control dates—no target date offset, 1-step ahead modelling

Analysis type	Index RIC	Unique stocks (historical constituents)	Target dates	Randomisation tail (s)	p value	Reject H_0
Individual index	.FTSE	149	5023	Both	0	Yes
	.FTSE	149	5023	Right	0	Yes
	.GDAXI	37	1724	Both	0	Yes
	.GDAXI	37	1724	Right	0	Yes
	.FCHI	54	6929	Both	0	Yes
	.FCHI	54	6929	Right	0	Yes
	.FTMIB	51	4934	Both	0	Yes
	.FTMIB	51	4934	Right	0	Yes
	.IBEX	44	5307	Both	0	Yes
	.IBEX	44	5307	Right	0	Yes
	.AEX	37	3633	Both	0	Yes
	.AEX	37	3633	Right	0	Yes
	.OMXS30	33	4858	Both	0	Yes
	.OMXS30	33	4858	Right	0	Yes
All indices	.FTSE, .GDAXI, .FCHI, .FTMIB, .IBEX, .AEX, .OMXS30	401	32,408	Both	0	Yes
	.FTSE, .GDAXI, .FCHI, .FTMIB, .IBEX, .AEX, .OMXS30	401	32,408	Right	0	Yes

Table 7 shows the randomisation test results for the index options and futures expiration day (i.e. no offset), using 1-step ahead modelling. The results include the aggregated indices, along with a breakdown by individual index, and monthly versus quarterly expiration day indices. Table 8 shows the results for the aggregated indices for offsets − 5 days to + 5 days. The randomisation tests reveal that the trading volume on the expiration day of each index is significantly higher. This is also the case for offsets '− 1', '+ 1' and '+ 2', meaning that the trading volume surges 1 day before the expiration day and remains at high levels for two trading days after the expiration day. The results are consistent across the sample period halves and there are no structural breaks for the futures and options expiration elevated volume. The multi-step ahead modelling rejects the null hypothesis for the same offsets, although the p value varies insignificantly in very few instances, without changing the null hypothesis rejection decision. Figure 3 illustrates the relative volume cumulative distribution for dates with index expiration days (i.e. target dates) and dates with no index expiration days (i.e. control dates), exhibiting larger trading volumes on futures and options expiration days.

Table 8 Randomisation tests between index options and futures expiration days and control dates—all indices, 1-step ahead modelling

Target date offset	Unique stocks (historical constituents)	Target dates	Randomisation tail (s)	p value	Reject H_0
0	401	32,408	Both	0	Yes
0	401	32,408	Right	0	Yes
− 5	401	32,413	Both	0	Yes
− 5	401	32,413	Right	1	No
− 4	401	32,406	Both	0.008	Yes
− 4	401	32,406	Right	0.003	Yes
− 3	401	32,403	Both	0.011	Yes
− 3	401	32,403	Right	0.002	Yes
− 2	401	32,411	Both	0.144	No
− 2	401	32,411	Right	0.041	Yes
− 1	401	32,414	Both	0	Yes
− 1	401	32,414	Right	0	Yes
1	401	32,415	Both	0	Yes
1	401	32,415	Right	0	Yes
2	401	32,416	Both	0	Yes
2	401	32,416	Right	0	Yes
3	401	32,411	Both	0	Yes
3	401	32,411	Right	1	No
4	401	32,411	Both	0	Yes
4	401	32,411	Right	1	No
5	401	32,407	Both	0	Yes
5	401	32,407	Right	1	No

6.2 Index options and futures expiration days versus Fridays

Next, we investigate whether the higher volume associated with the futures and options expiration days is actually caused by the Friday effect or whether it is driven solely by the index options and futures expiration day. The target dates consist of all futures and options expiration days falling on Fridays. There are 30 instances of expiration days falling on the previous day, i.e. on a Thursday. These 30 non-Friday expiration days belong to various indices and there are actually 13 unique non-Friday expiration days, associated with 912 stocks that have been discarded for this randomisation test. The control date for each target date is the closest Friday (in terms of the difference in calendar days from the target date) falling 1 or 2 weeks from the expiration day (i.e. − 2, − 1, + 1, + 2 week/s relative to the expiration day). The alternative hypothesis is that the relative volume on index options and futures expiration days is significantly different from (for the two-tailed test) or larger than (for the right-tailed test) the relative volume on non-expiration Fridays. The randomisation tests in Table 9 reject the null

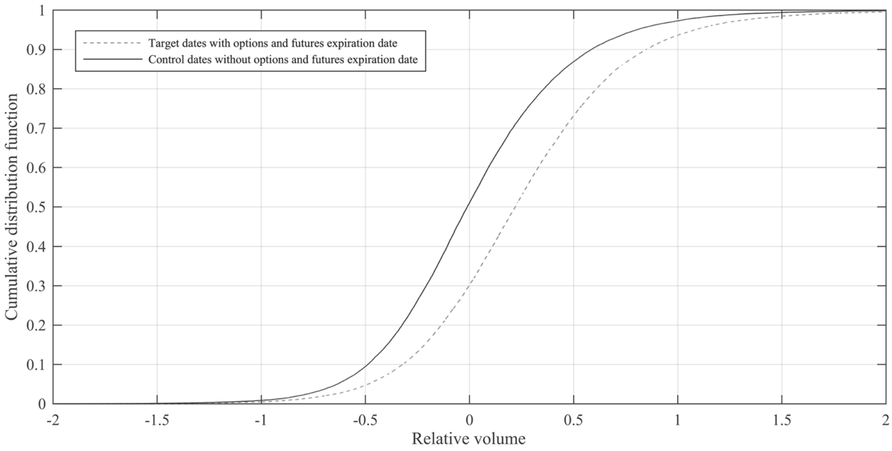

Fig. 3 Relative volume cumulative distribution for dates with index options and futures expiration days and dates with no expiration days

Table 9 Randomisation tests between index options and futures expiration days and Fridays—1-step ahead modelling, all futures and options indices

Unique stocks (historical constituents)	Target dates	Randomisation tail (s)	*p* value	Reject H_0
401	31,496	Both	0	Yes
401	31,496	Right	0	Yes

hypothesis and conclude that the Fridays with futures and options expiration days are the drivers of increased volumes on Fridays. The results are consistent among the two sample halves, i.e. 2000–2007 and 2008–2015. Figure 4 contains the cumulative distributions of the relative volume for the Fridays with and without index options and futures expiration days and illustrates the larger volumes associated with the expiration Fridays.

6.3 MSCI rebalances versus control dates

We further test whether the relative trading volume on MSCI rebalances is higher than the volume on the last trading day of the previous or following month. The target dates consist of all (offset) MSCI rebalance days. For each target date, we find the closest control date that is the last trading day of the previous or the following month. If the target date is offset, then the control date is offset as well. We perform a two-tailed test and a right-tailed test. The alternative hypothesis of the two-tailed test is that the relative trading volume of the relative dates is significantly different from the volume on control dates, whereas the alternative hypothesis of the right-tailed test is that the relative volume of the target dates is larger than the relative volume of the control dates. Table 10 shows the randomisation test results, which confirm that the relative

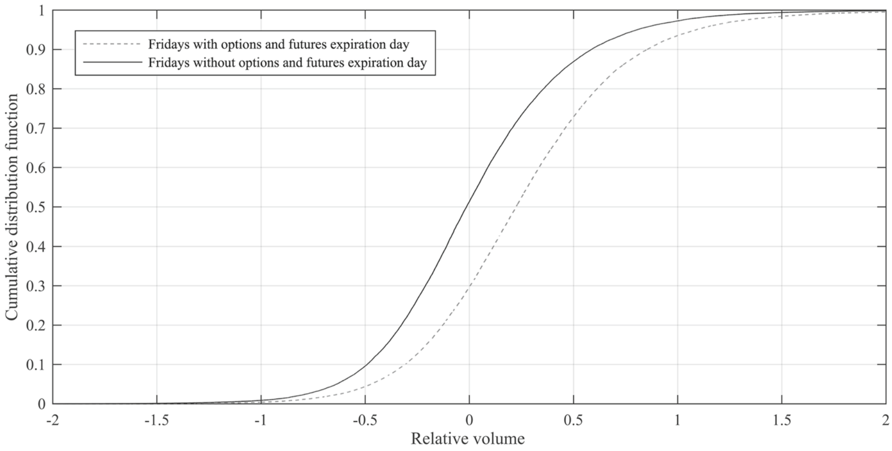

Fig. 4 Relative volume cumulative distribution for Fridays with index options and futures expiration days and Fridays with no index expiration days

Table 10 Randomisation tests between MSCI rebalances and control dates—1-step ahead modelling

Target date offset	Unique stocks (historical constituents)	Target dates	Randomisation tail (s)	*p* value	Reject H_0
0	338	10,298	Both	0	Yes
0	338	10,298	Right	0	Yes
− 5	338	10,340	Both	0	Yes
− 5	338	10,340	Right	1	No
− 4	338	10,338	Both	0	Yes
− 4	338	10,338	Right	1	No
− 3	338	10,341	Both	0.181	No
− 3	338	10,341	Right	0.069	No
− 2	338	10,341	Both	0	Yes
− 2	338	10,341	Right	1	No
− 1	338	10,341	Both	0.002	Yes
− 1	338	10,341	Right	0	Yes
1	338	10,341	Both	0.726	No
1	338	10,341	Right	0.377	No
2	338	10,337	Both	0	Yes
2	338	10,337	Right	1	No
3	338	10,337	Both	0	Yes
3	338	10,337	Right	1	No
4	338	10,338	Both	0	Yes
4	338	10,338	Right	1	No
5	338	10,340	Both	0.001	Yes
5	338	10,340	Right	1	No

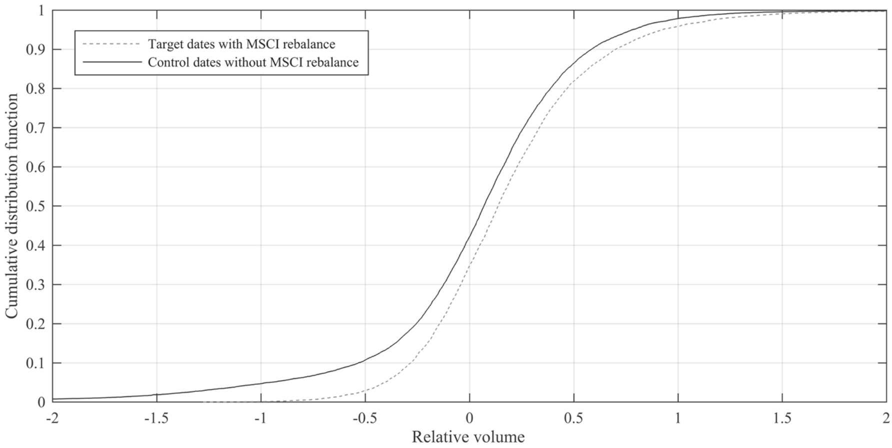

Fig. 5 Relative volume cumulative distribution for dates with MSCI rebalances and dates with no MSCI rebalances

volume on MSCI rebalances is significantly higher than the relative volume of the last trading days of the months without MSCI rebalances. This is also the case for offset '− 1' (for 1-step ahead and 2-step ahead analyses only). Therefore, the trading volume surges one day before the review date, and then goes back to the normal level after the rebalancing. The same results are obtained for 2000–2007. Slightly different results are generated for 2008–2015, where the offset with larger volume is '+ 1', instead of '− 1' trading days. We conclude that the trading volumes are generally larger on the trading day before the review day and on the effective MSCI rebalance day.

Figure 5 illustrates the relative volume cumulative distribution for dates with MSCI rebalances (i.e. target dates) being slightly higher than the relative volumes on dates with no MSCI rebalances (i.e. control dates).

6.4 MSCI rebalances versus end-of-month effects

The randomisation test between MSCI rebalances and end-of-month effects aims to identify the main driver of larger volumes around the end of the month. For this test, we define the relative monthly trading volume as outlined in Eq. (4). We use the arithmetic mean instead of median (as with the relative volumes for a certain target date) because in this case, we are quantifying the volumes occurring at the beginning of month and at the end of the month, and the arithmetic mean better incorporates all observations throughout these periods. Certain volume trends occur over multiple dates, and therefore, such effects would be better accounted for by using the arithmetic mean.

$$V_{\text{rel month}} = \log \frac{\text{mean(last 5 trading days of the month)}}{\text{mean(first 10 trading days of the month)}} \tag{4}$$

The target dates consist of all MSCI rebalance months. For each MSCI quarterly review month, we consider the previous and following months and ultimately flip a

Table 11 Randomisation tests between MSCI rebalances and end-of-month effects—1-step ahead modelling

Sample period (s)	Stocks	Target dates	Randomisation tail (s)	p value	Reject H_0
2000–2007, 2008–2015, 2000–2015	338	10,298	Both	0.005	Yes
	338	10,298	Right	0.999	No

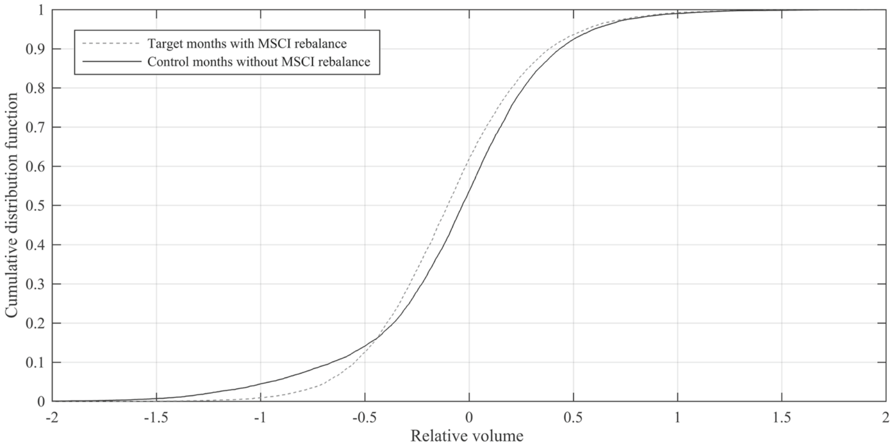

Fig. 6 Relative volume cumulative distribution for months with MSCI rebalance and months with no MSCI rebalances

coin in order to choose whether the previous month or the following month is selected as the control date. We perform a two-tailed test and a right-tailed test for the relative monthly volume of the target months and control months. The alternative hypothesis is that the relative monthly volume on MSCI quarterly review months is significantly different from (for the two-tailed test) or significantly larger than (for the right-tailed test) the relative monthly volume on the months with no MSCI rebalance. Based on the results in Table 11, we report that volume on MSCI rebalance months is significantly different from the volume on months with no MSCI review, but the large trading activity associated with the MSCI rebalances cannot explain the large volumes around the end of the month. Figure 6 visually supports this conclusion and illustrates the relative volume cumulative distribution for months with MSCI rebalances (i.e. target months) and months with no MSCI rebalances (i.e. control months). The monthly volume on MSCI review months has a higher kurtosis than the months with no MSCI rebalances; the monthly volume for control dates has more extreme values on both tails, having a larger dispersion than the target months.

6.5 Summary

The previous randomisation tests provide a methodological rigour for inferring a conclusion with regard to the existence of the studied phenomena. The tests generally found no structural breaks around the financial crisis of 2007–2008, with the exception of a reversing effect for a couple of days adjacent to the MSCI quarterly review dates.

We report significantly higher trading volumes associated with both index options and futures expiration days (starting one day before the expiration day and lasting two days after the expiration day) and MSCI rebalances (starting on the day preceding the rebalance and returning to normal levels the following day after the quarterly review day) relative to the pairwise control dates. However, when comparing the volume on special dates, i.e. index options and futures expiration days and MSCI rebalances, to the cumulative volume on the adjacent days, we can only observe higher trading volume on the expiration day and quarterly review date themselves. We found that the Friday effect does not explain the surge in volumes on futures and options expiration days. Despite presenting evidence that the trading volumes of the months with MSCI quarterly reviews are statistically significant, we draw the conclusion that the larger volumes of the MSCI rebalances cannot explain the end-of-month effect.

7 Predictive modelling

Given the empirical evidence provided by the randomisation tests and the OLS regression, we further investigate the effect size of the index options and futures expiration days and MSCI rebalances in connection with trading volume.

7.1 Modelling approach

The models follow a general stepwise regression framework, which starts by collecting the data, depending on the model (i.e. expiration day or rebalance model), and aggregates the predictors for each target date in the regression matrix. It then performs stratified partitioning on the data set, by creating tenfolds of random subsamples with similar proportions of observation classes. Each class is defined for a unique combination of values for the indicator variables (i.e. predictors whose values are only binary, e.g. 'trading *country code*', 'expiration day *index RIC*', 'offset $\pm n$ days' etc.). The stratified partitioning provides robust results since the classes are evenly distributed across the folds, especially when the data set is unbalanced, and the models are trained and tested based on observations from all classes. Once the tenfolds are defined, the framework proceeds to fitting a multiple linear regression, followed by forward feature selection, where the variable selection objective function minimises the mean squared error (MSE) using tenfold cross-validation (CV). We did not use backward elimination because the models are defined with a constant term (or intercept) and the regression design matrix contains full categorical variables (i.e. categorical variables with n possible values are encoded as n predictors, instead of $n - 1$, because we are exploring the statistical significance of these predictors and perform feature selection on the n possible values) and would lead to multicollinearity issues, where the regression design matrix is rank deficient.

The study also investigates the volume autoregression in the context of special dates (i.e. expiration days and rebalances). Hence, we fit the two model classes with and without 20 lagged volumes, which are normalised by dividing them by their benchmark volume (i.e. the median of the 20 lagged volumes). The volume normalisation is performed in order to account for the different magnitude of the trading volume across different stocks. The normalisation is consistent with the relative volume, which also divides the target volume by the benchmark volume.

We fit a linear regression model for the stock index futures and options effect, and another one for the MSCI rebalance effect. All of the models contain a constant/intercept term. We reduce the dimensionality of these full models by performing sequential feature selection and retrieving a reduced model with fewer features (or predictor variables), while minimising the predictive error of the fit models using different subsets. When performing feature selection, the intercept is always kept in the reduced model. Similarly, if a given model is defined with 20 lagged volumes, these predictors are kept in the model. The objective function of the sequential feature selection seeks to minimise the criterion, which we chose to be the MSE, throughout the potential feature subsets.

We employed a forward selection sequential search algorithm for feature selection, where features are sequentially added to the starting model (i.e. only the constant/intercept term, and possibly the 20 lagged volumes) until no other features can be added in order to decrease the criterion. It is unfeasible to have an exhaustive approach and fit all the feature subsets of a model with *n* features due to time and processing constraints, and therefore, the sequential search algorithm moves only in one direction, always growing the candidate feature set (if using forward selection).

Every time a candidate feature is added to or removed from the model feature set, the candidate model with the new feature set is cross-validated using the objective function, which minimises the MSE criterion. Tenfold stratified cross-validation is applied throughout the analyses of this study, using the same tenfolds that were initially defined in the stratified partitioning of the data set.

7.2 Model outline

There are eight full models that are fit in this study, and Table 12 outlines their full candidate feature sets. The features whose names are marked in italics on the left-hand

Table 12 Regression models—full candidate features

	Index expiration day models				MSCI rebalance models			
Intercept	✔	✔	✔	✔	✔	✔	✔	✔
Trading *country code*					✔	✔	✔	✔
Expiration day *index RIC*	✔	✔	✔	✔				
Target date *offset (from* -5 *to 5 days)*	✔	✔			✔	✔		
20 lagged normalised volumes	✔		✔		✔		✔	

side column indicate multiple features. For instance, 'Trading *country*' would substitute *country* by each trading country of the constituents of the MSCI Pan-European Index, e.g. 'Trading GB', 'Trading DE', 'Trading FR' etc. There are also 20 features for the lagged normalised volume corresponding to each trading day.

The study provides two separate model classes for the expiration day effect, one for the stock index options and futures expiration day and one for the MSCI quarterly index review.

7.2.1 Index expiration day models

For this part of the study, we use the stocks that are members of one of the 7 indices allowing for futures and options. The target date can vary from 5 days prior to the expiration day to 5 days after the expiration day, and therefore, the benchmark period of 20 days is shifted accordingly, accounting for the chosen step size as well (expressed in days). The left-hand side column in Fig. 7 (i.e. Panels A–F) shows the relative volume distribution for the negative target date offsets, ranging from 1 to 5 days prior to the index options and futures expiration day, whereas the right-hand side column, corresponding to Panels G–L, includes the positive target date offsets, ranging from 1 to 5 days after the expiration days. In both columns, the top panel (i.e. Panel A and Panel G) illustrates the volume on the index options and futures expiration day. There is a rather negatively skewed distribution of the relative volume on the expiration day and on the 2 days in the run-up to the expiration day.

The stock index futures and options expiration day models include the constant term and 7 'expiration day *index RIC*' indicator variables. Depending on the model definition, the predictors of some models could include 20 lagged normalised volumes and 11 indicator variables for the target date offset (ranging from − 5 days to + 5 days), where the 0 target date offset is the actual expiration day; this indicator variable is always part of the design matrix regardless of the target date offset configuration.

7.2.2 MSCI rebalance models

The MSCI rebalance effect analysis consists of 204 constituents of the MSCI International Pan Euro Price Index from 15 European countries. This is a heuristic approach having a general date for MSCI quarterly index review, which does not account accurately for every country. The target date of the regression model can vary from 5 days prior to the rebalance day to 5 days after the rebalance day. The benchmark volumes are calculated depending on the chosen target date and step size. The model full candidate features include the intercept and 'trading *country code*' for each of the unique countries where MSCI constituents trade in. Certain model definitions allow for 11 indicator variables for the target date offset (from − 5 days to + 5 days) and 20 lagged normalised volumes.

Figure 8 contains the relative volumes for the negative target date offsets on the left-hand side column, corresponding to Panels A–F, and the positive target date offsets, corresponding to Panels G–L. The figure illustrates the slight negatively skewed distribution of the relative volume on the MSCI quarterly index review day only.

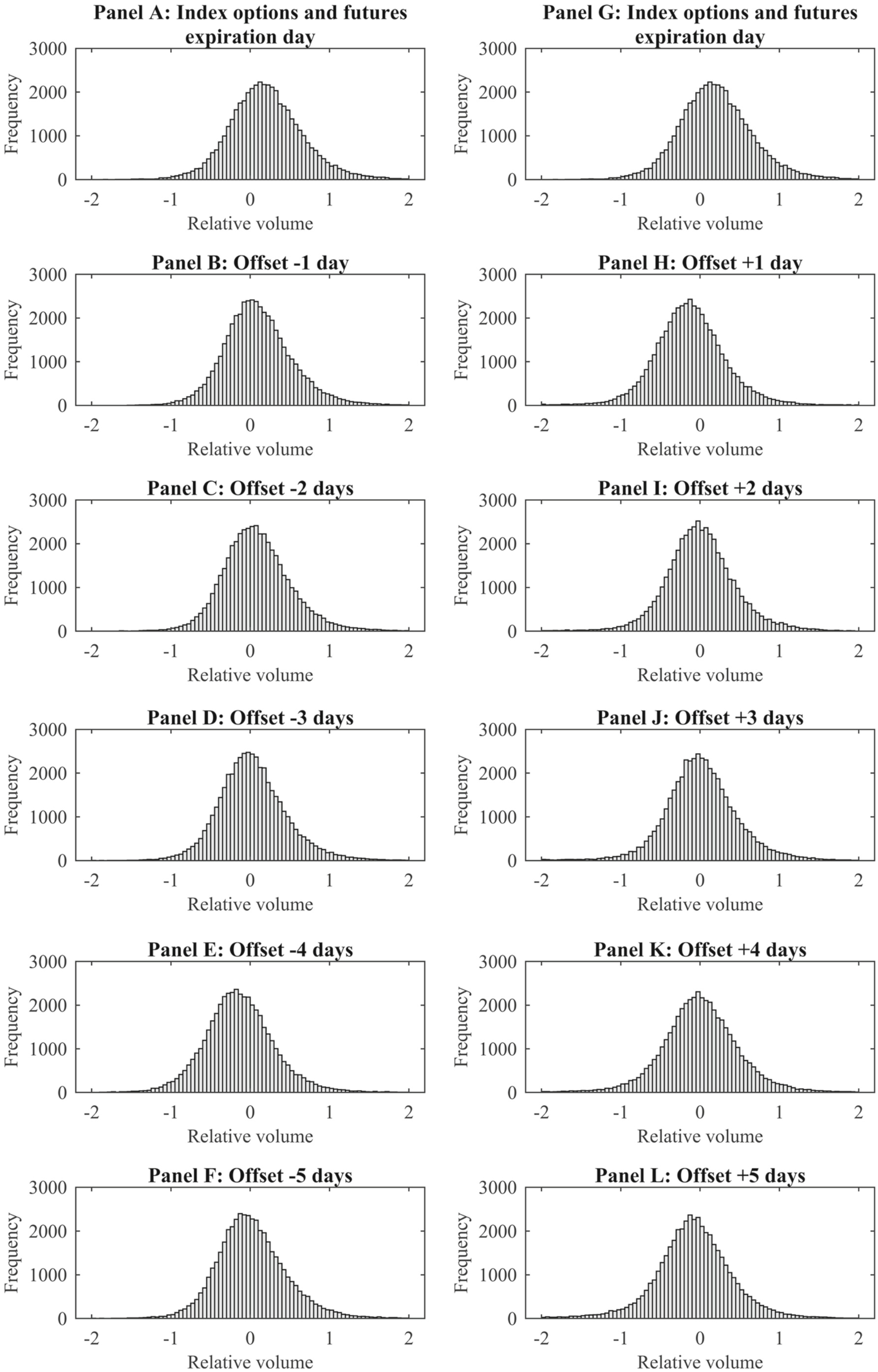

Fig. 7 Relative volume distribution for positive target date offsets (**A**–**F**) and negative target date offsets (**G**–**L**) relative to the index options and futures expiration days

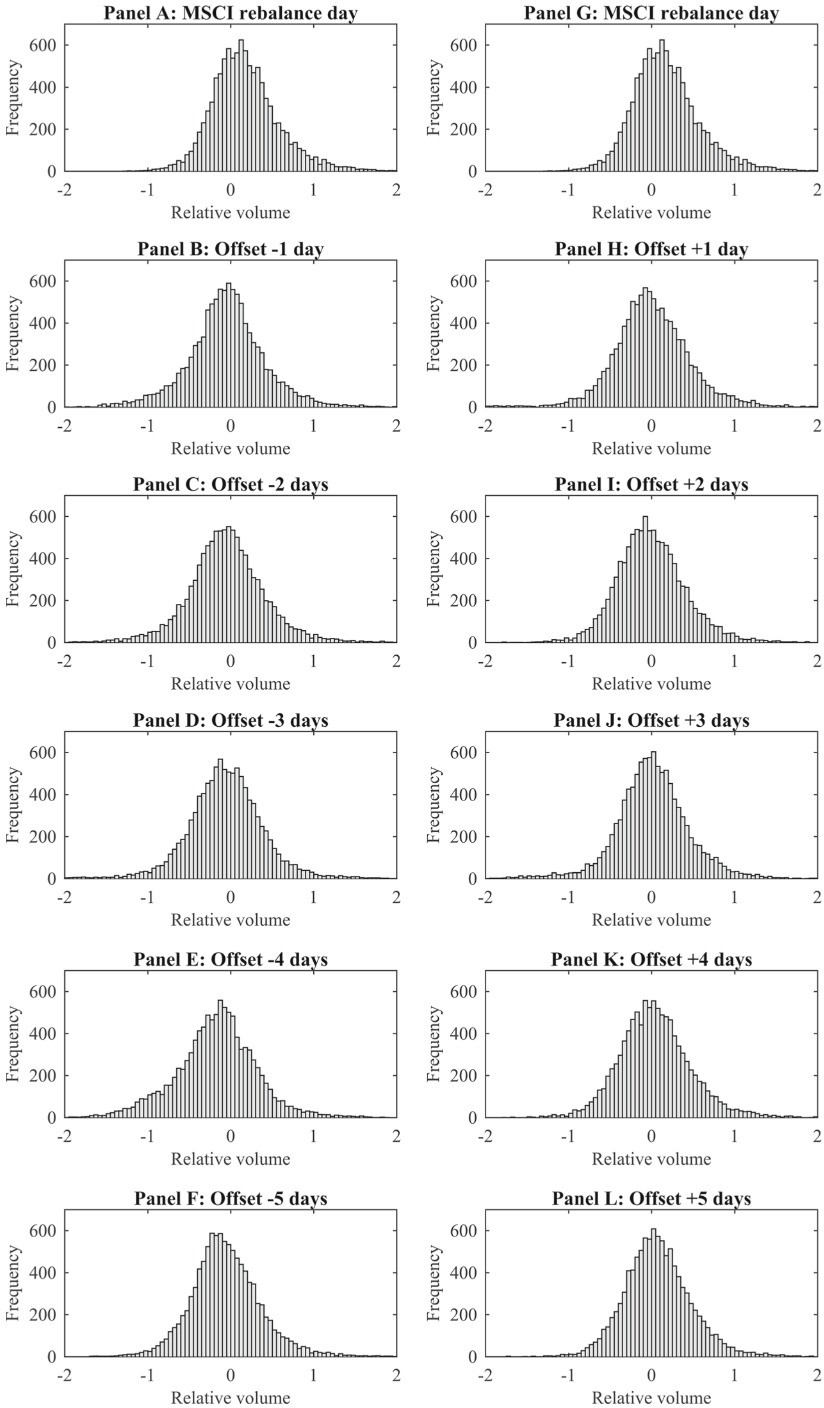

Fig. 8 Relative volume distribution for positive target date offsets (**A**–**F**) and negative target date offsets (**G**–**L**) relative to the MSCI rebalances

Table 13 Comparison of the presence and absence of lagged volumes

Model	Lagged volumes	Observations	CV MSE
Expiration day	Yes	45,912	0.17842
	No	45,912	0.22255
MSCI rebalance	Yes	10,298	0.14490
	No	10,298	0.17587

Table 14 Comparison of the presence and absence of offsets

Model	Target date offset	Observations	CV MSE
Expiration day	Yes	45,912	0.22495
	No	45,912	0.22255
MSCI rebalance	Yes	10,298	0.20140
	No	10,298	0.17587

Next, we examine the results of the index expiration day and MSCI rebalance models and inspect a series of aspects regarding the coefficients and feature sets of these models.

7.3 Volume autoregression

Trading volume autoregression is constantly reported among the index expiration day and MSCI rebalance models. There is a significantly lower cross-validation MSE associated with the models fit with 20 lagged normalised volumes, as outlined in Table 13.

7.4 Target date offset

Fitting the observations for all the offsets that we considered (i.e. − 5 trading days to + 5 trading days, relative to the expiration/rebalance day) and including them into a model with 11-indicator variable for the target date offsets significantly increases the cross-validation MSE, which is reported in Table 14 for models fit with and without target date offsets.

Table 15 outlines the large volume associated with the expiration day and the 2 days prior to the expiration day in the reduced model for futures and options expiration day; there is a significantly positive correlation between trading volume and the MSCI rebalance day indicator. None of the days prior to or after the MSCI rebalance has any significance in terms of predicting the volumes. These coefficients represent the contribution of each feature to the trading volume and do not reflect the phenomenon documented in the previous randomisation tests, where the index options and futures expiration days are associated with high trading volumes from 4 days before the expiration day and until 2 days after the expiration day, and MSCI rebalances cause higher volumes on the day before the rebalance and on the rebalance effective date.

Table 15 Target date offset coefficients

Model	− 5 days	− 4 days	− 3 days	− 2 days	− 1 day	Expiration/rebalance day	+ 1 day	+ 2 days	+ 3 days	+ 4 days	+ 5 days
Index expiration day	0.02	− 0.14	0.03	0.08	0.10	0.20	− 0.14			− 0.01	− 0.10
MSCI rebalance		− 0.12	− 0.01			0.23	0.05	0.05	0.07	0.09	0.13

Based on the previous empirical findings, we fit a futures and options expiration day model and an MSCI rebalance model with 20 lagged normalised volumes and without offsets (i.e. considering only the index options and futures expiration days and the MSCI rebalances as target dates).

7.5 Trading volume on stock index futures and options expiration days

The regression coefficients for the reduced and full index expiration day models are summarised in Table 16, except for the coefficients for the 20 lagged normalised volumes. The 7 ‘expiration day index’ predictors consist of indicator variables which are set to 1 if a given stock is the constituent of this index whose options and futures expiration day relative volume is the target variable. There is certainly strong multicollinearity, reflected by the zero coefficients of DAX and AEX in the full model. We conclude that we cannot discriminate between the expiration day indices of the stocks. Figure 9 illustrates the relative volume cumulative distribution on the target dates (i.e. the index options and futures expiration days) and on the control dates (i.e. dates with no expiration day, falling on the same day of the week as the index expiration day, with an offset up to 2 weeks relative to the expiration day) which were previously generated in the index expiration day randomisation test. We observe strong positive effects driven by the expiration day. DAX 30 exhibits conspicuous expiration day effects. The selected variables in the reduced model and the nearly zero-valued coefficients of AEX and IBEX in the full model are most probably caused by multicollinearity among the predictors.

7.6 Trading volume on MSCI rebalance days

Table 17 outlines the coefficient values for the ‘trading *country code*’ features for the MSCI rebalance reduced and full models. The models are trained with 20 lagged normalised volumes and no target date offsets (i.e. we only consider the MSCI quarterly review dates). The ‘trading country’ predictors are indicator variables denoting the exchange country of each stock that is part of the MSCI index constituent list. We argue that there is no clear discrimination by country of the effect magnitude of MSCI rebalance on the stock volume. The coefficients have high variability between the reduced and full models, which is likely caused by multicollinearity (e.g. Italy’s and Sweden’s coefficients are zero-valued in the full model, while they experience a great increase in the reduced model). The MSCI rebalance randomisation test performed in the Randomisation Analysis section provides evidence of a significantly greater trading volume on MSCI rebalances.

7.7 Multi-step ahead analysis

Multi-step ahead predictions are proposed besides the standard one-step ahead prediction, in order to allow traders to plan their portfolios by predicting an expiration day effect on a stock’s trading volume. A common use case of multi-step ahead pre-

Table 16 Index expiration day model coefficients

Model	Observations	CV MSE	Intercept	Expiration day index						
				FTSE	DAX	CAC	FTSE MIB	IBEX	AEX	OMXS30
Full model	45,912	0.178431591	0.17	− 0.05	0.19	− 0.03	− 0.02	− 0.01	0.00	− 0.14
Reduced model	45,912	0.17842	0.17	− 0.05	0.20	− 0.02	− 0.01			− 0.13

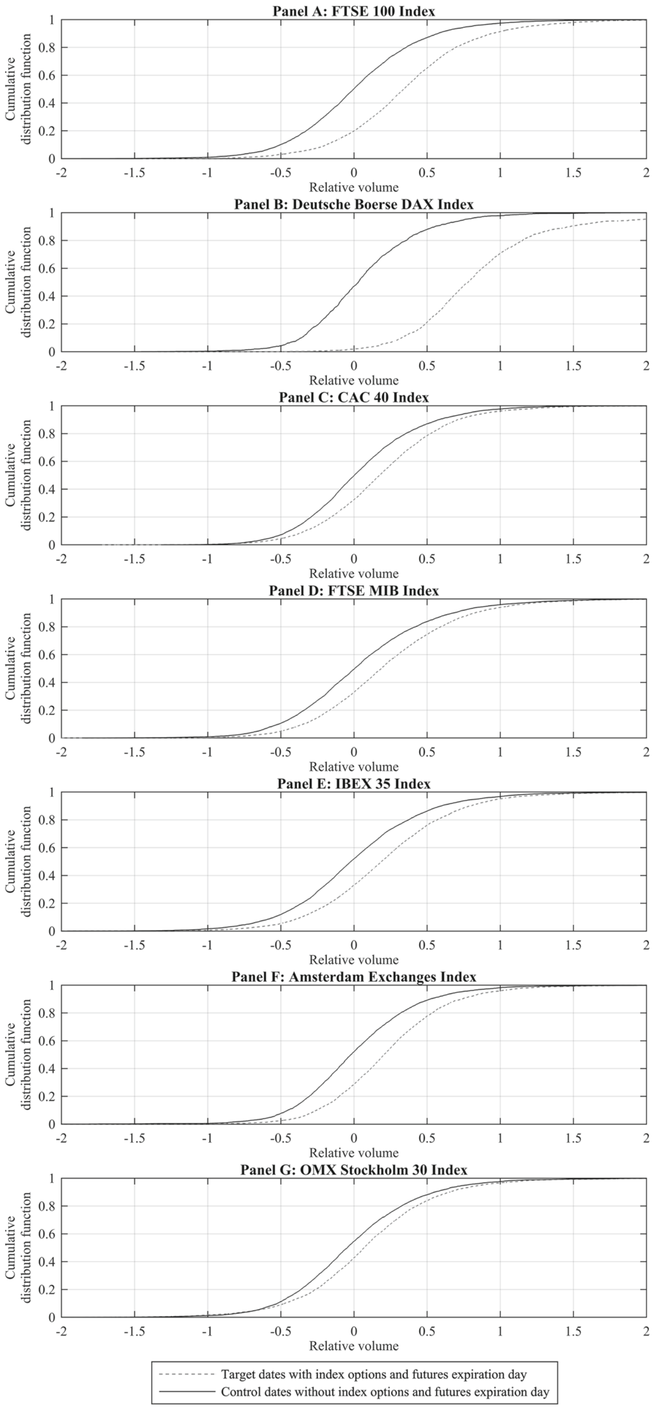

Fig. 9 Relative volume cumulative distribution for the target and control dates for the expiration day of each stock index analysed

Table 17 Pan-European MSCI rebalance model—reduced feature set (selected rebalance-related features exhibited)

Model	Samples	CV MSE	Intercept	Trading country														
				AT	BE	CH	DE	DK	ES	FI	FR	GB	IE	IT	NL	NO	PT	SE
Full model	10,298	0.1449504058	0.41	− 0.06	− 0.11	− 0.22	− 0.24	− 0.15	− 0.18	− 0.21	− 0.17	− 0.24	0.07	0.00	− 0.27	− 0.21	− 0.20	0.00
Reduced model	10,298	0.1448999032	0.18	0.18	0.13			0.09	0.06		0.07		0.31	0.24	− 0.03	0.03	0.03	0.23

Table 18 Comparison of the cross-validation MSE between 1-step ahead and multi-step ahead reduced models

Model name	1-step ahead	Multi-step ahead				
		2	3	4	5	6
Index expiration day	0.17842	0.20623	0.21552	0.22359	0.23179	0.23780
MSCI rebalance	0.14490	0.16417	0.17407	0.17671	0.17879	0.18616

diction for trading volume consists of traders and portfolio managers wanting to size a multi-day order allocation with the aim of minimising the market impact based on the available liquidity. One of the questions they could ask is how the trading volume would be throughout the next days, knowing that the options or futures on the index including a given stock expire in a few days' time. Traders and portfolio managers need to be able to quantify and forecast the volume trends in order to plan multi-day trades. This practical problem has not yet been addressed properly.

Supposing one wants to predict the impact of the expiration day effect on volume in n days' time, then one computes the benchmark volume between $(t - n)$ and $(t - 20 - n)$ and compares it against the volume on the expiration/rebalance day (i.e. V_0) in order to train the model. All the n-step ahead expiration/review day models are fit for each step size n, between 1 day and 6 days, and dimensionality reduction is performed on these full models.

The multi-step ahead models perform similarly to the 1-step ahead analysis, for n ranging from 2 to 6. Their reduced models have similar feature sets to the 1-step ahead analysis. The cross-validation MSE is directly proportional with the step size and there is a constant trend of increasing the MSE as the prediction step ahead lag grows, as described in Table 18.

8 Discussion

The empirical evidence provided by this study supports a futures and options expiration day effect and an MSCI rebalance effect, corresponding to an increase in trading volume for the constituents of these indices on the index options and futures expiration days and the MSCI quarterly reviews, respectively. The expiration day effect could be caused either by the stock index futures and options roll forwards or by hedge rebalancing. The study investigates the European equity markets using a comprehensive pan-European stock universe of almost 500 stocks, with 45,912 observations for the stock index futures and options expiration day analysis, and 10,298 observations for the MSCI rebalance analysis that span almost 16 years. This study complements the existing literature by providing a pan-European empirical study for the expiration day effect on liquidity. We first explore the relationship between trading volume and the analysed periodic events, we then examine the existence of the expiration day effect, and finally propose a predictive model. The randomisation tests are an instance of the methodological rigour of this study, while fitting a number of models by applying stepwise regression represents a methodological novelty in finance, besides the traditional OLS model fitting.

Trading activity surges on the expiration days of stock index futures and options. The volumes exhibit statistically significantly higher volumes relative to their pairwise control dates. A similar spike in trading volume is observed on the MSCI rebalance effective date, with statistically significantly higher volumes compared to their pairwise control dates. This study confirms that equity markets are in a rather steady state, but the market dynamics differ on some periodic notable events, which have been investigated in this study in order to document the temporal factors driving trading volume. The results are validated by the initial randomisation tests and the large European data universe.

We investigate whether it is the Friday effect or the Friday futures and options expiration day that drives the trading volume up and we provide evidence of a strong index options and futures expiration day effect. Furthermore, we analyse whether the MSCI rebalances can explain the end-of-month larger volumes; however, we conclude that the magnitude of the MSCI quarterly reviews is not sufficient to cause a generalised increase in volumes at the end of the month throughout the year. There is a potential end-of-month effect itself, which is driven by various factors that are well-documented in the literature, e.g. buying pressure around the end of the month, standardisation of payments around the turn-of-the-month, or the release of major US macroeconomic news.

Trading volume constantly exhibits a significant autoregressive property among the index options and futures expiration day and MSCI rebalance models. The study comes to an end by proposing a multi-step ahead prediction framework, which could be adapted in the industry such that traders and hedge fund managers could anticipate an expiration day effect by planning their portfolio in advance based on the predicted trading activity.

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OPTIONS EXPIRATION EFFECTS AND THE ROLE OF INDIVIDUAL SHARE FUTURES CONTRACTS

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LI YANG*

This note examines options expiration effects in the presence of individual stock futures contracts with different settlement methods. It is found that the availability of the futures contracts attenuate the expiration effects on price volatility and trading volume of individual stocks. Also, the stock price tends to move up near expiration days after physical delivery replaces cash settlement. These results provide empirical support to the conjectures made in Corredor et al. (2001). © 2003 Wiley Periodicals, Inc. Jrl Fut Mark 23:1107–1118, 2003

INTRODUCTION

Options expiration effects describe the seemingly aberrant behavior of the underlying security price when the corresponding options are near contract expiration. Stoll and Whaley (1997) suggest that the exploitation

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of arbitrage, cash settlement, and manipulation all contribute to the prevalence of the expiration effects. Mayhew (2000) summarizes the empirical findings in the literature and concludes that, while trading volume tends to be unusually high around the expiration dates, there is little evidence of a strong systematic price effect or volatility effect (especially after 1987). Corredor et al. (2001) argue that the no-effect conclusions are likely due to the high level of liquidity of the security markets examined by the previous literature. In small, illiquid markets, stronger expiration effects are expected.

Using Spanish data, Corredor et al. (2001) find that, consistent with Mayhew (2000), index options lead to an increase in trading volume with no significant changes in prices or volatility. On the other hand, much stronger expiration effects are established in stock options: an increase in volume, a reduction in volatility, and a downward pressure in prices. Corredor et al. (2001) attribute the difference to two possible factors. First, there is an active stock index futures market, but no individual stock futures markets are available for trading. Second, the stock options are settled by physical delivery, whereas the index option uses a cash settlement method. A futures market promotes arbitrages resulting in better liquidity, which in turn, depresses the expiration effects. On the other hand, Stoll and Whaley (1997) suggest that cash settlement on futures contracts is likely to induce expirations effects, particularly when the settlement price is not the same as the spot price at close. For Australian individual share futures contracts, the settlement prices are set at the average of last bid and ask futures prices (when the contracts are settled in cash), which may not be the same as the spot price at close. Therefore, stronger expiration effects are expected when cash-settled futures contracts are traded. Nonetheless, empirical findings in Stoll and Whaley (1997) do not support this conjecture. Corredor et al. (2001) state that, when options contracts are settled by physical delivery, there is pressure on the sales in the underlying market when the expiration date of options arrives as a result of ordering positions, promoting expiration effects.

This research investigates how expiration effects vary with respect to the availability and settlement method of individual share futures contracts using Australian data. Before 1994, while stock options were actively traded, there was no corresponding futures market on any stock. Then, 11 individual share futures (ISF) contracts were gradually introduced. Initially, all ISF contracts adopted the cash settlement method. In 1996, the Sydney Futures Exchange (SFE) began to replace cash settlement by physical delivery requirements. Thus, we have three periods to study expiration effects. In the pre-1994 period, there are no individual stock futures contracts, a scenario similar to Corredor et al. (2001). During the 1994–1996 period, cash-settled ISF contracts are traded along side the stock options markets. In the post-1996 period, only ISF contracts settled by physical delivery are available. By comparing expiration effects across these three periods, the two conjectures provided by Corredor et al. (2001) can be examined.

INDIVIDUAL SHARE FUTURES AND OPTIONS CONTRACTS IN AUSTRALIA

ISF contracts are futures contracts on the shares of listed companies on the exchanges. In Australia, ISF contracts were introduced in 1994 on the SFE. Currently, there are ISF contracts underlying 11 individual stocks. Prior to March 1996, the ISF contracts were settled in cash. On March 29, 1996, SFE modified rules to switch ISF contracts of Broken Hill Proprietary, Ltd. (BHP), Western Mining (WMC), and Rio Tinto (RIO) from cash settlement to physical delivery of shares. Seven more ISF contracts were switched at later dates as their respective cash-settled contracts expired. Telstra Corporation is the lone exception. Its futures contract has been settled in cash since it was first introduced in November 1997. We, therefore, remove it from our analysis. Table I reports names, codes, and industry classification of stocks, listing dates of the corresponding futures contracts, and the switching dates from cash settlement to physical delivery of the corresponding futures contracts, respectively.

TABLE I

Australian Individual Share Futures Contracts: Names, Codes, and Industry Classification of Underlying Stocks, Listing Dates, and Settlement Method Switching Dates

Name of Company	*Code*	*Industry Classification*	*Listing Date*	*Switching Date*
Broken Hill Proprietary, Ltd.	BHP	Materials	May 16, 1994	March 29, 1996
National Australia Bank	NAB	Banks	May 16, 1994	April 26, 1996
News Corporation	NCP	Media	May 16, 1994	May 31, 1996
Mount Isa Mines Holdings	MIM	Materials	Sept. 26, 1994	April 26, 1996
Western Mining Corporation	WMC	Materials	Sept. 26, 1994	March 29, 1996
Western Banking Corporation	WBC	Banks	Sept. 26, 1994	April 29, 1996
Australia and New Zealand Banking Group	ANZ	Banks	March 13, 1995	April 26, 1996
Fosters Brewing Group	FBG	Food Beverage	March 13, 1995	April 26, 1996
Rio Tinto	RIO	Materials	March 13, 1995	March 29, 1996
Pacific Dunlop	PDP	Materials	Oct. 18, 1995	May 31, 1996
Telstra	TLS	Telecommunication	Nov. 28, 1997	

TABLE II
Specifications of Broken Hill Proprietary (BHP) Stock Futures and Options Contracts Traded on the Sydney Futures Exchange and Australian Stock Exchange, Respectively

Futures on BHP	
Contract unit	1,000 Broken Hill Proprietary (BHP) Shares
Contract months	March/June/September/December up to four quarter months ahead
Quotations/tick size	Prices are quoted in terms of cents per share with a minimum fluctuation of 1 cent (A$ 10.00 per contract)
Last trading day	Trading ceases at 4:40 p.m. on the last Thursday of the settlement month (timed to coincide with the expiry of ASX equity options)
Settlement day	The business day following the last day of trading
Trading hours	5:10 p.m.–7:00 a.m. and 9:50 a.m.–4:30 p.m. (Australian winter time)
	5:10 p.m.–8:00 a.m. and 9:50 a.m.–4:30 p.m. (Australian summer time)
Settlement method	1,000 underlying shares per contract. Delivery occurs via ASX's CHESS system on Settlement Day. No adjustments for dividends and an identical adjustment outcome to ASX equity options for all other capital reconstructions (share splits, bonus, and rights issues, etc.)
Options on BHP	
Contract unit	1,000 shares per contract. This may be adjusted for rights, bonus issues, and other capital adjustment events.
Tick size	$0.001 per share ($1 per contract)
Exercise style	Usually American, i.e., exercisable on or before the expiry date
Type	Call and put options
Contract months	In expiry cycle of March, June, September, and December
Last trading	Last business day of the contract month
Trading hours	Normal trading 10:00 a.m.–12:30 p.m. and 2:00 p.m.–4:15 p.m. (Sydney time). Late trading 4:15 p.m.–5:00 p.m. and overseas trading in accordance with the ASX Business Rules.
Settlement	Physical delivery of underlying security

Source: Sydney Futures Exchange and Australian Stock Exchange.

Exchange traded stock options first appeared on the Australian Stock Exchange (ASX) in February 1976. Currently, there are options underlying 62 ASX listed stocks. The stock options are American options. The settlement of the contract is by physical delivery. Table II provides the example of futures and options contract specification of the Broken Hill Proprietary (BHP) stock.

DATA DESCRIPTIONS

Daily data are used in our analysis, specifically, daily closing prices and trading volumes of 10 stocks underlying the ISF contracts. The sample period covers from January 1991 to December 2000. We divide the sample into three periods to study the effect of the options expiration on the underlying stock market in presence of the ISF contracts with different settlement methods. The first period, in which only stock options were traded, covers from January 1991 to the day before each cash-settled ISF contract was introduced. The second period, in which cash-settled ISF contracts were traded alongside the stock options markets, covers from the first day of each cash-settled ISF contract introduced to the day of each cash-settled ISF contract switched to physical delivery (note that Table I provides information on listing and switching dates for each stock futures contract). The third period, in which the ISF contracts were settled by physical delivery and traded alongside the stock option markets, covers from the day after the switching date of each ISF contract to December 2000. Daily stock price and volume data are collected from Datastream. The listing and switching dates of the stock futures contracts are obtained from SFE.

EFFECTS ON STOCK RETURNS

To test for the effects of expiration days on stock returns, we consider the following statistical model:

$$R_t = \alpha_0 + \alpha_1 D_{ft} + \alpha_2 D_{pt} + (\beta_0 + \beta_1 D_{ft} + \beta_2 D_{pt}) R_{t-1} + (\gamma_0 + \gamma_1 D_{ft} + \gamma_2 D_{pt}) D_t + \varepsilon_t \quad (1)$$

where R_t is the nominal return of the stock, i.e., the change in the logarithmic stock price; and R_{t-1} is the lagged return. The dummy variables, D_{ft} and D_{pt}, are used to capture the different periods of futures availability and settlement method. $D_{ft} = 1$ if the ISF contract is available at time t, and 0 otherwise. $D_{pt} = 1$ if the existing ISF contract is settled by physical delivery at time t, and 0 otherwise. An additional set of dummy variables, $D_t = (D_{1t}, D_{2t}, D_{5t})$, are used to measure the expiration effects. $D_{1t} = 1$ if t is an expiration day, and 0 otherwise. $D_{2t} = 1$ if t is an expiration day or 1 day before an expiration day, and 0 otherwise. $D_{5t} = 1$ if t is an expiration day or less than 5 days prior to an expiration days, and 0 otherwise. We estimate the model three times, each using one of the dummy variables (D_{1t}, D_{2t}, and D_{5t}). The coefficients, α_0, α_1, and α_2 measure the additional returns attributable to the availability and settlement method of the futures contracts, respectively. The coefficients, β_0, β_1, and β_2 measure the impact of the availability and settlement method of the futures contracts on the relations between stock returns and lagged returns, respectively. Moreover, the coefficients, γ_0, γ_1, and γ_2 measure the additional returns attributable to the availability and settlement method of the futures contracts on the expiration date (when D_t is replaced by D_{1t} in the model), on the expiration date and one day before (when D_t is replaced by D_{2t} in the model), or on the expiration date and previous 4 trading days (when D_t is replaced by D_{5t} in the model), respectively.

We first use OLS to estimate the model. After applying the heteroskedasticity test of Engle (1982) on the residuals, we find the ARCH effects. Hence, we introduce the time-varying variance in the model. We consider the GARCH model and several variations. Finally, the GJR model (Glosten et al., 1993), which allows for asymmetric effect of lagged shocks on the volatility, is adopted for the variance equation[1]:

$$\sigma_t^2 = \varphi_0 + \varphi_1\sigma_{t-1}^2 + \varphi_2\varepsilon_{t-1}^2 + \varphi_3 S_{t-1}^{-}\varepsilon_{t-1}^2 \quad (2)$$

where ε_t is a normal random variable with zero mean and variance ${\sigma_t}^2$; $S_{t-1}^{-} = 1$ when $\varepsilon_t < 0$, and 0 otherwise. Thus, φ_3 captures the asymmetric effect. We use the maximum likelihood method to estimate the model of the mean Equation (1) and variance Equation (2). We estimate it three times, each using one of the dummy variables (D_{1t}, D_{2t}, and D_{5t}). Here, we report only the coefficients for each expiration dummy variable (γ_0, γ_1, and γ_2) and their corresponding t statistics in Table III. Complete estimation results are available upon request from the authors.

On the expiration day (D_{1t}), none of the coefficients γ_0, γ_1, and γ_2 across 10 stocks are significantly different from zero. On the day before the expiration day (D_{2t}), one of γ_1 (MIM) and one of γ_2 (MIM) have changed from insignificant to significant, whereas γ_0 across 10 stocks remain unchanged. Five days prior to the option expiration day (D_{5t}), 4 out of 10 stocks (BHP, MIM, ANZ, and FBG) experience (statistically) significant upward price movement after the settlement method of their ISF contracts are switched from cash settlement to physical delivery. In addition, two stocks (WBC and ANZ) show significant price increase in the absence of their ISF contracts, and one stock (WBC) displays a significant price decrease after introduction of its ISF contract.

The above results indicate that there is no options expiration day effect on the stock return before the corresponding futures contract is introduced. The introduction of a cash-settled stock futures contract does not change the results. In fact, the addition of the stock futures contracts should reduce the expiration effects. Given that there is no such effect in the absence of the futures contract, we expect the

[1]In the variance equation, we do not consider the possibility of expiration effects because we discuss this topic specifically in the next section.

TABLE III
Expiration Effects on Stock Returns

	D_{1t}			D_{2t}			D_{5t}		
	γ_0	γ_1	γ_2	γ_0	γ_1	γ_2	γ_0	γ_1	γ_2
BHP	0.14	0.40	−0.44	0.08	0.19	−0.20	0.17	−0.40	0.71
	(0.75)	(1.30)	(−1.38)	(0.47)	(0.64)	(−0.55)	(0.97)	(−1.39)	(1.91)*
NAB	0.18	−0.09	0.00	0.15	0.04	−0.02	0.00	−0.02	0.32
	(0.99)	(−0.29)	(0.01)	(0.89)	(0.13)	(−0.06)	(−0.01)	(−0.08)	(0.86)
NCP	0.30	−0.22	−0.12	0.13	0.06	−0.18	0.44	−0.45	0.77
	(0.97)	(−0.48)	(−0.27)	(0.45)	(0.15)	(−0.33)	(1.52)	(−1.04)	(1.43)
MIM	0.11	−0.39	0.18	−0.02	0.81	−1.25	−0.02	0.37	1.26
	(0.42)	(−0.78)	(0.33)	(−0.09)	(1.71)*	(−2.04)**	(−0.08)	(0.78)	(2.06)**
WMC	−0.18	0.25	0.05	0.16	0.20	−0.40	0.13	−0.16	0.77
	(−0.75)	(0.56)	(0.12)	(0.72)	(0.49)	(−0.80)	(0.56)	(−0.38)	(1.53)
WBC	−0.03	0.48	−0.27	−0.15	0.31	0.31	0.54	−0.68	0.12
	(−0.13)	(1.33)	(−0.80)	(−0.65)	(0.88)	(0.69)	(2.50)***	(−1.93)*	(0.26)
ANZ	0.05	−0.17	0.45	0.08	−0.06	0.26	0.40	−0.54	1.01
	(0.21)	(−0.41)	(1.14)	(0.42)	(−0.15)	(0.52)	(1.95)*	(−1.38)	(2.07)**
FBG	0.06	−0.09	0.17	0.03	0.21	−0.36	0.22	−0.41	0.78
	(0.23)	(−0.22)	(0.44)	(0.14)	(0.51)	(−0.76)	(0.93)	(−1.01)	(1.69)*
RIO	0.17	−0.09	0.18	0.24	−0.15	0.27	0.07	0.06	0.50
	(0.89)	(−0.24)	(0.46)	(1.33)	(−0.42)	(0.64)	(0.37)	(0.16)	(1.20)
PDP	0.10	−0.16	0.06	−0.10	−0.09	0.49	0.15	−0.04	0.19
	(0.50)	(−0.37)	(0.13)	(−0.60)	(−0.20)	(0.82)	(0.86)	(−0.08)	(0.31)

*Denotes statistical significance at the 10% level.
**Denotes statistical significance at the 5% level.
***Denotes statistical significance at the 1% level.

conclusion to extend to the case where the ISF contracts are available. On the other hand, the change in settlement method provides a different story. Five days prior to the option expiration day, statistically significant price increases are observed for 4 of 10 stocks. As suggested by Corredor et al. (2001), a physical delivery requirement promotes security market trading and, therefore, enhances the expiration effect. Although Corredor et al. (2001) report a downward pressure associated with the week before the expiration, we detect an upward movement.

EFFECTS ON STOCK VOLATILITY

To examine the effects of expiration days on stock volatility, we follow the method by Antoniou and Holmes (1995) and include the expiration dummy variables in the variance equation and take out the dummy variables from the mean Equation (1). The model to examine the expiration effect on the stock volatility is modified as follows:

$$R_t = \lambda_0 + \lambda_1 R_{t-1} + \mu_t \tag{3}$$

and

$$\sigma_t^2 = (\varphi_0^0 + \varphi_0^1 D_{ft} + \varphi_0^2 D_{pt}) + (\varphi_1^0 + \varphi_1^1 D_{ft} + \varphi_1^2 D_{pt})\sigma_{t-1}^2 + (\varphi_2^0 + \varphi_2^1 D_{ft} + \varphi_2^2 D_{pt})\varepsilon_{t-1}^2 + (\varphi_3^0 + \varphi_3^1 D_{ft} + \varphi_3^2 D_{pt})S_{t-1}^- \varepsilon_{t-1}^2 + (\varphi_4^0 + \varphi_4^1 D_{ft} + \varphi_4^2 D_{cp})D_t \quad (4)$$

All the dummy variables are defined as the above. The coefficients, φ_0^0, φ_0^1, and φ_0^2, measure the additional volatility attributable to the availability and settlement method of the ISF contracts, respectively. The coefficient sets, φ_1^0, φ_1^1, and φ_1^2, and φ_2^0, φ_2^1, and φ_2^2, measure the impact of the availability and settlement method of the ISF contracts on the relations between stock volatility and lagged volatility and on the relationship between stock volatility and the size of previous residuals, respectively. The coefficients, φ_3^0, φ_3^1, and φ_3^2, measure the asymmetric effects associated with the availability and settlement method of the ISF contracts, respectively. Most importantly, the coefficients, φ_4^0, φ_4^1, and φ_4^2, measure the options expiration effects associated with availability and settlement method of the ISF contract, respectively. The maximum likelihood method is used to estimate the model. We report only the estimation results on the coefficients, φ_4^0, φ_4^1, and φ_4^2, which are related to the expiration dummy variables (D_{1t}, D_{2t}, and D_{5t}), and their corresponding t statistics in Table IV. Complete estimation results are available upon request from the authors.

In absence of the ISF contracts, the volatility of stock WMC increases significantly, whereas the volatility of NAB decreases significantly on the expiration day and the day before the expiration day. The effects disappear in the next period when the cash-settled ISF contracts are available. In addition, no significant effects are observed for stock RIO 5 days prior to the expiration day in the absence of the ISF contracts. When the cash-settled futures contracts are available, the volatility of RIO decreases significantly. On the other hand, the volatility of PDP and ANZ decreases significantly on the expiration day and 1 day before the expiration day, and 5 days prior to the expiration day, respectively, in absence of the ISF contracts. But, the volatility reduction is replaced by volatility enhancement when the cash-settled futures contracts are available. Overall, individual stock futures markets have some impact on the expiration effects on stock volatility. Most likely the ISF markets depress the expiration effects on stock volatility; however, the empirical support is rather weak.

TABLE IV
Expiration Effects on Stock Volatility

	D_{1t}			D_{2t}			D_{5t}		
	φ_4^0	φ_4^1	φ_4^2	φ_4^0	φ_4^1	φ_4^2	φ_4^0	φ_4^1	φ_4^2
BHP	−0.14	0.36	−0.24	−0.08	0.12	−0.10	−0.05	−0.01	−0.03
	(−0.82)	(1.04)	(−0.50)	(−0.82)	(0.64)	(−0.39)	(−1.03)	(−0.10)	(−0.26)
NAB	−0.51	−0.05	0.73	−0.31	−0.01	0.38	−0.17	−0.01	0.10
	(−3.47)***	(−0.22)	(1.76)*	(−3.99)***	(−0.10)	(1.72)*	(−1.64)	(−0.04)	(0.69)
NCP	−0.15	−0.17	0.37	−0.06	0.28	−0.20	−0.14	0.20	0.23
	(−0.33)	(−0.22)	(0.42)	(−0.23)	(0.61)	(−0.40)	(−1.04)	(0.94)	(0.92)
MIM	0.26	−0.64	−0.41	0.19	−0.17	−0.42	0.02	−0.20	0.22
	(0.70)	(−0.76)	(−0.38)	(0.94)	(−0.37)	(−0.69)	(0.22)	(−1.08)	(0.87)
WMC	0.76	−0.25	−0.67	0.30	0.09	−0.43	0.02	−0.03	−0.03
	(2.18)***	(−0.37)	(−0.97)	(1.69)*	(0.24)	(−1.11)	(0.27)	(−0.16)	(−0.18)
WBC	−0.14	0.19	1.49	−0.16	0.15	0.86	−0.16	0.13	0.22
	(−0.35)	(0.40)	(1.85)*	(−0.80)	(0.59)	(2.05)**	(−1.63)	(1.02)	(0.92)
ANZ	−0.35	0.99	−0.03	−0.17	0.36	0.03	−0.24	0.42	−0.22
	(−1.09)	(1.74)*	(−0.04)	(−0.98)	(1.25)	(0.07)	(−2.96)***	(2.62)***	(−1.12)
FBG	0.14	0.43	−0.56	−0.14	0.35	−0.40	−0.29	0.22	−0.18
	(0.29)	(0.67)	(−0.85)	(−0.53)	(1.03)	(−1.17)	(−1.94)*	(1.31)	(−1.20)
RIO	0.02	−0.20	0.08	−0.01	−0.30	0.22	−0.13	−0.25	0.32
	(0.09)	(−0.39)	(0.15)	(−0.06)	(−1.24)	(0.72)	(−1.50)	(−2.37)***	(2.45)***
PDP	−0.96	1.56	−1.56	−0.60	0.67	−0.72	−0.03	−0.25	0.00
	(−5.59)***	(2.16)**	(−1.94)*	(−4.28)***	(1.89)*	(−1.73)*	(−0.28)	(−1.30)	(0.00)

*Denotes statistical significance at the 10% level.
**Denotes statistical significance at the 5% level.
***Denotes statistical significance at the 1% level.

After the futures contract is switched from cash settlement to physical delivery, the volatility of stocks NAB and WBC increases significantly whereas the volatility of PDP decreases significantly on the expiration day and 1 day before expiration day. The volatility of stock RIO increases significantly 5 days prior to the expiration day. This observation is more in line with the conjecture that the physical delivery promotes stock at contract expiration. Nonetheless, the empirical support is not sufficient.

EFFECTS ON TRADING VOLUME

Because the daily time series of trading volume is nonstationary, the logarithms of volume are taken and then detrended by deducting its 100-day moving average. To avoid the problem of zero daily trading volume, following the literature a very small value (0.00000255) is added to volume before taking logs (see, e.g., Cready & Ramanan, 1991). Applying the Phillips-Perron test to the final series, we reject the unit root hypothesis.

Let V_t denote the (detrended) volume at time t. We consider the following regression model:

$$V_t = \sum_{j=1}^{5} V_{t-j} + \omega_1 D_{\text{Mon}} + \omega_2 D_{\text{Tue}} + \omega_3 D_{\text{Wed}} + \omega_4 D_{\text{Fri}} + (\rho_0 + \rho_1 D_{ft} + \rho_2 D_{pt}) D_t + v_t \quad (5)$$

Five lagged variables of trading volume are used to take into account of the partial autocorrelation function. Five dummy variables of weekdays (Monday, Tuesday, Wednesday, Thursday, and Friday) are also added. The other dummy variables are defined as the above. The coefficients, ρ_0, ρ_1, and ρ_2, measure the additional trading volume attributable to the availability and settlement method of the ISF contracts on the expiration day (when D_t is replaced by D_{1t} in the model), 1 day before the expiration day (when D_t is replaced by D_{2t} in the model), and 5 days prior to the expiration day (when D_t is replaced by D_{5t} in the model), respectively. Estimation results ρ_0, ρ_1, and ρ_2, along with their corresponding t statistics, are reported in Table V.

TABLE V

Expiration Effects on Trading Volume

	D_{1t}			D_{2t}			D_{5t}		
	ρ_0	ρ_1	ρ_2	ρ_0	ρ_1	ρ_2	ρ_0	ρ_1	ρ_2
BHP	0.052	0.010	0.076	0.055	−0.044	0.105	0.011	0.003	−0.008
	(1.317)	(0.160)	(0.965)	(1.947)**	(−1.021)	(1.931)**	(0.598)	(0.097)	(−0.221)
NAB	−0.080	0.129	0.095	−0.036	0.103	0.018	−0.011	0.007	0.027
	(−2.009)**	(2.108)**	(1.189)	(−1.272)	(2.40)***	(0.320)	(−0.610)	(0.254)	(0.769)
NCP	0.079	−0.040	0.036	0.032	0.049	0.010	−0.004	0.040	0.005
	(1.914)*	(−0.631)	(0.436)	(1.107)	(1.094)	(0.167)	(−0.235)	(1.415)	(0.132)
MIM	−0.010	0.042	−0.018	−0.042	0.013	0.034	−0.050	0.009	0.055
	(−0.231)	(0.572)	(−0.184)	(−1.362)	(0.247)	(0.506)	(−2.561)**	(0.282)	(1.328)
WMC	−0.009	0.029	0.002	−0.003	0.066	−0.029	−0.028	0.044	−0.040
	(−0.231)	(0.439)	(0.024)	(−0.095)	(1.443)	(−0.516)	(−1.679)*	(1.516)	(−1.123)
WBC	0.013	0.039	0.055	0.023	0.044	0.000	−0.009	−0.015	0.059
	(0.313)	(0.566)	(0.618)	(0.818)	(0.930)	(0.002)	(−0.477)	(−0.487)	(1.538)
ANZ	0.058	−0.030	0.102	0.025	0.003	0.068	−0.003	−0.015	0.052
	(1.539)	(−0.405)	(1.090)	(0.933)	(0.058)	(1.042)	(−0.152)	(−0.451)	(1.256)
FBG	−0.023	0.089	−0.016	−0.020	0.060	0.048	−0.035	0.060	−0.052
	(−0.483)	(0.943)	(−0.137)	(−0.604)	(0.897)	(0.574)	(−1.623)	(1.397)	(−0.985)
RIO	0.011	−0.033	0.176	0.011	−0.026	0.071	−0.012	0.020	0.032
	(0.264)	(−0.397)	(1.718)*	(0.369)	(−0.439)	(0.984)	(−0.677)	(0.511)	(0.704)
PDP	−0.073	−0.059	0.109	−0.061	0.031	−0.008	−0.037	−0.033	0.078
	(−1.886)*	(−0.526)	(0.847)	(−2.233)**	(0.404)	(−0.093)	(−2.137)**	(−0.679)	(1.389)

*Denotes statistical significance at the 10% level.
**Denotes statistical significance at the 5% level.
***Denotes statistical significance at the 1% level.

Overall, 5 days prior to the expiration day, the stock trading volume of MIM, WMC, and PDP decrease when the stock futures markets are not available. This effect disappears once their corresponding stock futures contracts are introduced. Similarly, the trading volume of PDP decreases on the expiration day and 1 day before the expiration day, whereas the trading volume of NCP and BHP increases on the expiration day and 1 day before the expiration day, respectively. The effects vanish in the next period. Although the volume reduction effect that prevailed in the first period (no futures contracts) contradicts the findings in the current literature, the finding for the two other periods (cash-settled futures and futures with physical delivery) confirms the finding that the individual stock futures contracts reduce the expiration effect (on individual stock trading volume).

CONCLUSIONS

This research applies the Australian stock options data to examine the impact of the availability of individual stock futures contracts and the contract settlement methods on the possibility and scale of options expiration effects. We find some supporting evidence that the ISF contracts dampen the expiration effects on price volatility and trading volume of individual stocks. Also, we find that the stock prices tend to move up near expiration days after physical delivery replaced cash settlement in the ISF contracts. The settlement method change, however, had little impact on the expiration effects in terms of stock volatility and trading volume.

The above results are established using the GARCH-type approach of Corredor et al. (2001) to examine expiration effects. The method is applied to daily data. An alternative approach advocated in Stoll and Whaley (1997) and Chow et al. (2003) suggest that expiration effects occur within the last trading hours of expiration days. Consequently, the possible prevalence of expiration effects is evaluated by applying nonparametric tests to intraday data. Future research will adopt this alternative approach to investigate the impacts of individual share futures contracts and the underlying settlement methods on expiration effects.

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Price reversal as potential expiration day effect of stock and index futures: evidence from Warsaw Stock Exchange

1. Introduction

Since 1986, when Stoll and Whaley published their first article about expiration day effects of index options and futures on the US market, many authors have researched the anomalies observable on different equity markets on days of derivatives' expirations. Such undesirable effects can be especially strong on days when several derivatives expire. Stoll and Whaley (1990) researched the effects of the so-called "triple witching days" when index futures, index options, and options on index futures expired simultaneously. In the literature, potential anomalies of expiration days on the main market are divided into price effects and volume effects. Alkebäck and Hagelin (2004) described the possible sources of these effects. The first one is the activity of arbitragers who unwind their positions on the stock market. If, during a contracts' life, the difference between the contract price and its theoretical value (basis) is non-zero, arbitrage transactions can be conducted only if the difference is great enough to exceed the required transaction costs. Arbitragers open opposite positions on the equity market and the derivative market. Unwinding positions on the equity market is always connected with buying or selling shares, while on the derivative market, only unwinding before the expiration demands trading. Thereupon, as Stoll and Whaley wrote (1987), it is useful for arbitragers to keep their positions until a derivative's expiration, as (in this case) the liquidation does not require any activity on the derivative market and thereby does not involve unnecessary transaction costs. If there are many arbitragers unwinding their positions in the same direction, price effects are possible.

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The second source of expiration effects specified by Alkebäck and Hagelin (2004) arises from the activity of speculators. Investors who have naked positions in expiring contracts can try to manipulate its settlement price by the appropriate transactions on the equity market. Affecting the underlying asset price, they simultaneously affect the settlement price of the contract.

Such increased activity of investors on an expiration day should be reflected in increased price volatility. Furthermore, if the price effect is drawn mostly by arbitragers unwinding in the same direction, abnormal price changes can be observed. Intensified activity of speculators can also abnormally lower or raise the underlying assets' price upon expiration. After the expiration, however, prices should return to a "normal" level. Stoll and Whaley (1986) wrote about price reversal after expiration as a second potential price effect. Beyond these, trading volume that was significantly higher than on non-expiration days has been reported by many researchers as an effect of expiration day. On the markets where the settlement price is determined on the basis of stock prices from a certain time interval (usually from the last trading hour or the last 30 minutes of trading), the trading volume is especially high during this time span.

Most researchers study the expiration day effects of index futures and index options. Derivatives on individual stocks are less common; for this reason, they rarely form a subject of research. Results of the studies of expiration day effects vary depending on the research method, market under study, and period of time from which the data originates. Stoll and Whaley (1986) proposed a comparison of returns and trading volume of an underlying asset on expiration days to the corresponding returns and volume on control days by using some statistical tests. Significant differences between these variables on expiration and non-expiration days are evidence of the influence that the derivatives' expiration has on the equity market. Most other researchers have based their findings on this method, employing it in sundry variations to daily or intraday data.

The existence of a volume effect of an index futures and index options expiration days was first confirmed for the US market (Stoll and Whaley [1986, 1987]; Chen and Williams [1994]). Since then, research on expiration effects has been extended to other markets. As a result, the increased trading volume of underlying assets on the day of a derivative's expiration was detected on the markets of Japan (Karolyi [1996]), Germany (Schlag [1996]), Australia (Stoll and Whaley [1997]), Sweden (Alkebäck and Hagelin [2004]), Poland (Morawska [2007]), China (Fung and Jung [2009]), Spain (Illueca and Lafuente [2006]), and India (Narang and Vij [2013]), among others.

While the existence of the volume effect of an expiration day seems to be widespread, researchers are not unanimous about the price effects. Increased volatility around the expiration has been reported, for example, by Stoll and

Whaley (1987, 1997), Day and Lewis (1988), Chamberlain et al. (1989), Diz and Finucane (1998), Alkebäck and Hagelin (2004) (for the earlier of two sub-periods under study), Chow et al. (2003), Lien and Li (2005), Illueca and Lafuente (2006), Morawska (2007), and Narang and Vij (2013). Other authors did not find evidence of a volatility effect (see Chen and Williams [1994], Karolyi [1996], Bollen and Whaley [1999]). This ambiguity in the results surely indicates differences between the markets on that score, but this can also come from that facts that researchers use various volatility measurements for data on different frequencies and that they study the expiration of different derivatives.

The occurrence of the phenomenon of price reversal after expiration was identified, for example, by Stoll and Whaley (1987) and Chamberlain et al. (1989). Definitely more researches report no price reversal effect (see, e.g., Karolyi [1996], Stoll and Whaley [1997], Alkebäck and Hagelin [2004], Chow et al. [2003], Morawska [2007], Fung and Jung [2009], and Narang and Vij [2013]). Schlag (1996) found reversal only in case of futures that expire at the open. For options expiring at the close, no price reversal was found. Stoll and Whaley (1986, 1987) defined a few ways of calculating the reversal based on the comparison between signs of an underlying asset return on the expiration day and the return on the next day. These definitions were then used by others (e.g., Bollen and Whaley [1999], Chamberlain et al. [1989], Alkebäck and Hagelin [2004], Chow et al. [2003], and Morawska [2007]) to variously defined returns.

The above-mentioned authors studied either futures or options (or both) expiring simultaneously. This research only studies futures, as options are still not very popular derivatives on the Polish terminal market. According to the author's knowledge, the only research about futures' expiration day effects on the Polish equity market was conducted by Morawska (2004, 2007). Unfortunately, the full text of the first article (2004) is not available to the author. In (2007), Morawska studies 15 futures on WIG20 expirations between the first of January 2002 and 30th of June 2006. These contracts expired each year on the third Friday of March, June, September, and December. Each expiration date was researched separately. Following Stoll and Whaley (1986), the WIG20 Index returns and volume is studied by comparing the expiration days with control days. Control days are defined as the first and second Friday of the expiration month.

As a measurement of abnormal trading volume, Morawska (2007) took the relative trading volume at the close – the ratio of the volume values of particular stocks in the index from the last hour of the trading day to their volume values from the whole day. On 7 out of 15 events, she found a significantly higher average relative trading volume on expiration days than on control days. The volatility effect is measured by the variance of one-minute intraday WIG20 returns. To check if an index price reversal after expiration can be observed, Morawska (2007) compares the sign of the index return from the last 30 minutes on the expiration day with the sign of the return after the close (defined as a return calculated from the opening rate on the day after expiration and the rate of the index at the close of expiration day). The volatility effect and price reversal are also measured by a comparison with the control group. In 14 out of 15 events, abnormal volatility was detected. Price reversal, on the other hand, occurred only once.

The first futures contract on the WIG20 Index was introduced in 1998. This was also the first derivative on the Polish market (which has remained the most-liquid one to this day). Since 1998, more and more futures have been introduced; however, some of them have already been withdrawn from the market. Currently, two types of index futures are being traded: futures on the WIG20 Index and futures on the mWIG40 Index. Since 2001, futures on individual stocks have also been introduced to the Polish derivative market. Since the research conducted by Morawska (2007) covers only a period of six years (when the derivative market was relatively young) and only studies futures on the WIG20 Index, it seems to be desirable to extend the research of expiration day effects on the Polish equity market by taking into account more types of derivatives and expanding the time span of a study.

In this paper, we focus only on the price reversal effect of futures' expirations and check, if the effect is observable on the Warsaw Stock Exchange. Studies from other markets are not unequivocal about this effect, so an in-depth analysis of this phenomenon is desirable. Concededly, Morawska (2007) wrote that this effect does not exist on the Warsaw Stock Exchange, but this study broadens her research in several ways. First of all, beyond futures on the WIG20 Index, futures on the mWIG40 Index and futures on individual stocks are also studied. What is more, the derivative market today is more developed and liquid, so there are probably better conditions for speculations and arbitrage that can result in expiration day effects. The research covers a much-longer time span that was considered by Morawska (2007). The occurrence of a potential price reversal effect is also tested in different ways. First, an appropriate regression model is used to determine an underlying asset's returns. Second, the measures of reversal proposed by Stoll and Whaley (1986, 1987) are calculated. Finally, abnormal price changes around expiration are tested with the use of event study methodology, which has not been employed to the analysis of expiration day effects so far (according to this author's knowledge).

The structure of the paper is as follows: Section 2 describes the data and methodology; empirical results of the research are demonstrated and discussed in Section 3; and Section 4 concludes the paper. A list of futures along with their underlying assets used in this study is presented in the appendix.

2. Data and methodology

The dataset contains the daily markings of futures on individual stocks and futures on the indexes (WIG20 and mWIG40) as well as the markings on their underlying assets within a period from the first of January 2001 to the 31st of December 2016. The choice of such a time span was dictated by the availability of data at www.gpwinfostrefa.pl. During this period, there were 64 expiration days of futures on the WIG20 Index. Futures on the individual stocks were researched over a somewhat shorter time span (starting from 2003). During the early years of the markings, the frequency of the expiration of some futures on stocks changed (for example, in 2001 and 2002, futures on the PKN expired every month); therefore, the time horizon of the research is chosen so as to contain only futures with the same characteristics in the sample. The first futures contract on the mWIG4o Index expired in May 2007, so there are 39 days of this contract's expiration in the dataset.

Except for index futures and stock futures, European put and call options on the WIG20 Index (which expire on the third Friday of each month) are also available on the Polish derivative market. However, options have only started to become more popular over the last few years, and there is still much-lower interest in these instruments than in futures (in 2016, 95.4% of the total volume value on the derivative market came from futures). For this reason, the author only takes futures into consideration, bearing in mind that their expiration occurs simultaneously with the expiration of WIG20 options.

All of the contracts that are the subject of this study have some common characteristics. The value of each contract is equal to its rate multiplied by a given number. Futures on the individual stocks have a multiplier of 100 or 1000. Futures on the mWIG40 (as well as futures on the WIG20 through 2013) have a multiplier of 10. In September 2013, futures on the WIG20 with a multiplier of 20 were put on the market. The contracts expire simultaneously (four times a year – namely, on the third Friday of each March, June, September, and December) and are listed for nine months. The contracts are cash settled. Every day, the settlement price of the contract is defined as its closing price. The final settlement rates for index futures are calculated as the arithmetic mean of all index values of a continuous quotation during the last hour of trading on the expiration day and its value at the close (after eliminating the five highest and five lowest values). In the case of futures on the individual stocks, the final settlement price is equal to the rate of the underlying asset used in the last transaction made on the equity market on the expiration day. The list of futures used in the research (as well as the names of their underlying assets and their multipliers) are presented in Table 6 in the appendix. In the table, the first expiration means the first one included in the research. If some contract was introduced before the period under study, it is not its first expiration at all.

In this article, the effect of price reversal after expiration is explored. The existence of this effect is researched in three different ways. The results from the analysis of expiration days are compared with the analogous results from control days. To obtain the control group (equinumerous to the research group), control days are defined as the third Friday of January, April, July, and October. First, a simple regression model is employed to the returns of the futures' underlying assets:

$$R_{i,1} = \alpha + \beta R_{i,0} + \varepsilon_i$$

where $R_{i,0}$ represents the return on the expiration or control day, respectively, while $R_{i,1}$ represents the return on the day following the expiration day or control day, respectively. Two regression models are checked. In both, independent variable $R_{i,0}$ is defined as the daily logarithmic rate of the return of an underlying asset, but the dependent variable changes. In the first model, this is represented by the logarithmic rate of return on the day following the event day, while in the second model, $R_{i,1}$ is defined as the overnight return; that is, the natural logarithm of the ratio of return on the opening on the day after the expiration (or control) day to return at the close on the event day.

Second, the three measures of price reversal used by Alkebäck and Hagelin (2004) and taken from Stoll and Whaley (1987) and Chamberlain et al. (1989) are calculated for the expiration and control days.

Type 0 reversal:

$$REV_{i,0} = \begin{cases} R_{i,1} & if \quad R_{i,0} < 0 \\ -R_{i,1} & if \quad R_{i,0} \geq 0 \end{cases}$$

has a positive value in the case of price reversal and a negative value in the case of continuation. The average $REV_{i,0}$ is calculated in the group of expiration days and control days, respectively, and the *t*-test is used to check if the difference between them is significant.

Type 1 reversal:

$$REV_{i,1} = \begin{cases} \left|R_{i,1}\right| & if \;\; sign\left(R_{i,1}\right) \neq sign\left(R_{i,0}\right) \\ 0 & \text{otherwise} \end{cases}$$

and Type 2 reversal:

$$REV_{i,2} = \begin{cases} \left|R_{i,0}\right| & if \;\; sign\left(R_{i,1}\right) \neq sign\left(R_{i,0}\right) \\ 0 & \text{otherwise} \end{cases}$$

have only nonnegative values. In contrast to the Type 0 reversal, these measures are only descriptive, as the above-mentioned authors do not give any tests that could determine whether the reversal is significant. The average $REV_{i,1}$ and $REV_{i,2}$ are calculated in the group of expiration days and control days, respectively. The greater the value of the average measure, the stronger the phenomenon of price reversal. As in the case of the regression models, these measures are defined in two ways (depending on the definition of $R_{i,1}$).

Finally, the event study methodology is used to more-deeply explore the phenomenon of abnormal price changes around the expiration of the futures. This methodology is usually used to check the impact of different unexpected events on the equity market (see, for example, Gurgul [2006]). According to the author's knowledge, it has yet to be employed to the analysis of expiration day effects. Although future expiration cannot be perceived as an unexpected event in terms of the expiration date (which is preconceived), the impact of this event on the stock returns is unforeseeable (as it depends on the investors' activity on this day). In the author's opinion, event study analysis applied in an appropriate manner should be able to detect price reversal after expiration. However, as it is usually employed for abnormal returns, the reversal has a slightly different definition in this case than in the previously mentioned measures.

The analysis is used separately for expiration days and control days, and the results are compared. The event day (expiration day and control day, respectively) is designated by $t = 0$. The pre-event window covers 45 days from $t = -50$ to $t = -6$. It is as wide as possible to avoid an overlap with the previous event window. The event window contains 11 days around the date of the event; it starts 5 days before the expiration day or control day, respectively ($t = -5$), and ends 5 days after it ($t = 5$).

Abnormal returns for each day in the pre-event and event windows are defined as the difference between the actual rate of return and its expected value:

$$AR_{i,t} = R_{i,t} - E\left(R_{i,t}\right)$$

is the logarithmic rate of return of the shares or index on day t. For the individual stocks, the expected returns are calculated with the classical market model from the estimation window:

$$R_{i,t} = \alpha + \beta R_{m,t} + \varepsilon_{i,t}$$

where $R_{m,t}$ is the logarithmic rate of the WIG20 return and $\varepsilon_{i,t}$ is the error on a given day. For the WIG20 and mWIG40 indexes, the expected returns are equal to the mean of returns in the estimation window, as the market model cannot be applied in this case. The use of parametric tests in the event study requires the normal distribution of residuals, a lack of autocorrelation, and homoskedasticity. Most of the data fails to satisfy at least one of these assumptions. For this reason, the non-parametric generalized rank test proposed by Kolari and Pynnönen (2001) is applied. As the authors explain, the test is robust for event-induced volatility and to a certain degree of cross-correlation caused by event day clustering. Moreover, it is reasonably robust to the autocorrelation of abnormal returns. Finally, it does not require an assumption about the normality of abnormal returns, and its power dominates the power of popular tests used in the event studies.

To construct the test statistic, abnormal returns for each event are standardized; that is, they are divided by the standard deviation of abnormal returns from pre-event window:

$$SAR_{i,t} = AR_{i,t} \,/\, S\left(AR_i\right)$$

Thereafter, adjusted standardized abnormal returns are computed in order to account for any event-induced increase in volatility:

$$SAR'_{i,t} = \begin{cases} SAR_{i,t} & t = -50,\ldots,-6 \\ SAR_{i,t} \,/\, S\left(SAR_t\right) & t = -5,\ldots,5 \end{cases}$$

where $S(SAR_t)$ is a cross-sectional standard deviation of standardized abnormal returns defined as:

$$S\left(SAR_t\right) = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(SAR_{i,t} - \overline{SAR_t}\right)^2}$$

and N is the number of events in the sample. $SAR'_{i,t}$ are random variables with an expected value of zero and a unit variance under the null hypothesis of no event effect. Abnormal returns on each day t_0 in the event window are tested separately. For this reason, the demeaned standardized abnormal ranks are defined as:

$$U_{i,t} = \frac{rank\left(SAR'_{i,t}\right)}{T+1} - \frac{1}{2}$$

for $i = 1,\ldots, N$, and $t \in \Omega = \{-50, \ldots, -6, t_0\}$. $T - 1$ is the length of the pre-event window, and $rank(SAR'_{i,t})$ is the rank of $SAR'_{i,t}$ within the group of adjusted standardized abnormal returns from the pre-event window and SAR'_{i,t_0}. The null hypothesis about the no event effect is, thus, equivalent to the hypothesis that:

$$E\left(U_{i,t_0}\right) = 0$$

This hypothesis is tested with the use of generalized rank test statistic τ_{grank} defined by Kolari and Pynnönen (2001) as:

$$\tau_{grank} = Z\sqrt{\frac{T-2}{T-1-Z^2}}$$

where:

$$Z = \frac{\overline{U_{t_0}}}{S_{\bar{U}}}, \quad \overline{U_t} = \frac{1}{N}\sum_{i=1}^{N} U_{i,t}, \quad S_{\bar{U}} = \sqrt{\frac{1}{T}\sum_{t\in\Omega} \bar{U}_t^2}$$

Under the null hypothesis of the no event effect, the distribution of the τ_{grank} statistic converges to t-student distribution with $T-2$ degrees of freedom when sample size N increases.

Normally, an event study analysis is based on abnormal returns, which are defined as the difference between actual returns and their expected values. For an individual stock, the expected value is usually received from an appropriate model that describes the relationship between the return of the stock and the market rate of the return (see Gurgul [2006], page 41). Thus, the event study is able to detect price changes that are inconsistent with expectations. For example, a positive abnormal return on an expiration is a sign that the price on this day was higher than expected. The study is conducted it two clusters of events: expiration (or control) days with positive abnormal returns and expiration (or control) days with negative abnormal returns. In each of the clusters, the attention is focused on the day after the expiration. If the test statistic on day $t = 1$ is significantly different from zero and has an opposite sign to the sign of abnormal returns on the event day, this is a signal that an unexpected change in price has taken place and that the change went the opposite direction of the change from the day before. This is not tantamount to saying that the price has changed in the opposite direction than the day before, so this conception of price reversal is slightly different than the one proposed by Stoll and Whaley (1986) and employed by other research. For example, if there is a rapidly growing trend in prices and an abnormal return is positive on the day of expiration, this means that the price rose even more than was expected. If, on the next day, the abnormal return is negative, this does not necessarily mean that the price dropped, but it is a signal that the trend was disturbed in the opposite direction than the day before (the trend was constricted). When a price reversal is defined as the change of the return's sign, the above-mentioned situation appearing as an effect of expiration is not taken into account. Thus, it is desirable to check whether the effect of a future's expiration day is reflected in the abnormal returns.

To avoid making the article too weighty, the results of the event study analysis conducted on the control groups are only briefly described, but they are not presented in the tables. However, these can be provided by the author upon request.

3. Empirical results

3.1. Results from analysis of regression models

As an initial study of the price reversal effect of expiration, two regression models are matched to the returns of the futures' underlying assets. In the models, an independent variable represents the daily logarithmic rate of return on the expiration day (or control day), while the dependent variables are defined in two different ways and describe the returns on the day following the expiration day (or control day). In the case of a price reversal, the coefficient corresponding to the explanatory variable should be negative. Results from the analysis are presented in Table 1. Panel A presents the results from the model with the dependent variable defined as the logarithmic rate of return on the day following the event day. In Panel B, results from the model with the dependent variable defined as the overnight return (that is, the logarithm of the ratio of the return on the opening on the day after expiration or the control day to return at the close on the event day) are presented. The expiration and the control group each have 64 observations for WIG20, 39 observations for mWIG40, and 591 observations for the individual stocks.

Table 1

Results from regression models employed to returns of futures' underlying assets

PANEL A						
Underlying asset	**Expiration days**			**Control days**		
	coefficient	**estimate**	**p-value**	**coefficient**	**estimate**	**p-value**
WIG20	α (intercept)	0.000	0.986	α (intercept)	−0.002	0.377
	$\beta(R_{i,0})$	−0.128	0.376	$\beta(R_{i,0})$	0.048	0.744
	Multiple R^2: 0.013			Multiple R^2: 0.002		
PANEL A						
Underlying asset	**Expiration days**			**Control days**		
	coefficient	**estimate**	**p-value**	**coefficient**	**estimate**	**p-value**
mWIG40	α (intercept)	0.000	0.854	α (intercept)	−0.002	0.307
	$\beta(R_{i,0})$	−0.136	0.400	$\beta(R_{i,0})$	0.084	0.753
	Multiple R^2: 0,019			Multiple R^2: 0.003		

Table 1 cont.

individual stocks	α (intercept)	0.002	**0,023**	α (intercept)	0.000	0.747
	$\beta(R_{i,0})$	−0.049	0,213	$\beta(R_{i,0})$	0.252	**0.000**
	Multiple R^2: 0.003			Multiple R^2: 0.040		
PANEL B						
Underlying asset	**Expiration days**			**Control days**		
	coefficient	**estimate**	**p-value**	**coefficient**	**estimate**	**p-value**
WIG20	α (intercept)	0.002	0.061	α (intercept)	−0.002	0.077
	$\beta(R_{i,0})$	−0.094	0.181	$\beta(R_{i,0})$	−0.050	0.502
	Multiple R^2: 0,029			Multiple R^2: 0,007		
mWIG40	α (intercept)	0.001	**0.050**	α (intercept)	0.001	0.743
	$\beta(R_{i,0})$	0.034	0.550	$\beta(R_{i,0})$	0.249	0.977
	Multiple R^2:	0.010		Multiple R^2:	0.083	
individual stocks	α (intercept)	0.001	**0.037**	α (intercept)	−0.002	**0.002**
	$\beta(R_{i,0})$	−0.535	**0.007**	$\beta(R_{i,0})$	0.017	0.581
	Multiple R^2: 0.012			Multiple R^2: 0.001		

Source: own calculations

In each of the three models from Panel A (for WIG20, mWIG40, and the individual stocks), the coefficient corresponding to the explanatory variable is negative in the group of expiration days, suggesting that the higher the rate of return on the event day, the lower the rate on the following day, and (conversely) a negative rate of return on the expiration day has a positive impact on the rate of return on the next day. Unfortunately, the coefficients are not statistically significant from zero, so this impact is not strong enough to be a convincing sign of a price reversal. In the control group, coefficient β is positive in each of the models, but it is only statistically significant (at a 1% level) in the case of an individual stock's returns. This is a confirmation that, on days without a futures' expiration, returns of the stocks tend to follow the trend. This feature seems to be disturbed by the expiration. In the WIG20 and mWIG40 index returns, there are no significant differences on the days with and without an expiration. The daily rate of return, employed as a dependent variable in the first model, contains information about the change in price during the whole day following the expiration. Thereby, many different events on this day can have an impact on it, disturbing its possibility to reflect the price reversal. As the models in Panel A do not provide satisfying clear-cut results, a second model is employed to check if it is possible that the price reversal after expiration is immediate and can be reflected in the overnight rather than daily returns. Thus, in the second model, the dependent variable is defined as the logarithm of the ratio of the price on the opening of the day after the expiration (or control) day to the price at the close of the event day.

In all of the models constructed for the indexes, coefficient β does not differ significantly from zero. For the mWIG40 returns, this coefficient is even positive (but insignificant) in the group of expiration days. However, the results obtained for the individual stocks are interesting. Coefficient β is negative and significant on expiration days yet positive (but not significant) on control says. This suggests that the price reversal appears directly after a future's expiration, while the continuation of the trend on ordinary days is connected with investor activities during the day and is reflected in the daily rather than overnight returns.

A slightly different regression model (but one that also describes the relationship between the returns on the expiration day and on the following day) was employed by Alkebäck and Hagelin (2004). They study futures on the OMX index and do not find a statistically significant reversal of the index returns after expiration. Narang and Vij (2013) also use some regression model (but definitely more complicated) for the daily data to evaluate the price and volume effects of an index derivative's expiration, and their results also indicate that there is no price reversal.

This preliminary research of regression models suggests that the expiration day effect may not be reflected in the index returns but might be visible in the prices of these stocks that set an underlying asset of a contract. In this case, an abnormal change in price on the expiration day may be immediately rectified after expiration and be reflected in the overnight stock returns. Further research will be conducted to support this thesis.

3.2. Results from analysis of reversal measures

Three measures of price reversal used in foregoing studies of futures' expiration effects (see, e.g., Stoll and Whaley [1987], Chamberlain et al. [1989], Alkebäck and Hagelin [2004]) are constructed for the returns of the WIG20 and mWIG40 indexes as well as for the individual stocks on the expiration and control days. As in the case of the regression models, the measures are defined in two different ways depending on the definition of the returns after expiration. These results are presented in Table 2. The expiration and control groups each have 64 observations for WIG20, 39 observations for mWIG40, and 591 observations for the individual stocks.

Table 2

Average price reversal measures in percentages as well as percentages of number of days with reversals

Panel A				
Underlying asset	**Type of reversal**	**Expiration days [%]**	**Control days [%]**	**p-value of t-test**
WIG20	Type O reversal	0.036	0.091	0.858
	Type 1 reversal	0.582	0.673	–
	Type 2 reversal	0.543	0.587	–
	Percentage of reversals	48%	56%	–
mWIG40	Type O reversal	0.096	−0.176	0.343
	Type 1 reversal	0.431	0.467	–
	Type 2 reversal	0.479	0.280	–
	Percentage of reversals	64%	38%	–
individual stocks	Type O reversal	0.164	−0.195	**0.009**
	Type 1 reversal	0.899	0.822	–
	Type 2 reversal	0.864	0.626	–
	Percentage of reversals	53%	46%	–
Panel B				
Underlying asset	**Type of reversal**	**Expiration days [%]**	**Control days [%]**	**p-value of t-test**
WIG20	Type O reversal	0.050	–0.035	0.587
	Type 1 reversal	0.027	0.289	–
	Type 2 reversal	0.451	0.599	–
	Percentage of reversals	50%	42%	–
mWIG40	Type O reversal	0.022	–0.077	0.474
	Type 1 reversal	0.164	0.233	–
	Type 2 reversal	0.322	0.310	–
	Percentage of reversals	59%	44%	–
individual stocks	Type O reversal	0.065	–0.069	0,078
	Type 1 reversal	0.417	0.407	–
	Type 2 reversal	1.044	0.809	–
	Percentage of reversals	47%	39%	–

Source: own calculations

Panel A includes measures drawn by comparing the daily logarithmic rate of a return on the day of expiration (or on the control day) to the daily logarithmic rate of return on the following day. The average Type 0 reversal for mWIG40 as well as for the individual stocks is positive on expiration days and negative on control days. This measure takes a positive value in the case of price reversal and negative otherwise, so the results are consistent with the assumption of reversal after the expiration and continuation in prices when no contract expires. However, the test statistic of the differences in means indicates that the difference between average Type 0 reversal on the expiration and control days is significant only in the group of individual stock prices. For the WIG20 index, the Type 0 reversal is positive both on expiration and control days, suggesting no reversal. The Type 1 and Type 2 reversals take strictly nonnegative values. These measures are only descriptive. The higher the value of the average measure, the stronger the phenomenon of price reversal. It can be noticed that the means of both measures are higher on expiration days than on control days only in the case of individual stocks; however, the differences are not substantial. In the table, the percentages of the number of days with reversals is presented (calculated as the percentage of the number of days with a positive Type 0 reversal). For the mWIG40 index as well as the individual stocks, this is higher on expiration days than on control days; but again, the differences are moderate.

The averaged measures presented in Panel B were calculated with the use of the daily logarithmic rate of return on the event day and the overnight return on the following day. The results are mostly consistent with those from Panel A. This time, however, the average Type O reversal has a positive sign on expiration days and negative on control days in each of the three groups (but the t-statistic values are not significant). Only for the individual stock returns, the difference between the average Type 0 reversal on expiration and control days can be detected at a 10% level. The average Type 1 and Type 2 reversals for the stocks are somewhat higher in the group of expiration days. The values of these measures for WIG20 and mWIG40 do not confirm reversal after expiration.

From among the foregoing studies of price reversal after index future expiration that used such measures, Stoll and Whaley (1987) on the US market and Chamberlain et. al. (1989) on the Canadian market detect the phenomenon of price reversal, while Stoll and Whaley (1997) on the Australian market and Alkebäck and Hagelin (2004) on the Swedish market do not find it.

As in the analysis of the regression model, the measures do not indicate a reversal of the WIG20 and mWIG40 indexes, but they do suggest that such a reversal appears in the individual stock prices.

3.3. Results from event study analysis of daily returns

In this part of the research, a slightly different definition of price reversal is employed. As an event study analysis is normally based on the differences between actual returns and their expected values, price reversal here means that an unexpected rise in the returns on the following day occurs after an unexpected drop in returns on the day of expiration; conversely, returns that are higher than expected on the day of expiration are followed by returns lower than expected on the next day. This is not tantamount to literal meaning of the phrase “price reversal,” which suggests that the price rose and then dropped (or vice versa).

To detect price reversal after future expiration using the event study methodology, each group of events (expiration of futures on WIG20, mWIG40, and for individual stocks) is divided into two subgroups: expiration days with positive abnormal returns and expiration days with negative abnormal returns. Then, an event study analysis is conducted in each of the two clusters with the use of a generalized rank test. The significance of the test statistic on the event day in the groups is obvious due to their definitions. The attention is focused on the day following expiration, so this day is treated as an event day. A test statistic significantly different from zero and with a sign opposite to the sign of a test statistic on expiration day is a signal of price reversal.

Table 3

Reaction of daily abnormal returns of individual stocks to expiration of futures

	Individual stocks (positive abnormal returns on day *t* = 0)			**Individual stocks (negative abnormal returns on day *t* = 0)**		
t	$\overline{AR_t}$ **[%]**	**τ-grank**	**p-value**	$\overline{AR_t}$ **[%]**	**τ-grank**	**p-value**
	311 events			**280 events**		
−5	0.055	1.040	0.304	−0.075	−0.253	0.802
−4	0.122	0.941	0.352	0.018	0.482	0.632
−3	−0.007	0.618	0.540	−0.033	0.464	0.645
−2	0.065	0.924	0.361	0.063	0.286	0.776
−1	−0.055	0.285	0.777	0.049	0.843	0.404
1	−0.064	−0.656	0.515	**0.202**	**2.433**	**0.019**
2	−0.188	−1.224	0.228	**0.104**	**2.337**	**0.024**
3	−0.134	−0.641	0.525	−0.128	−0.389	0.699
4	−0.123	−0.121	0.904	−0.024	1.001	0.322
5	−0.132	−0.480	0.634	0.060	1.277	0.208

Source: own calculations

Table 3 presents the following results: the mean abnormal returns in percentages, value of the generalized rank test statistic, and p-values of the test for the research conducted on the individual stocks' daily logarithmic rate of returns. The event day is not included in the table, as the significance of the test statistic on this day is evident in view of the clusters' definitions. In the cluster of expiration days with positive abnormal stock returns, there is no value significantly different from zero throughout the event window. The mean abnormal returns and test statistic on days following an expiration day are negative; however, as they are not significant, they cannot support the assumption of price reversal after expiration. However, in the cluster of expiration days with negative abnormal returns, the test statistic on the two days following expiration are significantly positive (at a 5% level). This means that the prices being lower than expected on the expiration day can be the effect of unwinding long arbitrage positions or speculations conducted on the stocks by investors who have tried to change the settlement price of the contract. After expiration, the prices return to the higher level. Long arbitrage (that is, buying stocks and selling a contract) is more popular than short arbitrage, as it is easier to conduct. Short arbitrage requires the short selling of stocks. Until the release of European Union regulations concerning short selling in May 2015, GPW had published lists of stocks that could have been the objects of short selling. The stocks were required to fulfill the appropriate requirements regarding liquidity. This had caused that short selling had not been practically used. The regulation from May 2015 made short selling easier to conduct, but most of the data in the research came from the period of time from before this change. If the unwinding of arbitrage positions poses an essential part of price changes on expiration day, it is not surprising that price reversal is visible only in the group of expiration days with negative returns, as simply unwinding long arbitrage is connected to selling stocks, resulting in price falls. Even if the speculations have an important influence on prices on expiration, price reversal should be stronger in the cluster of days with negative abnormal returns if arbitragers also have a contribution to this effect.

Analogous research was also conducted in the control group to check if the potential price reversal could be interpreted as the effect of expiration or if it might have been a calendar effect. Detailed results can be provided by the author upon request. All of the test statistic values in the event windows are insignificant, and in both clusters, the average abnormal return on the day following a control day have the same sign as the abnormal returns on day $t = 0$, which rather suggests continuation than reversal in the returns. This supports the conclusion about reversal being caused by future expiration.

The results from the event study analysis conducted for the WIG20 and mWIG40 returns are presented in Table 4. As in the case of the regression models and reversals measures, no evidence of reversal in the returns after expiration were found.

Table 4

Reaction of daily abnormal returns of WIG20 and mWIG40 indexes to expiration of futures

	WIG20 Index (positive abnormal returns on day t = 0)			**WIG20 Index (negative abnormal returns on day t = 0)**			**mWIG40 Index (positive abnormal returns on day t = 0)**			**mWIG40 Index (negative abnormal returns on day t = 0)**		
t	$\overline{AR_t}$ [%]	**τ-grank**	**p-value**	$\overline{AR_t}$ [%]	**τ-grank**	**p-value**	$\overline{AR_t}$ [%]	**τ-grank**	**p-value**	$\overline{AR_t}$ [%]	**τ-grank**	**p-value**
	35 events			**32 events**			**23 events**			**18 events**		
−5	**−0.673**	**−2.093**	**0.042**	−0.521	−1.013	0.317	−0.175	−0.797	0.430	−0.488	−1.642	0.108
−4	−0.374	−0.340	0.736	−0.423	−1.346	0.185	−0.409	−0.614	0.543	−0.043	−0.768	0.447
−3	−0.205	−0.484	0.631	−0.053	−0.196	0.846	0.089	1.106	0.275	−0.098	−0.036	0.972
−2	−0.135	0.570	0.572	0.247	1.086	0.284	0.200	0.535	0.596	−0.181	−0.567	0.573
−1	0.435	1.278	0.208	−0.034	0.474	0.638	0.106	−0.141	0.889	0.110	0.817	0.418
1	−0.013	0.399	0.692	−0.010	0.195	0.846	0.048	−0.440	0.662	−0.083	−0.125	0.901
2	−0.165	−0.424	0.674	0.234	0.540	0.592	0.052	0.094	0.925	−0.194	−1.347	0.185
3	0.048	−0.423	0.674	0.006	−0.103	0.918	0.223	0.725	0.472	0.056	−0.355	0.724
4	−0.140	−0.097	0.923	0.084	0.227	0.821	−0.083	0.362	0.719	−0.368	−0.764	0.449
5	−0.246	−0.541	0.591	0.154	0.000	1.000	−0.487	−1.370	0.178	0.223	1.633	0.110

Source: own calculations

Most of the test statistic values in the event windows are not significantly different from zero. Only for WIG20 in the group of expiration days with positive returns, the value of the test statistic five days before expiration is significantly negative (at a 5% level), but this seems to have no connection with the expiration. In the clusters constructed for WIG20 abnormal returns on control days (not presented in the article), there is no test statistic value significantly different from zero. In the case of the mWIG40 Index, the only significant value (at a 5% level) of the test statistic on control days appears in the cluster constructed for days with negative abnormal returns (three days before the control day, and it is also negative). However, the number of events in each sample constructed for mWIG40 is small. The distribution of the test statistic converges to t-student distribution as the sample size increases, so the results here are not quite reliable.

3.4. Results from the event study analysis of overnight and daylong returns of individual stocks

As the analysis of the individual stocks' daily returns gives the basis for the occurrence of the price reversal effect of future expiration, more-detailed research is conducted. Alkebäck and Hagelin (2004) suggested that day-to-day returns can be unable to reflect price reversal, as prices can reverse before the close of the market. To check whether the effect appears immediately after expiration and if it can be reflected in the overnight returns of the stocks, overnight abnormal returns are calculated with the use of the market model, and the generalized rank test is used analogously to the daily abnormal returns. Clusters of days with negative and positive abnormal returns are, however, defined in terms of daily abnormal returns on the expiration day, because the overnight returns on the expiration do not mirror the activity of investors on this day, so they are probably not influenced by the expiration. Results presented on the left-hand side of Table 5 show that, in both clusters of expiration days, the test statistic is significant (at a 1% level) on the day after expiration, and the sign of the statistic is opposite to the sign of the abnormal returns on expiration. This is strong evidence that price reversal occurs immediately after expiration and is reflected in the overnight returns (even in the group of expiration days with negative returns, in which this effect was not reflected by the daily returns). Analogous research was conducted in the control group. These results can be provided by the author upon request. In the cluster of control days determined by positive abnormal daily returns, the test statistic is significant and positive on day $t = 0$. This means that positive abnormal daily returns can be a continuation of some trend, as they occur after positive overnight returns. In the cluster of control days with negative abnormal returns, the test statistic is significantly positive (at a 5% level) two days after the event day, but it is difficult for the author to find a potential reason for this significance.

In the next part of the research of the individual stocks returns, the same study is conducted on daylong abnormal returns. Daylong returns are calculated as the natural logarithm of the ratio of stock prices at the close and at the opening on a given day. Abnormal daylong returns are calculated with the use of the market model. The event study was conducted in two clusters, which are defined (as previously) in terms of the sign of the daily abnormal returns on the expiration day. These results are presented on the right-hand side of Table 5. The test statistics are significant on day $t = 0$ in both clusters, which is not surprising (as the daylong returns are usually the same sign as the corresponding daily returns). This time, in the two clusters for expiration days, there is no significance of the test statistic on day $t = 1$. This suggests that, even on days with negative daily returns (in which the research conducted on the daily returns gives a significant and positive statistic on the day following the expiration day), the phenomenon of price reversal occurs immediately after expiration. However, it is stronger in this case and can have a continuation, as the test statistic is also significant (at a 5% level) on the second day after expiration. In the two clusters for the control days (not presented), the abnormal daylong returns follow this trend. The test statistic is significant and positive one day after day $t = 0$ with the positive abnormal returns. In the second cluster, the statistic is not significantly different from zero on each of the days after day $t = 0$, but it is negative through the end of the event window.

As a complement to the research, the event study analysis was also conducted with the use of normal daily returns. The methodology is the same as previously; but now, the expected value of the return is assumed to be equal to zero. Thereby, abnormal returns are equal to the normal daily returns. The significant test statistic on day $t = 1$ with the sign opposite to the sign of the test statistic on the event day suggests a price reversal. Here, the reversal is consistent with the definition employed in the regression models and reversal measures. The results are not presented to avoid making the article too weighty, but they can be provided by the author upon request. They are similar to those from the analysis of daily abnormal returns. In the case of the individual stocks, there is no clear-cut evidence of the reversal in the cluster with positive returns upon expiration. In the cluster with negative returns on day $t = 1$, the test statistic is significantly positive (at a 5% level) on the day following expiration. This supports the previous results that, in this cluster, the reversal is more visible. In the case of WIG20 and mWIG40 returns, no test statistic values statistically different from zero could be found throughout the entire event window. Like the previous methods, this one also does not detect a reversal in the indexes' returns after future expiration.

Table 5

Reaction of overnight and daylong abnormal returns of individual stocks to futures expirations

	Overnight returns						**Daylong returns**					
	Individual stocks (positive daily abnormal returns on day $t = 0$)			**Individual stocks (negative daily abnormal returns on day $t = 0$)**			**Individual stocks (positive daily abnormal returns on day $t = 0$)**			**Individual stocks (negative daily abnormal returns on day $t = 0$)**		
t	$\overline{AR_t}$ [%]	**τ-grank**	**p-value**	$\overline{AR_t}$ [%]	**τ-grank**	**p-value**	$\overline{AR_t}$ [%]	**τ-grank**	**p-value**	$\overline{AR_t}$ [%]	**τ-grank**	**p-value**
	311 events			**280 events**			**311 events**			**280 events**		
−5	0.088	1.958	0.057	−0.044	−0.490	0.627	−0.045	0.368	0.715	−0.045	0.084	0.933
−4	0.071	0.516	0.609	−0.029	−0.695	0.491	0.046	1.248	0.218	0.064	0.900	0.373
−3	−0.012	−0.405	0.687	−0.037	0.259	0.797	0.008	1.164	0.251	−0.024	0.489	0.627
−2	0.020	0.465	0.644	−0.025	0.434	0.666	0.067	1.007	0.319	0.092	0.633	0.530
−1	−0.013	−0.365	0.717	0.056	0.314	0.755	−0.002	1.011	0.318	0.005	0.684	0.498
0	0.090	1.972	0.055	−0.074	−1.758	0.086	**1.331**	**19.113**	**0.000**	**−1.176**	**−10.964**	**0.000**
1	**−0.135**	**−3.275**	**0.002**	**0.147**	**3.988**	**0.000**	0.122	1.542	0.130	0.050	0.929	0.358
2	−0.039	−0.847	0.401	−0.008	0.508	0.614	−0.174	−1.212	0.232	**0.083**	**2.158**	**0.036**
3	0.013	−0.475	0.637	0.014	0.545	0.589	−0.145	−0.658	0.514	−0.176	−0.871	0.389
4	0.034	0.790	0.434	0.026	1.169	0.249	−0.185	−0.225	0.823	−0.039	1.003	0.321
5	−0.181	−0.951	0.347	−0.075	0.244	0.808	0.004	0.496	0.622	0.086	1.394	0.170

Source: own calculations

4. Conclusions

In this paper, the impact of futures' expiration days on the returns of their underlying assets was researched. The data covers the period from January 2001 to December 2016. Three potential effects of future expiration are evident in the literature: increased trading volume on the day of expiration, increased volatility in the prices, and abnormal price changes upon expiration resulting in price reversal on the following day. The author focused on the last of the above-mentioned effects and conducted detailed research on abnormal price changes around the expiration of futures on the WI20 and mWIG40 indexes as well as futures on individual stocks. Three different methods were employed to investigate the occurrence of the phenomenon of price reversal. First, linear regression models were constructed with returns on the day following expiration as a dependent variable as well as returns on the day of expiration as an explanatory variable. Then, three measures of price reversal given by other researchers were calculated. Finally, an event study analysis was employed to test the occurrence of price reversal (which is defined in a slightly different way than in the two previous methods).

The research does not detect the reversal of index returns and, thus, does not confirm the previous results on this issue obtained by Morawska (2007). In the case of the individual stock returns, all three methods support the assumption that price reversal occurs after expiration. Results from the regression model as well as from the event study analysis show that the reversal is immediate and is reflected in overnight returns more than in daily returns. The phenomenon of price reversal seems to be stronger in the case of negative abnormal returns on the expiration day. Author suggests that it can be connected with the unwinding of long arbitrage positions. Short arbitrage, which involves the short selling of stocks, was constricted during the period under study due to the restrictive regulations regarding short selling.

The differences in the results obtained for the stocks and the indices are not surprising. The way the contracts are settled is a very important factor that influences the effects of expiration day. The final settlement price of futures on individual stocks is calculated as the rate of the stock from the last transaction on the expiration day. Thus, to manipulate the settlement price, speculators should increase their activity mostly at the close of the market. Long arbitragers (with long positions in stocks) have only to place market-on-close orders on the stocks to realize their strategies. In the case of index futures, the final settlement rate is equal to the mean of the continuous quotations from the last trading hour and the value at the close, where the five highest and five lowest values are eliminated. Speculation on an index is more difficult than on individual stocks, as an investor has to buy or sell only this one stock to manipulate the price of the stock. To manipulate the index, it is necessary to make appropriate transactions on all of the stocks in it. Changing the value of the index is quite difficult as the indices represent the entire market; therefore, as Stoll and Whaley (1986) write, they "are deeper and broader than the market in any stock." Construction of the settlement rate of index futures additionally restricts speculation on it in order to manipulate a contract's price.

The index arbitrage is also intrinsically more complex than the arbitrage on a single stock and is further hampered by the settlement procedure of index futures. Focusing on a long arbitrage (which is more-readily-available on the Polish market), the settlement procedure makes that unwinding a position in the stocks by ordinary market-on-close orders does not give an investor profits exactly equal to the costs associated with the trade of the contract.

All of the above-mentioned reasons suggest that the price effects of future expiration are more likely in stock prices than in the returns of the indices, and the results of the research confirm this thesis. There can be one additional reason why price effects in indice returns were not found. This research uses daily data. Alkebäck and Hagelin (2004) wrote that it is an "important methodological concern, whether lower frequency data allow expiration day effects to be detected." They give two arguments supporting the thesis that daily returns can be unable to detect price effects. First, extending the event window reduces the relative size of the effect, thereby reducing the probability of detection. Moreover, prices can be reversed before the exchange close, and the day-to-day returns cannot reflect the price distortion. The results from the analysis of the daily and overnight returns of the stocks reinforce the second argument. However, in the case of the WIG20 and mWIG40 indexes, an event study on the overnight returns was also conducted by the author; however, as it does not show any significant test statistic value in the event window, the results are not included in the article. Nevertheless, the issue of whether higher-frequency data is better able to detect expiration effects remains an open question that inspires this author to further study their use.

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Appendix

Table 6 contains list of futures used in the research with their characteristics. The names of the underlying assets are given by their abbreviations. The first expiration means the first one included in the research. If the contract was introduced before the period under study, it is not its first expiration at all.

Table 6

A list of futures used in research and their characteristics

Underlying asset (abbreviation)	Multiplier	First expiration	Number of expiration days (with positive number of opened positions)
WIG20	10,20*	13-06-2001	64
mWIG40	10	15-06-2007	39
ACP	100	18-06-2010	27
ALR	100	21-03-2014	9
ATT	100	16-12-2016	1
BRS	1,000	15-06-2012	13
BZW	100	20-06-2003**	24
CCC	100	18-12-2015	4
CDR	100	16-09-2011	22
CIE	100	16-12-2016	1
CPS	100	18-12-2015	4
ENA	100	18-12-2015	5
GPW	100	16-03-2012	20
GTC	1,000	16-12-2011	14
ING	100	16-12-2016	1
JSW	100	16-12-2011	21
KER	100	16-12-2011	15
KGH	100	21-03-2003	56
KRU	100	16-12-2016	1
LTS	100	26-06-2011	23
LWB	100	16-12-2011	21

Table 6 cont.

MBK	100	16-12-2016	1
MIL	1,000	20-06-2003***	17
OPL	100	21-03-2014	12
PEO	100	21-03-2003	56
PGE	100	18-06-2010	27
PGN	1,000	18-06-2010	27
PKN	100	21-03-2003	56
PKO	100	16-09-2005	46
PZU	100	17-09-2010	26
SNS	1,000	21-09-2012	17
TPE	1,000	18-03-2011	24

* First futures on WIG20 Index with multiplier 20 were put on the market in September 2013.

** Contracts on BZW had been traded through December 2008. Then, the markings were suspended and restarted in December 2016.

*** Contracts on MIL had been traded through March 2007. Then, the markings were suspended and restarted in December 2015.

Source: own compilation on the basis of data from www.gpwinfostrefa.pl

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Expiration day effects of stock and index futures on the Warsaw Stock Exchange

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Abstract

This paper examines the impact of stock and index futures expirations on the spot market on the Warsaw Stock Exchange. Three of the most commonly-observed effects are analysed, namely increased trading volume of the underlying asset, abnormally high volatility of returns on the expiration day and a price reversal after the expiration. The study confirms that index futures expirations induce increased trading activity of investors, reflected in abnormally high turnover and relative turnover values of stocks from the index. In the case of single stocks, however, all three effects are observed. The reversal of stock prices takes place just after futures expiration and is reflected in the opening prices on the next trading session. Additional analysis performed in sub-periods reveals a significant impact of changes in the short selling rules introduced in May 2015 on expiration day effects.

Keywords: futures market, expiration day effects, stock market, event study

JEL: C32, C14

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1 Introduction

Stock or index futures, as other financial derivatives, were introduced as useful tools for hedging stock market risk. However, they have also been widely applied for speculative reasons. Very high activity of investors implementing speculative or arbitrage strategies on stock and index futures may conduce to undesirable anomalies in markings of futures' underlying assets. These artificially induced price movements give false signals to uninformed traders and distort the process of discovering prices on the stock market. This adverse impact of the futures market on the stock market is particularly strong on the expiration days of these derivatives.

Expiration day effects of futures markets have been discovered on various stock markets such as the US, Canadian, German, Swedish, Japanese, Indian, and Australian stock markets (see, for example Karolyi 1996; Schlag 1996; Stoll, Whaley 1997; Alkebäck, Hagelin 2004; Vipul 2005; Debasish 2010; Tripathy 2010; Narang, Vij 2013; Fung, Jung 2009; Illueca, Lafuente 2006; Chow et al. 2013; Mahalwala 2016). These studies have specified three of the most commonly-observed expiration day effects: an increased trading volume of the underlying stock or index on the expiration day; an abnormally high return volatility on the expiration day; and a price reversal after the expiration.

One of the sources of the expiration day effects can be seen in the activity of arbitrageurs. If, during the contract life, its internal value differs significantly from its market value, investors have an opportunity to earn on this anomaly by holding a long position on a future and a short position on its' underlying asset, or vice versa, depending on the sign of the difference. These positions are often unwound on future expiration days. If many arbitrageurs unwind their positions in the same direction, price effects may occur (Alkebäck, Hagelin 2004; Chay 2011).

Speculators, who make up a vital group of investors trading on the futures market, may also contribute to the occurrence of expiration day effects. As the final settlement price of the contract is calculated on the basis of underlying asset prices from the expiration day, speculators are interested in manipulating the price so that the contract would be settled at a price profitable for them. Usually, such a price differs from the true value of the asset. However, on an effective market, an incorrectly priced asset attracts the attention of rational investors who take advantage of the opportunity. As a result, the price very quickly moves back to its intrinsic value. The change in the asset price implied by expiration day speculations is mainly temporal, but takes place just before the end of a trading day. Hence, a significant price reversal might be observed after the expiration day. Additionally, high activity of various groups of investors on the expiration day or just before the end of a trading session may lead to high trading volume and increased return volatility.

In this paper, we investigate expiration day effects on the Warsaw Stock Exchange. The WSE seems to be a perfect candidate to study expiration day effects on. First, both futures and underlying shares are traded on the WSE. Second, it is the largest stock market in the CEE region, and thus it provides enough liquidity to apply methodology and models from large developed markets. On the other hand, in the period under study, the WSE was seen as an emerging market, so it is expected to have been less efficient than Western European developed markets and expiration day effects are expected to be better pronounced on it. Successful application of arbitrage strategies or speculation is much more difficult on deep and effective developed markets because it needs more funds to be involved. Hence, the adverse impact of futures on a spot market is expected to be particularly visible on smaller, emerging markets where there are more opportunities to speculate.

There is very little research on expiration day effects on the Polish derivatives market. To our best knowledge, the only research in this field was conducted by Morawska (2004, 2007) and Suliga (2017). However, the studies of Morawska (2004, 2007) cover the very beginning phase of the development of the derivatives market in Poland. Moreover, the analysis is performed on WIG20 index futures only, while on the WSE there are also futures listed on the mWIG40 index and futures on individual stocks. The impact of single stock futures as well as index futures on the spot market was examined by Suliga (2017), but she studied price reversal only.

This paper extends the previous studies on the impact of derivatives on the spot market on the WSE, giving a comprehensive analysis of all three expiration day effects performed on the basis of the more recent data. In this study, we examine and compare how index futures and single stock futures influence trading volume, volatility and prices of the underlying assets. The comparison of the results of the paper with the previous results from the literature, particularly concerning developed markets, will show similarities and differences in expiration day effects on the WSE and on these markets. It will also be an indicator of the degree of the development of the Polish stock market.

The important goal of the analysis is the examination of the dynamics of interrelationships between derivative and spot markets in Poland. The results can give valuable hints to regulators on whether the settlement procedure defined on the futures market works properly or if it needs to be adjusted or corrected to prevent adverse influence of the derivatives market on the spot market.

Additional analysis in sub-periods shows how expiration day effects on the WSE have changed over the recent years.

To the best of our knowledge, this research is the first conducted on the WSE in recent years which covers all of the expiration day effects. Except for the paper of Suliga (2017), it is also the only study that involves the effects of individual stock futures expirations. Thus, the contribution of the work to the research on futures' expiration day effects on the WSE is meaningful.

The structure of the paper is as follows. The next section describes previous literature on expiration day effects and is followed by a section presenting the data and empirical methodology. The results of the research are described and discussed in Section 4. Section 5 concludes the paper.

2 Literature review

2.1 Volume effects

Most of the foregoing studies on expiration day effects confirm the existence of increased trading volume on an expiration day. This anomaly was first detected by Stoll and Whaley (1986) on the New York Stock Exchange when index futures and index options expired. They found that on quarterly Friday expirations when futures on S&P500, as well as options on S&P500 and S&P100 expired simultaneously, the daily market trading volume was about 8% higher than the average daily total volume in the expiration week. On the other hand, in weeks without derivatives' expirations the difference was only about 0.2%. Moreover, the changes in trading activity were not uniform during the whole trading session on the expiration day. The trading volume in the last trading hour on expiration Fridays was about 58% higher than the average hourly trading volume during the rest of the day. On non-expiration Fridays, completely different relationships were observed because the last-hour volume was smaller than the trading volume computed during other hours of the trading session. As a result of these differences, the average last-hour trading volume on expiration Fridays was about twice as high as on non-expiration Fridays. Very strong volume effects in the last hour of trading on futures and options on S&P500 index expirations were also confirmed in the more detailed analysis of Stoll and Whaley (1987).

After this first research, volume effects were investigated on various markets and confirmed among others on the spot market in Germany (Schlag 1996), Australia (Stoll, Whaley 1997), Sweden (Alkebäck, Hagelin 2004), India (Vipul 2005; Debasish 2010; Tripathy 2010; Narang, Vij 2013; Mahalwala 2016), Poland (Morawska 2007), China (Fung, Jung 2009), Spain (Illueca, Lafuente 2006), and Taiwan (Chow et al. 2013).

Despite analysing the same effect, some of these papers differ considerably. They present various measures and definitions of extended trading volume or they examine expiration day effects only in the case of futures or simultaneous impact of futures and options expirations. For example, Schlag (1996) analysed the impact of expirations of options and futures on the DAX index in the period from September 1991 to December 1994. He found that on quarterly expiration Fridays when futures and options expired simultaneously, the total daily trading volume of stocks from DAX was about 3.5 times higher than on other Fridays. On the other hand, on monthly expiration Fridays of options only, the number of shares traded was much lower. Hence, Schlag (1996) concluded that the observed volume effect was mainly due to futures expirations.

Stoll and Whaley (1997) examined volume effect on the Australian market between January 1993 and June 1996. As a measure, they used the relative trading volume for stocks from the AOI index defined as the ratio of the dollar trading volume from the last 30 minutes of the expiration day to the total dollar trading volume on that day. As a result, Stoll and Whaley (1997) showed that the relative trading volume from expiration days was usually higher than on control days, defined as non-expiration Fridays one and two weeks prior to the expiration days.

Alkebäck and Hagelin (2004) investigated the impact of simultaneous expiration of futures and options on the Swedish OMX index between January 1988 and December 1998, dividing the period into two sub-periods: before and after the removal of the transaction tax in December 1991. The detrended trading volumes of all stocks from the OMX index for expiration days were compared with the same measure for control days as defined in Stoll and Whaley (1997). A comparison was also made between whole expiration week and the corresponding control weeks. Alkebäck and Hagelin (2004) observed increased trading volume not only on the expiration days (on average, trading volume was about 9.4% higher on expirations than on control days), but also on earlier days from the expiration week. The authors suggested that this early increase in trading volume was caused by arbitrageurs unwinding their positions on spot and derivatives markets before expiration to mitigate the risk coming from the final settlement price of the contract. A similar observation was made, for example, by Debasish (2010) on the Indian market in the case of NSE Nifty index futures expirations between June 2000 and May 2009. On the other hand, other authors (Stoll, Whaley 1986; Illueca, Lafuente 2006; Morawska 2007) found that if the final settlement price of the derivative depends on the underlying asset's prices from a very short time period (usually from the last hour of trading on the expiration day) or only on the closing price, then increased trading volume indicating intensified trade on the underlying asset of expiring derivatives took place, especially in the final trading phase of the expiration day.

2.2 Volatility effects

Similar to trading volume, increased volatility implied by expiration of derivatives was detected, for example, in the USA (Stoll, Whaley 1986; Day, Lewis 1988; Diz, Finucane 1998), Australia (Stoll, Whaley 1997; Lien, Yang 2005), Canada (Chamberlain, Cheung, Kwan 1989), Sweden (Alkebäck, Hagelin 2004), Spain (Illueca, Lafuente 2006), Poland (Morawska 2007), India (Narang, Vij 2013; Agarwalla, Pandey 2013), and Taiwan (Chow et al. 2013).

To assess the impact of expiration on S&P500, Stoll and Whaley (1986) used two measures of index volatility, namely the standard deviation of daily returns of an index and its absolute abnormal returns. They computed and compared them for three types of days: expiration of S&P500 futures, expiration of CBOE options, and Fridays when nothing expired. The same volatility measures were calculated for the data from the last hour of trading. Stoll and Whaley (1986) found that the increased volatility on expiration is not observed for daily data, but it is visible when intraday returns are analysed. More precisely, quarterly expirations, when futures on S&P500 expired, imply significantly greater volatility in the last 30 minutes of trading. On the other hand, the effect is much smaller when options expire. These effects were observed only on stocks from S&P500, while there were no price effects on non--S&P500 stocks. In line with these results, Alkebäck and Hagelin (2004) suggest that close-to-close returns were unable to properly reflect price distortions implied by futures expiration. For this reason, as a measure of volatility they proposed to apply a daily price range, defined as the natural logarithm of the highest price divided by the lowest price on the day. However, the results of the analysis of volatility effects with this measure and with standard deviation of daily returns were similar. Significantly higher volatility of the OMX index on expirations was detected only in the period 1988–1991 before the removal of the transaction tax.

Vipul (2005) also pointed out that closing prices do not contain enough information about changes in volatility. Thus, he estimated the daily volatility using the difference between the maximum and minimum price divided by its average to make the measure comparable across all shares and time periods. His study, investigating expiration day effects of index and single stock derivatives in India between November 2001 and May 2004, revealed that volatility of underlying shares was not significantly affected by the expiration of futures and options.

Xu (2014), who analysed expiration effects of index futures and options in Sweden, also applied a high-low estimator to measure volatility. However, she did not detect statistically significant differences between volatility on expiration Fridays and non-expiration Fridays.

2.3 Price reversal

If the underlying asset price on the expiration day increases or decreases as a result of speculators' activity or due to the fact that many arbitrageurs unwind their positions in the same direction, it deviates from its fundamental value. On the effective market, this incorrectly priced asset should be very quickly spotted by other investors and the price should come back to the "normal level" by movement in the opposite direction. As a result of these activities, a price reversal on the day after the expiration may occur. Reversal of the underlying asset price was defined by Stoll and Whaley (1986) as a change of the sign of the return on the following day in comparison to its sign on the expiration day. To check the existence of price reversal after index futures and options expirations, Stoll and Whaley (1986) applied various measures. One of them was computed on daily returns, while the others compared returns from the last 30 minutes of the expiration day with returns from the first 30 minutes of the next trading session. They also analysed correlation between daily returns from the expiration day and from the next day. Stoll and Whaley (1986) found the price reversal after expirations of futures on S&P500. The average reversal when futures expired was 0.38% for the S&P 500 index, 0.53% for the S&P100 index, and 0.46% for non-S&P100 stocks. In those cases, the serial correlation of returns was also negative. On the other hand, no reversal was found for non-S&P500 stocks. Except for S&P500, there was also a small reversal when nothing expired, but it was not connected with negative serial correlation. Analogous results were obtained on the detailed research of S&P500 futures expiration conducted one year later (Stoll, Whaley 1987). In their other research (Stoll, Whaley 1991), which investigated whether the change in the settlement of S&P500 and NYSE index futures and options contracts had an impact on expiration effect, the authors proposed one more measure of price reversal of the index, namely portfolio reversal based on portfolio returns.

The anomaly of price reversal was also confirmed by Chamberlain, Cheung and Kwan (1989), Schlag (1996) and Suliga (2017), who applied some of the measures from Stoll and Whaley (1986, 1987, 1991). However, other studies on this effect did not find any symptom of the reversal (e.g. Karolyi 1996; Stoll, Whaley 1997; Alkebäck, Hagelin 2004; Morawska 2007; Fung, Jung 2009; Narang, Vij 2013). Vipul (2005) suggests that the definition of price reversal given by Stoll and Whaley (1986, 1987, 1991), “ignores the total quantum of change in price, both in the same direction and in the opposite direction.” For this reason, he decided to study price shock around expiration rather than the price reversal. He found abnormally high rates of increase of returns on the day after the expiration. In most of the cases it is not the price reversal, but Vipul (2005) suggested that, “it certainly indicates a sudden upward acceleration in the prices after the expiration day, irrespective of the increase or decrease in the price on the expiration day”, which can be seen as a price effect of expiration. Price shock was also examined by Xu (2014) on the Swedish market, but she did not find any significant changes in price reversals and price shocks on expiration and non-expiration days.

The limitation of Stoll and Whaley’s (1986) definition of price reversal was also noticed by Suliga (2017) who analysed a change of the sign of abnormal returns computed as the difference between observed and expected returns.

2.4 Expiration day effects on the WSE

Expiration day effects of futures on the Warsaw Stock Exchange have been studied by Morawska (2004, 2007) and Suliga (2017). Morawska (2004, 2007) examined only the influence of the expiration of WIG20 index futures on returns of the index itself and on trading volume of the stocks from it. The results confirmed the effect of increased trading volume of the stocks and increased volatility of intraday returns of the index, but did not reveal price reversal of index returns after the expiration. It should be noted that Morawska carried out her research for the initial years of futures trading on the WSE and she studied only futures on the WIG20 index, as, in those years, the volume of futures on WIG20 formed about 97% of the whole volume on the derivatives market. Suliga (2017) largely extended the period under study by considering the expiration days from 2001 to 2016. Beside futures on

WIG20, she also analysed the impact of futures on mWIG40 and futures on individual stocks. To study the effect of price reversal after expiration, Suliga (2017) employed three different measures. All of them supported the thesis that price reversal in stocks' returns occurs after expiration of stock futures, but none of them confirmed the reversal in WIG20 and mWIG40 returns.

2.5 Price settlement procedures for futures contracts and expiration day effects

Results from research conducted on different foreign markets indicate that the way futures contracts are settled is a very important factor leading to expiration day effects or preventing them.

Stoll and Whaley (1986), who studied expiration day effects of futures on the S&P500 index and futures on the MMI index, verified that in the case of contracts that were settled at a closing index level on the expiration day, the activity of investors was intensified in the last minutes of trade, triggering expiration day effects. Similarly, an increase in trading volume and return volatility at the maturity of Ibex35 futures on the Spanish equity market was detected by Illueca and Lafuente (2006). The strongest volume and volatility effects were observed within the final interval of trading on expiration day (16:00–17:30) while the settlement price of these contracts was calculated as the arithmetic average of index values between 16:15 and 16:45.

Morawska (2007), who studied the expiration day effects of these futures in the period 2002–2006, detected significantly higher volatility of stocks from the index during the last hour of trading on expiration Fridays in comparison to non-expiration Fridays. Another confirmation of the fact that expiration day effects depend on the settlement procedure of futures contracts is the research on the effects of Hang Seng Index futures expirations conducted by Fung and Jung (2009) on the Chinese stock exchange. The final settlement price of these contracts was equal to the arithmetic average of the index values taken every five minutes on the whole expiration day. The authors demonstrated that close to the five-minute time marks, trading activity intensified both in frequency and volume.

Alkebäck and Hagelin (2004), who studied expiration day effects of futures and options on the Swedish OMX index, verified that if the settlement price of a derivative was based on intraday quotes of the underlying asset from the whole expiration day, the possibility of influencing the settlement price was limited and the price was easier to estimate. In fact, they showed that trading activity intensified during expiration week and on expiration day, but they did not find any sharp price movements on the expiration. According to them, a long settlement period helps to curb such unusual changes in stock prices and the activity of speculators and arbitrageurs did not cause any price distortion.

To check if the occurrence of the effects depends on the settlement price of the contract, Hsieh and Ma (2009) compared expiration day effects of two index futures with different settlement mechanisms which have the same underlying spot market. They found that to minimize the effects, "the average price is better than the opening price, which in turn is better than the closing price settlement."

From the abovementioned results, it follows that expiration day effects can occur particularly in the period of time from which the prices of underlying assets are used to calculate the final settlement price of the contract. Hence, the longer the settlement period is, the weaker the effects are.

On the WSE, the settlement price of futures on the WIG20 index, as well as futures on the mWIG40 index, is equal to the trimmed average of values of continuous trading of an index from the last hour of trading and the value at close. Before computing, the average 5 highest and 5 lowest values are removed. On the other hand, individual stock futures traded on the WSE are settled at a closing price. Thus, we expect the effects to be stronger in the case of single stock futures. However, it should be mentioned here that most of the stocks analysed in the paper are from the WIG20 index. As stock futures and index futures expire on the same days, the effects that can be seen in stock quotes may arise from both index futures and stock futures expirations. Although we expect expiration day effects on the WSE to exist, the use of daily data in this study may make it difficult to detect them if they occur in a short period of time. Thus, to detect price reversal, next to day-to-day returns, we also use overnight returns, as Alkebäck and Hagelin (2004) suggested that this effect can take place long before the markets close on the day following expiration.

3 Data, methodology and research hypotheses

In this paper, we examine the effect of increased volume, volatility and price reversals after expiration of individual stocks futures and on index futures on WIG20 and mWIG40. Hence, our dataset contains daily open, close, maximum, and minimum price and turnover value of WIG20, mWIG40 and underlying stocks from the WSE. For single stocks, we also take into account daily trading volume. Data covers the period from January 2001 to the end of December 2016. Due to quarterly expiration of index futures on the WSE, within the period under study there are 64 expiration days of futures on WIG20 and 60 expirations of futures on mWIG40 (the first futures on the stock market index of medium-sized companies expired in March 2002; in May 2007, the name of the index was changed from MIDWIG to mWIG40). The first futures on individual stocks were introduced in 2001, but before 2003 some of the stock futures (e.g. futures on PKN) used to expire every month. Since 2003, all futures on stocks have had the same expiration days as index futures that are third Fridays of the quarterly months (i.e. March, June, September, and December). Hence, to have in the sample futures with the same expiration days, we decided to study only stock futures expiring after January 2003. Table 1 presents a detailed list of futures under study together with information about the first expiration date and the number of expirations analysed. Not all expirations of futures were taken into account. We consider only stock futures with at least one opened position on the expiration day. Futures with no opened positions on the expiration were excluded from the sample.

To study the expiration day effects, we employed two different methodologies. The first one is based on a comparison of measures of the effects computed for expiration days and for control days. This stream of research was proposed by Stoll and Whaley (1986, 1987, 1991). In the following years, it has been used, inter alia, by Bollen and Whaley (1999), Alkebäck and Hagelin (2002), Morawska (2007), Hsieh (2009), Chay, Kim and Ryu (2013) and Xu (2014). Following Suliga (2017), in addition to classical measures of expiration day effects, we also used event study analysis as a second method of research.

3.1 Measures of expiration day effects

In foregoing studies on expiration day effects, authors have constructed various measures of expiration day effects. The most common method of analysis was the comparison of these measures computed for expiration days and for appropriately defined control days. Such a comparison was first proposed by Stoll and Whaley (1986, 1987, 1991) and then used by others (see, for example, Bollen, Whaley 1999; Alkebäck, Hagelin 2002; Morawska 2007; Hsieh 2009; Chay, Kim, Ryu 2013; Xu 2014). In the first part of our study, we will follow this methodology.

Trading activity

To measure volume effects on expiration days, we apply two measures: V_t – natural logarithms of daily turnover on the day t and relative turnover RV_t defined as a daily growth rate of turnover value for the stock or index:

$$RV_t = \ln\left(\frac{V_t}{V_{t-1}}\right) \tag{1}$$

A comparison of V_t on expiration days and on control days reveals how much higher (or lower) the trading activity on expiration days is than is usual on other Fridays. On the other hand, RV_t describes the dynamics of changes in trading activity from one day to another. The comparison of RV_t on expiration and non-expiration days will show whether the changes in the trading activity from Thursday to Friday are implied by futures expirations.

Bollen and Whaley (1999), as well as Xu (2014), considered measures analogous to RV_t, but defined on the basis of daily trading volume (a number of shares traded) instead of the turnover. We decided to apply the total value of shares traded as the main measure of trading activity because, in the case of stock market indexes (such as WIG20 and mWIG40), turnover is a more appropriate measure of trading activity. The trading volume of an index, defined as the sum of the trading volume of all its stocks, is an incorrect measure of the trading activity, because it may be dominated by the trading volume of a single stock with very cheap but numerous shares. However, in order to ensure comparability of this study with the previous results, in the analysis of expiration day effects implied by single stock futures we will apply measures based on the trading volume as well.

Volatility

In order to study the impact of expiration on stock price volatility, we apply a variety of measures. First, we consider absolute values of daily stock or index returns $|R_t|$ computed on the basis of closing prices, because absolute (or squared) returns are one of the most commonly used measures of daily stock price volatility. To take into account only volatility during the continuous trading phase, we consider absolute values of returns R_t^{oc} from opening to closing of a trading session:

$$R_t^{oc} = \ln\left(P_{t,\,close}\right) - \ln\left(P_{t,\,open}\right) \tag{2}$$

Intraday volatility of prices is also estimated on the basis of the difference between maximum and minimum price. More precisely, we use the estimator proposed by Vipul (2005):

$$VOL_t = \frac{P_{t,max} - P_{t,min}}{\frac{1}{2}\left(P_{t,\,max} + P_{t,\,min}\right)} \tag{3}$$

where $P_{t,\,max}$ and $P_{t,\,min}$ are the maximum and minimum prices of the stock (or index) on day t, respectively.

Parkinson (1980) showed that when the prices are log-normally distributed, then estimates based on differences between $P_{t,\, max}$ and $P_{t,\, min}$ are about five times more efficient than those based on closing prices. Moreover, these estimates are robust when the price distribution is not log-normal.

Price reversal

To study the price reversal effects, we analyse the behaviour of the overnight returns just after the expiration day. Thus, the price reversal measure after the expiration is defined as in Xu (2014) as:

$$REV_t^{ON} = \begin{cases} R_t^{co} & \text{if} \quad R_{t-1}^{oc} < 0 \\ -R_t^{co} & \text{if} \quad R_{t-1}^{oc} \geq 0 \end{cases} \tag{4}$$

where $R_{t-1}^{oc} = \ln\left(P_{t-1,\, close}\right) - \ln\left(P_{t-1,\, open}\right)$ is the log-return from the expiration (or control) Friday and $R_t^{co} = \ln\left(P_{t,\, open}\right) - \ln\left(P_{t-1,\, close}\right)$ is the overnight log-return just after the expiration (or control) day computed on the basis of the opening price on the next day (usually it is Monday) $P_{t,open}$ and $P_{t-1,\, close}$ the closing price $\left(P_{t-1,\, close}\right)$ from the expiration (control) day.

Its interpretation is as follows: if there is a price reversal and the price changes its direction immediately after the futures expiration, then negative returns $R_{t\text{-}1}^{co}$ on an expiration day are followed by positive overnight returns R_t^{co}, and vice versa, negative overnight returns R_t^{co} follow positive returns $R_{t\text{-}1}^{co}$ on the expiration day. Hence, significantly positive REV_t^{ON} indicate reversal of price direction during the night after futures expiration, while significantly negative REV_t^{ON} are indicators of price continuation.

A measure of price reversal similar to the above was first proposed by Stoll and Whaley (1986, 1987, 1991) and then employed by others (e.g. Chamberlain, Cheung, Kwan 1989; Alkebäck, Hagelin 2004; Xu 2014). However, in the first two articles, Stoll and Whaley defined it in terms of daily close--to-close returns on expiration day and on the next day. Stoll and Whaley (1991) used returns from the last-half hour of trading on expiration Friday and the first half-hour return on the next day. Alkebäck and Hagelin (2004) suggested that day-to-day returns may be unable to reflect price reversal because it takes place long before the market close the day after the expiration. If the reversal is immediate, it can be reflected even in the opening price on the day after expiration. Hence, we use the post-expiration overnight rather than daily returns in the analysis.

To measure the speed of potential price reversal, we also consider a price reversal measure based on close-to-close returns from the whole day after futures expiration:

$$REV_t = \begin{cases} R_t & \text{if} \quad R_{t-1}^{oc} < 0 \\ -R_t & \text{if} \quad R_{t-1}^{oc} \geq 0 \end{cases} \tag{5}$$

where $R_t = \ln\left(P_{t,\, close}\right) - \ln\left(P_{t\text{-}1,\, close}\right)$ is simply a daily return. This measure was applied by Suliga (2017).

Control days, which form the background for the comparison of the measures computed on expiration days, are defined in two different ways. In the first case (control days I), the measures computed for the first, second and fourth Friday of an expiration month are averaged to represent one control day. This approach ensures an equal number of the compared values of a measure from expiration and control days. In the second case (control days II), the control values are computed on the third Fridays of months without expiration. Thus, for each expiration day, the results for the third Friday of the preceding month and the third Friday of the following month are averaged to give one control value. The procedure of averaging observations from a few control days to one benchmark was also employed by Vipul (2005). Comparison of the results for expiration days with control days II also shows the impact on stocks from the WSE of futures expirations on other markets, particularly on Eurex, where futures contracts expire every month.

The values of the expiration day effects measures computed for expiration days and control days are compared with the use of the nonparametric Mann-Whitney U test (see Mann, Whitney 1947), which verifies whether there is a significant difference in their distributions. An unquestionable advantage of this test is the fact that it does not assume normality of data and therefore is more robust that the parametric *t*-test.

3.2 Event study analysis

In the second part of the research, we apply event study methodology to study expiration day effects on the WSE. This method was first applied to this issue by Suliga (2017) in the analysis of price reversal effect. We apply this methodology to study the impact of expiration day trading volume, volatility, and prices of the underlying assets.

First of all, we must define what we mean by the event. In this paper, the event is the expiration of futures. For such an event, we study how prices, volatility and trading activity measure for the underlying stock change just before and just after it. To do this, we define the pre-event and the event windows as follows. Let us denote the expiration day by $t = 0$. The event window starts five days before the expiration and ends two days after it ($t = -5, \ldots, 2$). Such a span of the event window is dictated by the suggestions from foregoing studies that expirations effects can be observed over a week before an expiration as a result of early unwinding of arbitrage positions (e.g. Stoll, Whaley 1986; Alkebäck, Hagelin 2004). The price reversal is the only effect that may occur after the expiration. As this phenomenon should be observed immediately after the expiration, we decided to include in the event window only two days after the expiration. We define the pre-event window as widely as possible in order not to overlap with the previous event window. Because futures on the WSE expire quarterly, the optimal choice is to define the pre-event window to cover 45 trading days before the event window ($t = -50, \ldots, -6$). The length of the pre-event window is chosen to prevent the occurrence of confounding events. The pre-event window almost reaches the event window of the previous expiration, but these windows do not overlap and the previous expiration day is not included in the pre-event window of the next expiration.

The fact that the same estimation window (and slightly wider event window starting five days before the expiration and ending five days after it) was used by Suliga (2017) enables us to compare our results with those she obtained.

The analysis of the impact of the futures market on the spot market is performed by testing whether turnover or volatility on the expiration day (or prices on the next day) deviate from their "normal" values. The appropriate test statistic is constructed on the basis of abnormal variables $AX_{i,t}$

defined for the *i*-th event as the difference between the value of the respective variable $X_{i,t}$ and its expected value $E(X_{it} \mid \Omega_{-6})$ conditional to data from the pre-event window, i.e. data set Ω_{-6} at t = -6:

$$AX_{i,t} = X_{i,t} - E(X_{it} \mid \Omega_{-6}) \tag{6}$$

In this paper $E(X_{it} \mid \Omega_{-6})$ is approximated by the average from the pre-event window. Because we study three different effects, three different kinds of variables $X_{i,t}$ are considered according to volatility, volume and price effects studied, namely natural logarithms of daily turnover value $\ln\left(v_{i,t}\right)$, daily volatility measure $VOL_{i,t}$ defined in Subsection 3.1, and the overnight log-returns $R_{i,t}^{co}$

On the basis of abnormal variables given by formula (6), we verify whether the futures market significantly impacts the spot market at $t = t_0$ by testing the following hypotheses:

$$\begin{aligned} &H_0 : E\left(AX_{it_0}\right) = 0 \\ &H_1 : E\left(AX_{it_0}\right) \neq 0 \end{aligned} \tag{7}$$

To verify these hypotheses, we apply the Kolari-Pynnönen test statistic, which verifies the significance of the mean of the abnormal variables in the event window. To compute the test statistics, we group events into clusters and then for each event i (i = 1,…, N) in the cluster, the values of the abnormal variable $AX_{i,t}$ in the event and pre-event windows are divided by their standard deviation from the pre-event window. The resulting standardized abnormal variables have the form:

$$SAX_{i,t} = AX_{i,t} / S\left(AX_i\right) \tag{8}$$

where $S(AX_i)$ is the standard deviation of forecast errors, which in the case of the constant mean model takes the form:

$$S\left(AX_i\right) = \sqrt{\frac{1}{44} \sum_{t=-50}^{-6} \left(AX_{i,t} - \overline{AX_i}\right)^2} \tag{9}$$

$$\overline{AX_i} = \sum_{t=-50}^{-6} AX_{i,t} \tag{10}$$

Then, to take into account an event-induced increase in volatility, standardized abnormal variables $SAX_{i,t}$ on each day t in the event window are divided by their cross-sectional standard deviation to obtain adjusted standardized abnormal returns:

$$SAX'_{i,t} = \begin{cases} SAX_{i,t} & t = -50,\ldots,-6 \\ SAX_{i,t} / S\left(SAX_t\right) & t = -5,\ldots,2 \end{cases} \tag{11}$$

where $S(SAX_t)$ is the cross-sectional standard deviation of $SAX_{i,t}$ on t-th day:

$$S\left(SAX_t\right)=\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(SAX_{i,t}-\overline{SAX_t}\right)^2} \tag{12}$$

and N is the number of events in the cluster. Under the null hypothesis of no event effect, for given t_0 in the event window, SAX'_{i,t_0} are zero mean and unit variance random variables. For each day $t_0\in\{-5,\dots,2\}$ separately, we test the significance of abnormal variables with the use of standardized ranks defined as:

$$U_{i,t}=\frac{rank\left(SAX'_{i,t}\right)}{47}-\frac{1}{2} \tag{13}$$

where $t\in\Omega=\{-50,\dots,-6,t_0\}$ and $i=1,\dots,N$, and $rank\left(SAX'_{i,t}\right)$ denotes the rank of $SAX'_{i,t}$ within the vector of adjusted standardized abnormal variables from the pre-event window and SAR'_{i,t_0}.

The null hypothesis of no event effect means that $E\left(U_{i,t_0}\right)=0$. To test this hypothesis, Kolari and Pynnönen (2011) propose a generalized rank test with the test statistics τ_{grank} defined as:

$$\tau_{grank}=Z\sqrt{\frac{T-2}{T-1-Z^2}} \tag{14}$$

where:

$$Z=\frac{\overline{U}_{t_0}}{S_{\overline{U}}},\quad \overline{U}_{t_0}=\frac{1}{N}\sum_{i=1}^{N}U_{i,t_0},\quad S_{\overline{U}}=\sqrt{\frac{1}{46}\sum_{t\in\Omega}\overline{U}_t^2} \tag{15}$$

If the null hypothesis is true, the distribution of τ_{grank} statistics converges to *t*-Student distribution with 44 degrees of freedom when the sample size N increases to infinity.

To verify the existence of price reversal after the expiration, the overnight returns are divided into two separate clusters according to the sign of the abnormal returns from open to close on the expiration day. The first cluster consists of overnight returns after the expiration days with positive daily abnormal returns (i.e. when prices increase more than expected), while the second one contains the overnight returns after the expiration days with negative daily abnormal returns (i.e. when prices decrease more than expected). In that way, we are able to analyse separately the price reversals after an unexpected increase or decrease of prices.

It should be stressed here that the method described above defines the price reversal differently, and, in our opinion, more appropriately than the measure proposed by Stoll and Whaley (1986) and employed in the first part of Section 4. In Stoll and Whaley (1986), price reversal was equivalent to the change of the return's sign, and, as was noted by Vipul (2005), "this leads to a loss of information in terms of the magnitude of total change." Here, price reversal was defined as a change in the direction in which the return significantly deviates from its expected value. The degree of discrepancy between the expected value of the return and its realised value seems to be an even more appropriate measure of the unusual price movement than the magnitude of the price change from expiration day to the next day.

The general assumption of the Kolari and Pynnönen (2011) test is that abnormal returns are independent and identically distributed. In this study, however, we apply the test to data that do not fulfil these conditions. In the constant mean model, abnormal returns have the same properties as returns, hence frequently they are autocorrelated and heteroscedastic. Similarly, measures of abnormal trading activity (volume and volatility) show strong and significant autocorrelation. Additionally, in the case of tests for the expiration day effect on single stocks, events are clustered, and thus cross-sectional correlation of abnormal variables may be observed. In their paper, Kolari and Pynnönen (2011) applied simulations to analyse the power and size of the τ_{grank} test. As a result, they showed that for daily returns the test is robust to possible autocorrelation and heteroscedasticity. However, we don't only consider returns. Hence, we perform an analogous simulation procedure to study how various properties of data applied in this paper impact the results of the Kolari and Pynnönen (2011) test. We described the simulation procedure on the example of the WIG20 trading volume.

As it was mentioned at the beginning of this section, and as it can be noticed from Table 3, for each index we studied about 60 events of futures contract expirations. From the whole sample of daily trading volume of WIG20 in the period from January 2001 to December 2016, we randomly select 1000 samples of $N = 60$ trading volume series. Each of these series has a length of 53 days (which corresponds to the length of the pre-event and event windows from Section 3.2) and the 51st element ($t = 0$) is an event day. Then, in each sample generated in that way, we compute the value for $t = 0$. On the basis of the whole sample of 1000 values of statistics, we computed rejection rates for various significance levels. Data in the sample is randomly chosen, so the null hypothesis in the event study analysis that there is no event effect is true. Hence, the rejection rates describe Type I errors. To study the power of the Kolari and Pynnönen test in the above simulation, we add a small value P^* to trading volume on the event days. P^* is defined as a fraction of trading volume standard deviation from the whole sample.

To study the properties of the Kolari and Pynnönen test in the case of the analysis of single stock futures expiration, the simulation procedure is as follows. First, from the sample of all trading days between March 2003 and December 2016 we randomly chose 30 days. These are event days. Next, for each event day we randomly chose ¾ of stocks mentioned in Table 1 that were traded on that day. For each of these stocks we take into account data from 50 days before the event to 2 days after it. As a result, we obtain a sample of about 500–600 series corresponding to 30 event days. On the basis of these data we compute the value of τ_{grank} statistics for the event day. The whole procedure is repeated 1000 times.

The simulation procedure described above generates data in which the null hypothesis of no event effect is true. Hence, its rejection rate in a simulated sample describes a Type I error. The results presented in Table 2 indicate that for the majority of data analysed in this paper, computed empirical values of Type I errors are very close to nominal significance levels. This ensures the correctness of the results of the empirical analysis presented in the next sections. Only in the case of log-turnover and volatility measure are the rejection rates outside their 95% confidence intervals. It is particularly visible in the case of the reaction of single stocks, and it means that for this data the Kolari-Pynnönen test tends to over-reject the true null hypothesis. The possible cause of the increased values of Type I errors for that data is a conjunction of high and significant correlation observed in log-volume and volatility time series with cross-sectional correlations induced by events clustering when the reaction of various stocks to common events is analysed. To take into account this negative impact of data properties on the size of the Kolari-Pynnönen test, on the basis of simulations we computed respective empirical critical values of the test. In the case of log-turnover of single stocks, the empirical critical values for the 1%, 5% and 10% significance levels are equal to 2.91, 2.19 and 1.86, respectively. For volatility measures, they are 2.89, 2.27 and 1.91. In the empirical analysis, these values should be applied instead of theoretical critical values from *t*-Student distribution with 44 degrees of freedom which are equal to 2.69, 2.02 and 1.68. However, as we see, the differences between empirical and theoretical critical values are small, and, as it will be stressed in Section 4, these differences do not impact the results of the analysis.

3.3 Research hypotheses

On the basis of the results from foreign markets, we formulate some hypotheses about expiration day effects on the Polish equity market.

Trading activity

As the volume effect of futures expirations was detected on each of the researched markets, we expect that this effect also occurs on the Polish market. Therefore we conjecture that on expiration days turnover values of underlying stocks and indexes strongly increase above expectations, and that their values are significantly larger on expiration day than on other Fridays without futures' expirations.

Volatility

Volatility effect varies depending on the market, the period under study, the employed measure of the effect or the settlement procedure of the contract. The comparison of different settlement procedures reveals that the longer the settlement period, the weaker the effects. Thus, we suppose that return volatility of individual stocks increases as an effect of stock futures expirations. On the other hand, due to different settlement procedures, we do not expect to detect such effects in the returns of indexes.

Price reversal

As it appears from the literature, price reversal after futures expiration occurs when stock prices return to their normal level. As it is much easier to change the closing price of individual stock than to influence the average price of the index, we expect that price reversal may occur in individual stock prices, but not in indexes. Additionally, since Chay, Kim and Ryu (2013), as well as Alkebäck and Hagelin (2004), suggest that incorrectly priced stocks should revert to a normal price level immediately after the expiration, we suppose that price reversal will be reflected in overnight returns rather than in close--to-close returns.

Evolution of expiration day effects

To check how the occurrence and the strength of the expiration day effect on the WSE were changing over time, we conduct the study in four sub-periods, as follows: 2 January 2003 – 31 December 2009;

2 January 2010 – 14 April 2013; 15 April 2013 – 31 May 2015; and 1 June 2015 – 31 December 2016. Each of these sub-periods contains about 150 expirations of single stocks futures. The first sub-period covers the beginning phase of the development of the futures market on the WSE, when the number of contracts traded was limited. Thus, it is much longer than the other periods. It also includes the global financial crisis of 2007–2009. The second sub-period contains data after the crisis up to the change of the trading system on the WSE. On 15 April 2013, the WARSET trading system was replaced by the UTP, which could potentially intensify expiration day effects as a faster and more advanced system facilitates carrying out speculative and arbitrage strategies. The third breakpoint is 1 June 2015, the day when changes in the rules regarding the short selling of stocks were introduced. These changes resulted from the adaptation of the foregoing regulations of the WSE to EU requirements, in particular to Regulation 236/2012. The restrictions on short selling related to the liquidity of shares were lifted, so since then the transaction system of the WSE has accepted every short sell order. What is more, the obligation to mark short sell orders was waived. As the changes significantly facilitated short selling, they might reduce investors' interest in futures and thus reduce expiration day effects because short positions in futures can be substituted by an appropriate short selling of stocks. Moreover, these changes make arbitrage strategies on stocks and futures regarding short position in stocks easier to conduct. This may also diminish price effects because of unwinding arbitrage positions in two opposite directions. Thus, while analysing expiration day effects in the sub-periods, we do not expect drastic changes in the impact of the futures market on the spot market; however, we suppose that there can be an intensification of the effects in the third sub-period and their attenuation in the last one.

4 Empirical results

4.1 Results for classical measures of expiration day effects

To compare expiration day effects on the WSE with previous results from literature, we first apply the classical measures described in Section 3.1. Table 3 presents means and medians of log-turnover V_t and relative turnover RV_t for underlying assets of index and single stock futures. We compute these measures on expiration days as well as on control days defined in Section 3.1. The results from these two groups of days are compared on the basis of Mann-Whitney U tests, whose p-values are also presented in Table 3. We decided to apply a nonparametric test rather than a parametric one because of the well-known non-normality of stock and index returns.

The leftmost columns of Panel A confirm the existence of increased trading activity on the largest stocks from the WSE. The mean and median of WIG20 turnover on expiration days are greater than on both kinds of control days, and the Mann-Whitney tests confirm the significance of these differences. It means that trading volume on expiration days is significantly higher than on other Fridays taken into consideration, particularly on the days when futures contracts on other markets expire. The results from Panel B also indicate that not only is the turnover value of stocks from WIG20 higher on expiration days, but also its change from Thursday to Friday is the strongest on expiration days. Both these results (from log-turnover and the relative turnover) confirm the existence of the effect of increased turnover value of the WIG20 index on expiration days.

Such conclusions cannot be drawn from the results of the analysis of mWIG40 turnover. Mean and median log-turnover values on expiration days are higher than on both types of control days, but the differences are statistically insignificant. Also, the relative turnover values of mWIG40 on expirations do not differ significantly from the values obtained for control days I (the first, second and fourth Friday of an expiration month).

In the case of stock futures, significantly higher trading turnover on underlying assets on expiration days similar to the WIG20 futures is observed. Additionally, day-to-day changes of trading activity are significantly different on expiration and control days.

Comparison of the means of log-turnover from Panel A shows how much the expiration of futures increases trading activity. In the case of the largest and the most liquid stocks from the WIG20 index, turnover on expiration days is on average (in terms of geometric mean) about 50% higher than on the other Fridays of expiration months and it is about twice as high as on the other third Fridays of the month. Expiration of single stock futures raises turnover of underlying assets by about 118% and 128%, respectively. On the other hand, the changes observed in the trading activity on medium-size stocks from mWIG40 are much smaller and more insignificant. They are equal to 8% and 19%, respectively.

From Panel B of Table 3, we can notice that, on average, the turnover value of WIG20 stocks increases on expiration day by about 40% when compared to the day before. This change in investors' activity implied by futures expiration is even more pronounced in the case of single stocks, where the average growth of turnover value from Thursday to expiration Friday is equal to about 80%. On Fridays without futures expirations, turnover value of underlying stocks is, on average, lower than on preceding Thursdays.

The above results confirm that the impact of the expiration of WIG20 index futures and single stock futures on trading activity on the WSE is strong and significant, particularly when compared with results from other markets. On many of them, futures expiration increases trading activity, similar to that for the mWIG40 index. For example, Alkebäck and Hagelin (2004) showed that between January 1988 and December 1998, the total trading volume of all stocks from the OMX Index on expiration days was, on average, 9.4% higher than on control days. The average growth of the daily volume of stocks was equal to 17% on the US market in the period from June 1982 to December 1985, when S&P500 futures and S&P100 options expired simultaneously (Stoll, Whaley 1986). On the Spanish equity market, on expiration days of Ibex35 futures between January 2000 and December 2002, the total volume of the stocks was, on average, 24% higher than on control days (Illueca, Lafuente 2006). Similar results were obtained on Asian markets: the average volume growth of stocks from the Hang Seng Index was equal to 19% when index futures expired (Fung, Jung 2009), while on the Indian market such growth reached 6% on the NSE Nifty Index futures expirations (Debasish 2010).

Results of the analysis of how expiration impacts return volatility presented in Table 4 are not as clear as the results from Table 3. All the differences between volatility measures based on opening and closing prices on expiration and control days are insignificant at the 5% level. However, it is in line with the arguments of Alkebäck and Hagelin (2004) that daily returns are poor measures of how futures expirations impact price volatility.

More clear-cut results come from the analysis of volatility measure based on maximal and minimal prices. The return volatility VOL_t of single stocks on expiration days is significantly higher than on the control days. In the case of index futures, the application of this measure does not reveal significant changes. Hence, expiration day effects on volatility are observed only in the case of single stocks.

A high-low estimator of volatility was also employed by Vipul (2005), who stated that on the Swedish equity market neither index futures expirations nor stock futures expirations significantly affected the volatility of underlying assets. However, the key difference between stock futures listed on the WSE and those analysed by Vipul (2005) lies in the settlement procedure. On the Warsaw futures market, the settlement price of stock futures is equal to the last transaction price of the underlying asset, while for OMX stocks it was calculated as the weighted average price from the last half-hour of the trading. The different results obtained for the Polish and Swedish markets seem to confirm the thesis formulated by Chung and Hseu (2008) that, "using an average price settlement based on a longer period would mitigate expiration day effects much better than a closing price settlement". This is also supported by the lack of volatility effect on WIG20 and mWIG40 as the settlement values of index contracts are based on the average values from the last hour of the expiration day.

Negative values of medians of the close-to-close price reversal measure REV_t in Table 5 computed for WIG20 show that the major index of the WSE does not change its direction after expiration of futures. It is rather the opposite: WIG20 tends to continue and the returns on the day after expiration usually have the same sign as the returns on expiration day. The same observation can be drawn when we restrict attention to overnight returns.

The behaviour of mWIG40 is quite different. The positive mean and median of REV_t indicates a reverse of mWIG40 returns after futures expiration. Moreover, negative values of these statistics for control days deny the existence of this phenomenon on other Fridays under study. Finally, p-values of the Mann-Whitney tests calculated both for the close-to-close and for overnight price reversal measure confirm the significance (at least at the 10% level) of price reversal of mWIG40 implied by futures expirations. Equally strong results, but with more significant differences, can be noticed when changes in prices of single stocks on the day after expiration are analysed. Similar conclusions are also valid for overnight returns. However, we observe a reduction in the differences between means and medians computed for expiration and control days. Additionally, overnight returns of single stocks after the other Fridays under study also tend to reverse their signs, as indicated by non-negative means and medians. Comparison of the results in Panel A and B in Table 5 indicates that price reversal of single stocks and the mWIG40 index is reflected both in close-to-close returns and in overnight returns. Chay, Kim and Ryu (2013) claimed that abnormal price levels caused by futures expiration should revert to the normal level on the following morning. The results from WSE only partially confirm this statement. Although the process of price reversal starts at the opening of the market on the day following expiration, it lasts until the end of the Monday trading session.

The results of the application of classical measures of expiration day effects reported in Tables 3–5 can be summarised as follows. Expiration of futures on the WSE significantly increases turnover of all underlying assets except for the mWIG40 index, whereas only the volatility of single stock prices increases. A price reversal effect can be noticed after the expiration of mWIG40 and single stock futures.

4.2 Results from event study analysis

The results in the previous subsection are based on the comparison of prices, volatility and turnover on expiration days with control days only. To describe the impact of futures expiration on the spot market from a different perspective, we apply event study analysis. This allows us to compare the behaviour of prices, volatility and turnover in expiration days with "normal" days from the pre-event window.

The event study analysis is performed for each measure considered in the previous subsection; however, in order to save space we present only the results for log-turnover, relative turnover, volatility measure and overnight returns. The results for WIG20 and mWIG40 are reported in Table 6, where for each variable we present the values of averages together with the values of the test statistic of the τ_{grank} test. However, the results of the analysis of volatility measures are not included in the table as all of them are insignificant.

The leftmost part of Panel A presenting the results for WIG20 contains averages of abnormal log-turnover. The average on a day $t = 0$ is equal to 0.545 and the value of the test statistics indicates a significantly positive (at the 1% level) impact of the event. It confirms the results from the previous subsection that futures expiration increases trading activity on expiration day. Here, log-turnover of WIG20 stocks on expiration days is about 55% higher than usual. On the next day, ($t = 1$) the average -0.262 is significantly negative at the 5% level, which suggests that the day after futures expiration, the activity of investors falls rapidly below its usual level. It is also smaller than activity on the other Monday in the event window ($t = -4$) which also has a significantly negative average. The other averages in the event window are insignificant.

The results of the event study analysis applied to relative turnover (the middle part of Panel A) show significantly positive averages on days $t = 0$, $t = 2$, and $t = -3$ (0.334, 0.2, and 0.188, respectively), and significantly negative averages on $t = 1$ and $t = -4$. This confirms the observations made on the basis of log-turnover that trading activity on expiration significantly increases (much more than expected) and then significantly decreases on the next day. The drop in the trading activity the day after expiration is so huge that the return back to its normal level on the next day is seen as a significantly positive change.

Significant changes for $t = -3$ and -4 suggest a periodic pattern in investors' trading activity as $t = -3$ and $t = 2$ are usually Thursdays and $t = -4$ and $t = 1$ are usually Mondays. However, the values of $\overline{ARU_t}$ for Mondays are very different from each other, indicating a strong impact of futures expiration on trading activity on the next day. On the other hand, the averages for Thursdays are very close, which indicates periodicity rather than the impact of expiration.

The other measures mentioned in Subsection 4.1 have insignificant averages around the event. In particular, there are no significant changes in any of the volatility measures for WIG20. Also, price reversal after expiration is not detected, which is reflected in the right part of Panel A of the table.

The results for mWIG40 futures in Panel B are very similar to those of WIG20. In contrast to the results based on the classical measures from the previous subsection, they clearly confirm the effect of increased turnover values of mWIG40, but do not confirm the effect of price reversal. On futures expirations, log-turnover values of the index are higher than expected as the average of abnormal log-turnover, $\overline{AV}_0$ is significantly positive. Moreover $\overline{AV}_1$ is significantly negative at the 5% level, which is a sign of reduced investors' activity after expiration.

On the other hand, day to day changes in trading activity are insignificant on the expiration day, but the changes in log-turnover in the two days after the expiration are similar to those in WIG20: the drop in turnover on the next day is greater than expected, and then its return back is also significantly stronger than usual.

The price reversal effect in Table 6 is analysed separately in two clusters according to the value of abnormal return AR_0 where the return R_0 is a log-return from open to close on the expiration day. In addition to this analysis, we study the price reversal effect when events are classified into respective clusters by abnormal daily close-to-close returns. In that case, averages of abnormal overnight returns before the expiration day are significant and their signs are in line with signs of close-to-close abnormal returns on the expiration day. This means that significant abnormal changes of indexes on the expiration day start the night before it. However, even in that classification means $\overline{AR}_t^{\prime co}$ remains insignificant on the day after the expiration.

The lack of the significant price reversal implied by mWIG40 futures expiration is due to the fact that in the event study analysis we define price reversal in a different way than in the analysis of classical measures. The results in Table 5 indicate that after futures expirations the changes of the sign of mWIG40 returns occur more often than its continuation. However, Table 6 shows that the returns on the day after expiration do not deviate from their expectations as the average of abnormal overnight returns $\overline{AR}_t^{co}$ is insignificant and even has the same sign as abnormal open-to-close returns on expiration. The analysis of abnormal close-to-close returns (not presented in the table) leads to an analogous conclusion. This example allows us to notice the limitation of the price reversal measure defined by Stoll and Whaley (1986). As was noticed by Vipul (2005), the measure skips information about the magnitude of total change, while this change can be negligible both from the investors' and regulators' point of view.

The last part of the event study analysis is conducted on turnover values and returns of individual stocks. Table 7 confirms the existence of all three expiration day effects under study. As for WIG20 and mWIG40, significantly positive $\overline{AV}_0$ confirms that expiration of single stock futures increases turnover of underlying assets on the expiration day above its expected level. Surprisingly, not only average daily abnormal turnover values are significantly positive for t = 0, but also for t = -1. This is evidence that trading on these assets increases significantly the day before expiration and remains high on the day of expiration. It is worth mentioning that the volume effect is the most pronounced for single stocks where the value of $\overline{AV}_0$ is visibly higher than the values for WIG20 and mWIG40. However, similarly to both the indexes, activity of investors diminishes after futures expiration, but this decline is significant at the 5% level. Let us note here that the application of trading volume instead of turnover value leads to the same conclusions.

Instead of reporting the results of the event study for relative turnover, which are similar to the results for indexes, we present in Table 7 the analysis of volatility effects, which shows significantly increased volatility of stock prices only on the expiration days. Due to simulations from Section 3.2 and the application of empirical critical values, we must consider $\overline{AVOL}_{-1}$ as insignificant.

The right-hand side of Table 7 confirms the existence of single stock prices reversion. This is when prices on an expiration day increase more than usual, then before the opening of the next session they fall significantly (at the 5% level) below their expected levels. The change after negative abnormal returns on expiration days is insignificant. These results supplement observations from Table 5. An interesting feature that can be observed in Table 7 is significantly positive $\overline{AR}_0^{co}$ for $AR_0 > 0$. It indicates that expiration days when stock prices fall more than usual are preceded by nights with unusually high increases.

The results from the event study analysis presented above show even more clearly than results based on classical measures that expiration day effects are much stronger in the case of single stock futures than in the case of index futures. It is in line with Chung and Hseu's (2008) opinion that the effects are particularly strong when the settlement price of the contract is based on the closing price of an underlying asset.

4.3 Evolution of expiration day effects on the WSE

In order to examine how the impact of futures expirations on stocks on the WSE was changing in the period under study, we repeat the above analysis for single stock futures in various sub-periods. To ensure adequate power of tests and comparability of results, we decided to divide the whole period of 2003–2016 into four sub-periods with a similar number of events under study in each, as follows: 2 January 2003 – 31 December 2009; 2 January 2010 – 14 April 2013; 15 April 2013 – 31 May 2015; and 1 June 2015 – 31 December 2016.

The comparison of turnover and relative turnover reported in Table 8 confirms the existence of volume effect in each of the sub-periods. Turnover on expiration days is significantly higher than on both kinds of control days. What is more, positive means and medians of the relative turnover in the right panel of Table 8 indicate that trading activity on expiration days is higher than on the day before. That change is significantly stronger than in the case of the other Fridays under study, when usually the drop in turnover and negative relative log-turnover is observed. The strongest change of the log-turnover on expiration days is observed in the second sub-period (January 2010 – April 2013), where the average of RV_t equals 0.781. These volume effects in each of the sub-periods are in line with the previous results from Table 3.

The application of the event study analysis (presented in Table 9) also confirms the very strong and persistent impact of single stock futures expiration on the turnover of underlying stocks. Averages $\overline{AV_0}$ are significantly positive in each sub-period. Their highest values (0.913 and 0.919) are observed between 2010 and 2015. Comparison of these values with the average log-turnover from the left-hand side of Table 8 leads to the conclusion that futures expiration doubles the turnover value of single stocks. In general, the averages $\overline{AV_t}$ are positive a few days before expiration and are negative on the next day. Besides these common features, some differences in changes of log-turnover in sub-periods are also observed. First, the drop in the trading activity on Mondays after expiration is significant only in the first two sub-periods (2003–2013). On the other hand, in the third sub-period (2013–2015) a significant abnormal increase in turnover is observed on the day before expiration. Other averages of abnormal log-turnover in the event windows are insignificant. This indicates that the total turnover of stocks with futures contracts does not change significantly in the week before expiration, except for the two cases described above.

Event study analysis performed for relative log-turnover (not presented here) confirms the results obtained in the case of log-turnover itself. In each sub-period, averages of abnormal relative turnover on expiration are significantly positive, whereas on the next day they are significantly negative. In the first two sub-periods, significantly positive averages are also observed two days after expiration. On the other hand, in the third sub-period (2013–2015) significantly positive abnormal change in trading activity appears on the day before expiration. This last result is in line with the observation made on the basis of results from Table 9 that in this period turnover increases significantly already on day $t = -1$.

Results in Panel B of Table 4 only partially indicate increased volatility of stock prices during trading sessions. Deeper analysis of this issue (Table 10) reveals that only in the third sub-period are absolute values of open-to-close returns on expiration significantly higher than on control days. In the other sub-periods, these differences are insignificant (1st and 2nd sub-period) or have the wrong sign (comparison with control days I in the fourth sub-period). A similar conclusion can be drawn from the analysis of volatility measures based on minimal and maximal values of stock prices during a trading session VOL_t. However, in that case, a significant difference is also observed in the 2nd and 4th sub- -periods when comparison is made with control days II (i.e. with third Fridays of months without futures expiration).

Due to the significant impact of expiration on volatility measured by VOL_t, further event study analysis is performed on that measure. As a result, in Table 11 a very strong impact of futures on volatility on spot market in the 2013–2015 period is also visible. In that period $\overline{AVOL}_t$ is significantly positive on expiration day as well as the day before. Significant $\overline{AVOL}_0$ is also observed in the second sub-period.

The results of the research on the price reversal effect in the sub-periods are presented in Table 12. In the first sub-period, stock prices tend to continue after expiration rather than reverse their direction. The average of REV_t, a reversal measure based on close-to-close returns after expiration, is negative (similar to averages on control days). On the other hand, when only overnight returns are applied, the average is positive. It suggests that during the night after the expiration, prices slightly change their direction, but even these changes disappear during the next day's trading session. However, price reversal is more pronounced in the next sub-periods. Averages and means of reversal measures on expiration days are positive and they are, in general, significantly greater than the values of the measures on control days. The differences in distribution of reversal measures on expiration and control days are significant particularly in the third sub-period. Prices reverse during the night after expiration, and then this change is amplified during the next trading session. In the second and fourth sub-periods, the overnight change of price direction is too weak to be significantly greater than on control days, but it begins the process which results in a significant change on the close of the next day.

Because we are mainly interested in an immediate change in price direction, in Table 13 we present results of event study analysis for overnight returns only. As before, we divide them into two clusters according to the value of abnormal price change during the session on an expiration day. As before, price reversal effects are visible mainly in the second and third sub-periods. In both cases $\overline{AR}_1^{co}$ s after $AR_0 > 0$ are significantly negative, which is in line with the results from Table 7.

The analysis of an expiration day effect conducted in the sub-periods reveals that regardless of the period of time, expiration of stock futures involves intensified activity of investors reflected in increased turnover value of underlying stocks. On the other hand, price effects like increased volatility and price reversal were especially strong between 2010 and 2015. The lack of these effects in the first of the examined sub-periods can be explained by the fact that stock futures were just being launched into the market. New and complex financial products had low liquidity and were not used in arbitrage strategies and speculations as often as in the following years. In 2015, between the third and fourth sub-periods, there is a clear-cut change in the occurrence of price effects of single stock futures expirations. Strong price effects seem to disappear after the introduction of changes in the short selling regulations. This conclusion is in line with the findings of Alkebäck and Hagelin (2004) and Debasish (2010), who also found that when the restriction of short selling has been lifted, price effects of futures disappear. This confirms the hypothesis that easy access to short selling lessens the impact of futures expiration on stock prices.

5 Summary and conclusions

There are three expiration day effects analysed in the recent literature that are most noticeable: increased turnover value, increased volatility, and price reversal after expiration. To study the existence of these effects on the Warsaw Stock Exchange, two methods were applied: event study analysis and comparison of various measures computed on expiration and on control days.

This study confirms the hypothesis formulated in Subsection 3.3 regarding the existence on the WSE of strong volume effects. Investors' trading activity on expiration days is significantly higher than its usual level. It is also higher than on third Fridays of months without futures expirations and on other Fridays from the expiration months. These significant results are valid when indexes WIG20 and mWIG40, as well as single stocks, are considered. However, the strongest changes in trading activity are observed in the case of single stocks, because they occur even on the day before the expiration.

As supposed in Subsection 3.3, the other expiration day effects, namely volatility effects and price reversals, are visible only in the case of single stocks. Their existence is confirmed by both analysis methods. The most interesting is, of course, how expiration of futures impacts stock prices. This study shows that, on average, stock prices tend to reverse after futures' expiration and the change of their directions is reflected both in close-to-close and in overnight returns. However, event study analysis reveals that overnight returns after expiration day differ significantly from their expected values only when prices on expiration are higher than expected.

Additional analysis in the sub-periods reveals that the strongest expiration day effects were observed between 2010 and 2015. Then, after the introduction of changes in the rules regarding short sale in May 2015, these effects diminished.

The results of the paper are mostly compatible with the foregoing studies on this topic conducted by Morawska (2004, 2007) and Suliga (2017). Only the effect of increased volatility in WIG20 returns detected by Morawska (2007) is not confirmed. The potential source of this difference is that Morawska studied expirations effects only on the basis of data from the initial period of the futures market on the WSE between December 2002 and June 2006.

There are a few reasons for the differences in the expiration day effects between single stocks and indexes, but the final settlement procedure of futures seems to be one of the most important factors. The settlement price of single stock futures is equal to the price of the stock from the last transaction on the expiration day. On the other hand, the final settlement price of index futures is calculated on the basis of the index value from the last trading hour and the value at the close. Thus, it is much easier to influence the price of the stock on market close than to influence the average return of the index from the last hour of trading. Moreover, to carry out an arbitrage strategy with opened positions on stock futures, it is sufficient to place market-on-close orders on expiration days. Index arbitrage, which is intrinsically much more expensive than arbitrage on stocks, is additionally constricted by an effective futures' settlement procedure.

The occurrence of expiration day effects of stock futures raises the question about the need to make changes in the way of calculating final settlement prices of these contracts. Chung and Hseu (2008), on the Singapore and Taiwan futures exchanges, as well as Hsieh and Ma (2009) on the Taiwan futures exchange, verify that average price settlement is much better than closing settlement. Also, Xu (2014) states that the desirable solution to reduce adverse expiration day effects is 'to adopt a long settlement period with an average price settlement procedure'.

The analysis of the expiration day effects conducted in the sub-periods shows that the adverse impact of stock futures on the spot market has decreased over time. It seems that the introduction of new rules of short sale have reduced price effects of stock futures expirations, and hence the changes in settlement procedure are not necessary. However, further study on this topic with the use of high--frequency data should be carried out to clearly confirm this hypothesis.

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Appendix

Table 1
The list of futures included in the research

First expiration	Underlying asset (abbreviation)	Number of expiration days
Jun 13, 2001	WIG20	64
Mar 15, 2002	mWIG40	60
Mar 21, 2003	KGH, PEO, PKN	56
Jun 20, 2003*	BZW	24
Jun 20, 2003**	MIL	17
Sep 16, 2005	PKO	46
Jun 18, 2010	ACP, PGE, PGN	27
Dec 17, 2010	PZU	25
Mar 18, 2011	TPE	24
Jun 26, 2011	LTS	23
Sep 16, 2011	CDR	22
Dec 16, 2011	JSW, LWB	21
Dec 16, 2011	KER	15
Dec 16, 2011	GTC	14
Mar 16, 2012	GPW	20
Sep 21, 2012	SNS	17
Jun 15, 2012	BRS	12
Mar 21, 2014	OPL	12
Mar 21, 2014	ALR	9
Dec 18, 2015	ENA	5
Dec 18, 2015	CCC, CPS	4
Dec 16, 2016	ATT, CIE, ING, KRU, MBK	1

* Markings of futures on BZW were suspended in December 2008 and restarted in December 2016.
** Markings of futures on MIL were suspended in March 2007 and restarted in December 2015.

Table 2

Rejection rates of test statistics of the null hypothesis of no event effect (in %)

	WIG20			**Single stocks**		
	1%	**5%**	**10%**	**1%**	**5%**	**10%**
Log-turnover V_t	1.8	6.1	10.4	1.7	6.6	12.9
Relative log-turnover RV_t	1.1	5.1	9.5	1.0	5.2	10.7
Absolute daily returns $\|R_t\|$	1.2	5.6	10.7	1.3	5.7	10.7
Absolute close-to-open returns $\|R_t^{oc}\|$	0.6	4	9.2	1.1	5.5	11.5
Volatility measure VOL_t	1.2	6.2	12.8	1.6	8.2	12.6
Overnight returns R_t^{ON}	0.7	4.8	10.1	1.0	4.3	9.9

Notes:
This Table presents the rejection rates of τ_{grank} test based on 1,000 simulations. In the case of WIG20 clusters of 60 events are randomly generated with replacement from trading days between March 2001 and December 2016. For single stock futures clusters of 30 events are randomly generated with replacement from trading days between March 2001 and December 2016. For each event data of about ¾ of stocks from Table 1 traded on that day are taken into account. Simulation is performed with pre-event window of length 45 (t = -50,…, -6) and the event window of length 8 (t = 5,…, 2). The 95 percent confidence intervals for rejection rates at the 1%, 5%, and 10% are [0.38%, 1.62%], [3.65%, 6.35%] and [8.14%, 11.86%], respectively.

Table 3

Measures of volume effects of futures expirations

	WIG20 futures (61 observations)			**mWIG40 futures (60 observations)**			**Single stock futures (589 observations)**		
	mean	**median**	**p-value**	**mean**	**median**	**p-value**	**mean**	**median**	**p-value**
Panel A: log-turnover V_t									
Expiration days	13.787	14.068	–	11.529	11.749	–	10.568	10.775	–
Control days I	13.377	13.473	**0**	11.455	11.571	0.168	9.789	9.837	**0**
Control days II	13.072	13.274	**0**	11.354	11.428	0.106	9.744	9.744	**0**
Panel B: relative log-turnover RV_t									
Expiration days	0.335	0.439	–	0.05	0.13	–	0.590	0.650	–
Control days I	0.068	-0.046	**0**	0.151	0.029	0.239	-0.069	-0.067	**0**
Control days II	-0.15	-0.125	**0**	-0.036	-0.063	**0.022**	-0.11	-0.11	**0**

Notes:
This Table presents the means and medians of two measures of trading activity, namely log-turnover and relative turnover. The measures are computed on expiration days and on two groups of control days: first, second and fourth Fridays of expiration months (control days I) and on third Fridays of months without expiration (control days II). Distributions of the turnover measures on expiration and on control days are compared via Mann-Whitney tests. Their p-values are also presented in the Table.

Table 4

Measures of volatility effects of futures expirations

	WIG20 futures (61 observations)			mWIG40 futures (60 observations)			Single stock futures (589 observations)		
	mean	**median**	**p-value**	**mean**	**median**	**p-value**	**mean**	**median**	**p-value**
Panel A: absolute values of close-to-close returns $\lvert R_t \rvert$									
Expiration days	0.984	0.775	–	0.7	0.429	–	1.634	1.217	–
Control days I	1.055	0.886	**0.059**	0.693	0.594	0.205	1.497	1.285	0.244
Control days II	1.038	0.831	0.342	0.677	0.522	0.325	1.426	1.426	0.505
Panel B: absolute values of close-to-open returns $\lvert R_t^{oc} \rvert$									
Expiration days	0.878	0.619	–	0.583	0.429	–	1.628	1.352	–
Control days I	0.970	0.807	**0.063**	0.581	0.479	0.249	1.497	1.306	0.857
Control days II	0.984	0.747	0.169	0.704	0.503	0.142	1.406	1.406	**0.051**
Panel C: volatility measure VOL_t									
Expiration days	1.744	1.472	–	1.232	1.03	–	3.204	2.877	–
Control days I	1.719	1.496	0.851	1.06	0.973	0.315	2.894	2.585	**0.009**
Control days II	1.857	1.519	0.566	1.256	1.035	0.865	2.829	2.829	**0**

Notes:
This Table presents the means and medians of three measures of volatility computed on expiration days and on two groups of control days: first, second and fourth Fridays of expiration months (control days I) and on third Fridays of months without expiration (control days II). Distributions of the volatility measures on expiration and on control days are compared via Mann-Whitney tests. Their p-values are also presented in the Table.

Table 5

Measures of price reversal effects

	WIG20 futures (61 observations)			**mWIG40 futures (60 observations)**			**Single stock futures (589 observations)**		
	mean	**median**	**p-value**	**mean**	**median**	**p-value**	**mean**	**median**	**p-value**
Panel A: close-to-close price reversal REV_t									
Expiration days	0.037	-0.104	–	0.022	0.111	–	0.161	0.187	–
Control days I	-0.205	-0.168	0.296	-0.288	-0.205	**0.045**	-0.236	-0.190	**0**
Control days II	-0.299	-0.15	0.398	-0.24	-0.187	**0.085**	-0.423	-0.178	**0**
Panel B: overnight price reversal REV_t^{ON}									
Expiration days	-0.019	-0.021	–	0.011	0.04	–	0.117	0	–
Control days I	-0.082	-0.097	0.406	-0.108	-0.105	**0.009**	0.011	0.052	**0.031**
Control days II	-0.111	-0.16	0.354	-0.177	-0.113	**0.034**	0.027	0	**0.006**

Notes:
This Table presents the values of means and medians of price reversal measures defined in Section 3.1 based on close--to-close (Panel A) and overnight returns (Panel B). Values of these measures are computed for WIG20, mWIG40 and single stocks mentioned in Table 1 for expiration days and for two kinds of control days: first, second and fourth Fridays of expiration months (control days I) and on third Fridays of months without expiration (control days II). The Table also presents p-values of nonparametric Mann-Whitney U test which is employed to verify whether there are significant differences between distribution of the measures on expiration days and control days.

Table 6
Expiration day effects of futures on WIG20 index and futures on mWIG40 returns. Results from event study analysis

Table 8

Measures of volume effects in the sub-periods

	Log-turnover V_t			Relative log-turnover RV_t		
	mean	**median**	**p-value**	**mean**	**median**	**p-value**
	January 2003 – December 2009 (135 observations)					
Expiration days	11.027	11.435	–	0.345	0.436	–
Control days I	10.45	10.865	**0**	-0.098	-0.108	**0**
Control days II	10.478	10.478	**0.001**	-0.131	-0.131	**0**
	January 2010 – April 2013 (156 observations)					
Expiration days	10.941	11.191	–	0.781	0.804	–
Control days I	10.04	9.913	**0**	0.02	0.044	**0**
Control days II	9.879	9.879	**0**	-0.157	-0.157	**0**
	April 2013 – June 2015 (148 observations)					
Expiration days	10.311	10.47	–	0.641	0.656	–
Control days I	9.385	9.293	**0**	-0.098	-0.073	**0**
Control days II	9.209	9.209	**0**	-0.123	-0.123	**0**
	June 2015 – December 2016 (155 observations)					
Expiration days	10.02	9.926	–	0.559	0.527	–
Control days I	9.333	9.227	**0**	-0.113	-0.112	**0**
Control days II	9.282	9.282	**0**	-0.033	-0.033	**0**

Notes:
This Table presents the values of means and medians of log-turnover and relative log-turnover described in Section 3.1. The values of these trading activity measures are computed for WIG20, mWIG40 and single stocks mentioned in Table 1 for expiration days and for two kinds of control days: first, second and fourth Fridays of expiration months (control days I) and on third Fridays of months without expiration (control days II). The Table also presents p-values of the nonparametric Mann-Whitney U test, which is employed to verify whether there are significant differences between the distribution of the measures on expiration days and control days.

Table 9

Event study analysis for log-turnover

t	2003–2009		2010–2013		2013–2015		2015–2016	
	$\overline{AV_t}$	τ–statistics	$\overline{AV_t}$	τ–statistics	$\overline{AV_t}$	τ–statistics	$\overline{AV_t}$	τ–statistics
-5	-0.113	-0.244	0.127	1.454	0.033	0.571	0.045	-0.069
-4	-0.196	-1.466	-0.232	-1.398	-0.075	-0.4	-0.061	-0.883
-3	-0.035	0.467	0.043	1.043	0.045	0.6	0.022	0.025
-2	0.029	1.244	0.064	1.002	0.045	0.822	0.000	-0.292
-1	0.018	0.981	0.133*	1.693	0.278**	2.516	0.156	0.77
0	**0.363*** **	**4.645**	**0.913*** **	**6.648**	**0.919*** **	**6.042**	**0.717*** **	**5.56**
1	-0.364**	-2.323	-0.246*	-1.685	-0.206	-1.627	-0.096	-1.156
2	-0.082	0.029	-0.054	0.059	-0.107	-0.758	0.051	0.104
n	135		156		148		150	

Notes:

This Table presents the results of event study analysis employed to detect the expiration day effect of stock futures as described in Section 3.2. For each day in the event window starting from the 5th day before expiration and ending on the 2nd day after it, average abnormal turnover value, in sub-periods are presented with corresponding *τ–grank* statistic values. Due to results of simulations in Section 3.2 empirical critical values are applied. For the 1%, 5%, and 10% significance levels they are: 2.91, 2.19, 1.68.

***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 10

Measures of volatility effects in the sub-periods

	$\lvert R_t^{oc} \rvert$			VOL_t		
	mean	**median**	**p-value**	**mean**	**median**	**p-value**
January 2003 – December 2009 (135 observations)						
Expiration days	1.555	1.431	–	3.21	3.003	–
Control days I	1.451	1.324	0.813	2.911	2.77	0.123
Control days II	1.816	1.816	0.146	3.458	3.458	0.732
January 2010 – April 2013 (156 observations)						
Expiration days	1.487	1.138	–	2.988	2.756	–
Control days I	1.437	1.226	0.333	2.847	2.559	0.272
Control days II	1.318	1.318	0.403	2.734	2.734	**0.027**
April 2013 – June 2015 (148 observations)						
Expiration days	1.845	1.375	–	3.471	2.76	–
Control days I	1.262	1.119	**0.043**	2.478	2.401	**0**
Control days II	1.204	1.204	**0.007**	2.474	2.474	**0**
June 2015 – December 2016 (155 observations)						
Expiration days	1.632	1.408	–	3.177	2.88	–
Control days I	1.853	1.486	**0.053**	3.353	2.935	0.22
Control days II	1.321	1.321	**0.088**	2.733	2.733	**0.014**

Notes:
This Table presents the means and medians of volatility computed on expiration days and on two groups of control days: first, second and fourth Fridays of expiration months (control days I) and on third Fridays of months without expiration (control days II). The analysis is performed in four sub-periods. The distributions of the volatility measures on expiration and on control days are compared via Mann-Whitney tests. Their p-values are also presented in the Table.

Table 11

Event study analysis for volatility

t	2003–2009		2010–2013		2013–2015		2015–2016	
	$\overline{AVOL_t}$	τ–statistics	$\overline{AVOL_t}$	τ–statistics	$\overline{AVOL_t}$	τ–statistics	$\overline{AVOL_t}$	τ–statistics
-5	-0.208	-1.057	0.213	1.021	-0.107	-0.493	0.181	1.079
-4	-0.291	-1.304	-0.24*	-1.836	0.324	1.301	0	-0.138
-3	-0.085	0.42	-0.057	-0.605	0.099	0.881	-0.209	-0.796
-2	0.043	0.286	-0.3–23	-1.795	0.012	0.447	0.036	0.383
-1	-0.128	0.029	-0.003	-0.364	0.517**	2.483	0.18	1.315
0	**-0.048**	**0.893**	**0.295****	**2.118**	**0.967*****	**3.772**	**0.276**	**1.374**
1	-0.323	-1.21	-0.128	-0.334	0.05	0.549	-0.062	0.123
2	-0.255	-0.868	-0.013	0.053	-0.074	-0.239	-0.295	-1.344
n	135		156		148		150	

Notes:

This Table presents the results of the event study analysis employed to detect the expiration day effect of stock futures as described in Section 3.2. For each day in the event window starting from the 5th day before expiration and ending on the 2nd day after it, average abnormal volatility measures in sub-periods are presented with corresponding *τ–grank* statistic values. Due to the results of the simulations in Section 3.2, empirical critical values are applied. For the 1%, 5%, and 10% significance levels they are: 2.89, 2.27, and 1.91.

***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 12

Measures of price reversal effects in the sub-periods

	REV_t			REV_t^{ON}		
	mean	**median**	**p-value**	**mean**	**median**	**p-value**
	January 2003 – December 2009 (135 observations)					
Expiration days	-0.013	0	–	0.064	0	–
Control days I	-0.171	-0.134	0.59	0.11	0.092	0.819
Control days II	-0.289	0	0.707	0.132	0.112	0.902
	January 2010 – April 2013 (156 observations)					
Expiration days	0.262	0.356	–	0.15	0	–
Control days I	-0.202	-0.029	**0.01**	0.069	0.144	0.903
Control days II	-0.45	-0.244	**0.001**	-0.165	-0.044	**0.029**
	April 2013 – June 2015 (148 observations)					
Expiration days	0.327	0.303	–	0.184	0.031	–
Control days I	-0.215	-0.321	**0.001**	-0.079	-0.015	**0.001**
Control days II	-0.321	-0.24	**0**	0.116	0	**0.067**
	June 2015 – December 2016 (155 observations)					
Expiration days	0.032	0.185	–	0.054	0	–
Control days I	-0.372	-0.306	**0.024**	-0.048	0.038	0.308
Control days II	-0.57	-0.057	**0.051**	0.057	-0.036	0.164

Notes:

This Table presents the values of means and medians of price reversal measures defined in Section 3.1. Values of these measures are computed in sub-periods for single stocks mentioned in the Appendix for expiration days and for two kinds of control days: first, second and fourth Fridays of expiration months (control days I) and on third Fridays of months without expiration (control days II). The Table also presents the p-values of the nonparametric Mann-Whitney U test, which is employed to verify whether there are significant differences between the distribution of the measures on expiration days and control days.

Table 13

Event study analysis of price reversal effects

t	2003–2009		2010–2013		2013–2015		2015–2016	
	$\overline{AR_t^{co}}$ (%)	τ–statistics	$\overline{AR_t^{co}}$ (%)	τ–statistics	$\overline{AR_t^{co}}$ (%)	τ–statistics	$\overline{AR_t^{co}}$ (%)	τ–statistics
				$AR_0 < 0$				
-5	-0.352	-1.271	0.096	0.3	-0.255	-1.921	0.102	0.417
-4	0.199	1.312	-0.108	-0.846	-0.017	-0.553	-0.293	-1.515
-3	-0.03	0.205	0.014	-0.017	-0.257	-1.42	0.043	0.178
-2	-0.257	0.026	0.24	1.643	-0.06	-0.309	0.082	0.561
-1	0.051	-0.33	-0.179*	-1.761	0.182	0.294	0.104	-0.107
0	**0.588**	**1.026**	**0.193**	**0.934**	**0.211***	**1.764**	**0.063**	**0.374**
1	0.55*	1.743	0.001	-0.257	0.065	0.325	0.133	0.54
2	-0.2	-0.99	-0.049	-0.39	0.247	1.313	0.058	0.692
n	58		83		70		65	
				$AR_0 > 0$				
-5	-0.038	0.319	0.059	0.119	-0.129	-0.639	0.367	1.605
-4	-0.075	-1.075	-0.128	-0.102	0.012	0.047	0.121	-0.647
-3	-0.235	-1.573	-0.067	-0.967	-0.221	-1.405	-0.053	-0.736
-2	0.052	-0.296	-0.005	-0.003	0.139	0.686	0.019	0.156
-1	-0.147	-0.945	-0.155**	-2.369	0.426*	1.768	-0.101	-0.935
0	**0.053**	**-0.43**	**0.167**	**0.552**	**0.045**	**-0.066**	**-0.096**	**-0.514**
1	0.222	-0.144	-0.296**	-2.399	-0.242**	-2.313	0.083	-0.054
2	-0.176	-1.24	-0.008	-0.329	-0.172	-1.15	-0.077	-0.408
n	77		73		78		85	

Notes:
This Table presents the results of the event study analysis employed to detect price reversal effect of single stock futures in sub-periods. For each day in the event window starting from the 5th day before expiration and ending on the 2nd day after it, average abnormal: turnover value, volatility and overnight returns are presented with corresponding *τ–grank* statistic values.
***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

EXPIRATION-DAY EFFECTS ON INDIVIDUAL STOCKS AND THE OVERALL MARKET: EVIDENCE FROM TAIWAN

WEN-LIANG GIDEON HSIEH*

On expiration days of the MSCI-TW index futures, the Taiwan spot market is associated with abnormally large volume and high index volatility, along with mild index reversal. The effects concentrate only in the last five minutes of expiration days and appear to be strengthened by the adoption a call auction closing procedure by the Taiwan Stock Exchange. Individual index stocks show high volatility and strong tendency of price reversal, with large- and small-cap stocks being affected more than the medium-sized stocks. The highest-weighted stocks exhibit excessive volume and volatility, which is disproportionate to the impact on all other index stocks, indicating that the expiration-day effects may have been amplified by the attempt of price manipulation using large-cap stocks. © 2009 Wiley Periodicals, Inc. Jrl Fut Mark 29:920–945, 2009

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INTRODUCTION

With the introduction of index futures, investors were provided with a means of hedging and speculating against the systematic risk of the stock market; however, one of the more controversial by-products of index futures is the "expiration-day effects." Expiration-day effects are generally viewed as a combined result of the cash settlement feature of index futures contracts and the unwinding of index arbitrage positions in the stock market (Stoll and Whaley, 1987). Such unwinding activities are often found to be concentrated at a point immediately prior to the contract expiration day, creating excess volume, and noticeable price pressure on the constituent index stocks. Regulators around the world have expressed concern about the resulted price distortion and market destabilization.[1] In contrast to strong regulatory responses, the empirical evidence with regard to the significance, or even existence, of expiration-day effects is rather mixed. In brief, although the abnormal volume reported in most of the prior studies appears to be related to the unwinding of arbitrage positions, the price effects are less pronounced whether assessed by either volatility or price reversal.[2]

This study examines the extent to which trading on the expiration days of the Morgan Stanley Capital Index, Taiwan (MSCI-TW) index futures affects cash market prices and trading volume in Taiwan. In addition to the effects on the overall index market, this study places specific focus on the behavior of individual stocks, an issue rarely explored in the prior studies. It is of significant importance to undertake analysis of individual stocks because the primary purpose of imposing regulatory controls is to protect retail investors, the majority of whom tend to trade in individual stocks as opposed to large index portfolios. The understanding of whether, and to what extent, individual stocks are affected by futures expiration helps in the formulation of regulatory changes that will be effective in mitigating the expiration-day effects, while not being overly restrictive on other normal market activities.[3] To date, the only study to have provided a comprehensive examination of expiration-day effects on individual stocks is Stoll and Whaley (1990).[4]

[1]Examples of attempts by regulators to mitigate the expiration-day effects include (i) shifting the final settlement price from the market close to the market open (the S&P 500 in the United States, the TOPIX and Nikkei in Japan, and the SPI in Australia); (ii) using the average price as the final settlement price for the index futures (the HSI in Hong Kong, the FTSE-100 in the United Kingdom, and the CAC-40 in France); and (iii) the application of restrictive rules on index arbitrage (the TOPIX and Nikkei Stock Average in Japan).
[2]See Chow, Yung, and Zhang (2003), Alkeback and Hagelin (2004), and Vipul (2005) for summaries of relevant studies.
[3]This is of particular crucial in an emerging market pre-dominated by retail investors. According to the Taiwan Stock Exchange annual report, trading by retail investors accounted for about 83% of all stock market volume in Taiwan during our sample period.
[4]Two other studies involving individual stocks are Karolyi (1996), in which 25 large stocks were used for a robustness check of the index reversals, and Stoll and Whaley (1997), in which analysis of individual stock volatility and reversals was undertaken.

We compare the volume, volatility, and return reversals on expiration and non-expiration days for the MSCI stocks, and also undertake a similar comparison for non-index stocks. Our investigation reveals strong evidence of higher volume and volatility for the MSCI index on expiration days, along with weak evidence of price reversals, both with and without adjustment for the "normal" levels of the non-index stocks. The abnormal volume and volatility are found to be concentrated only in the last five minutes of trading, as opposed to being evenly spread over the expiration days. Furthermore, we find that the effects became much more pronounced after the call auction closing procedure was adopted by the Taiwan Stock Exchange (TSE), indicating that this call procedure has failed to mitigate the expiration-day effects.

It should, however, be noted that the abnormal behavior of the index is the combined result of individual stocks; thus, any study of the index in isolation would tend to mask much of the behavior of individual stocks. An investigation of the behavior of individual stocks around the expiration period helps us to tackle three previously unanswered questions. The first of these seeks to determine whether a particular subset of stocks is more likely to experience greater price distortion, thus, a regulatory remedy could be proposed to deal specifically with such stocks, rather than all stocks. Our results show that all individual index stocks are significantly affected by futures expiration, but with different magnitudes. Abnormal volume and volatility are higher for large and small stocks than for medium-sized stocks; a result that indicates that some index arbitrageurs use only a specific subset of stocks, usually large stocks, rather than the entire index portfolio.

The second question deals with the abnormally large index volatility around the expiration period, seeking to determine whether this is due to the co-movement of index stocks, or increased volatility in individual stocks. If co-movement is the primary source of high index volatility, the expiration-day effects should be of no great concern because there is no temporary price distortion on individual stocks and no investors will be hurt. Conversely, the higher individual stock volatility around the expiration period would pose a potential threat to small investors. Our evidence shows that both effects exist on expiration days, with individual stocks revealing higher volatility and a greater tendency to move in the same direction.

The third question is related to whether manipulation also plays a role in the price distortion exhibited on expiration days. In their theoretical model, Kumar and Seppi (1992) demonstrated that for a cash-settled futures contract, uninformed manipulators could artificially bid up (down) the spot price so as to benefit their earlier established long (short) futures positions. Although the possibility of price manipulation on futures expiration days was recognized by Stoll (1988), Stoll and Whaley (1997), and Alkeback and Hagelin (2004), no empirical evidence has thus far been provided.

This study therefore addresses this issue by examining the behavior of the highest-weighted stock, because such a stock would clearly be the most feasible vehicle for such manipulation, given its considerable influence on the index. Our results indicate that attempts at price manipulation in Taiwan may have been responsible for intensifying the expiration-day effects; as we find that transactions in the highest-weighted stock can alone contribute a considerable proportion of the total market volume and volatility prior to contract expiration, with this proportion being substantially higher than both its own normal level and that of other individual stocks.

The remainder of this article is organized as follows. The section "Institutional Setting and Data" provides a description of the data and methodology used in this study, along with an introduction to the institutional setting of the SGX-traded MSCI-TW index futures and the underlying Taiwan stock market. The abnormal volume, volatility, and return reversals of the overall index market on expiration days, vis-(-vis those on non-expiration days, are presented in the section "The Overall Market Effects." The section "Individual Stock Effects" examines the expiration-day effects on individual stocks, with special focus on whether the effects differ across stocks of varying index weights, and whether an excessive price effect is discernible for the highest-weighted stocks. Finally, the conclusions drawn from this study are presented in the last section.

INSTITUTIONAL SETTING AND DATA

The SGX-traded Taiwan index futures contracts are based on the MSCI-TW. The index comprises 65–103 large-cap stocks, which together account for about 65% of the market capital of all listings (maximum 787 stocks in our study period) on the TSE. The MSCI-TW index futures, the daily volume of which amounted to around 30,000 contracts in 2004, are one of the most actively traded index contracts on the SGX. The contracts have a monthly expiration cycle, with the last trading day being the penultimate business day of the contract month. The final settlement price is based on the closing price of the MSCI-TW index on the last trading day, the "expiration day." According to Stoll and Whaley (1997), the settlement procedure involving a single price at the market close, as opposed to other procedures where the average price is used, or where settlement takes place at the market open, is most likely to induce significant expiration-day effects.

The expiration-day effects of MSCI-TW contracts have attracted much regulatory attention in Taiwan.[5] On July 1, 2002, the TSE changed the stock

[5]Given that MSCI-TW contracts are traded on the SGX-DT, the Taiwan authorities have little control over the rules for determining the futures settlement price. The Ministry of Finance and the Financial Supervisory Commission of Taiwan have consulted several times with the SGX for possible change in the settlement rules, but without success. See *Economic Daily News* (June 8, 2005 and August 16, 2005).

market closing procedure, from frequent calls (every 20–40 seconds), to a call procedure in which all orders for a particular stock are batched during the last five minutes and cleared at a single price. The change in the closing procedure was undertaken in the hope that the longer batch period would prove to be more capable of absorbing large order imbalances, thereby mitigating the expiration-day effects. However, as noted by Stoll and Whaley (1997), the outcome is dependent both on the transparency of the call procedure and the ability to prevent arbitrageurs from "gaming" the market (e.g. submitting false orders to affect the final clearing price).

This study uses intraday stock index data covering the period from January 1997 (the time of the launch of MSCI-TW contracts) to December 2005. The sample period comprises 107 expiration days and 2,160 non-expiration days.[6] In order to evaluate the impact of the change in the stock market closing procedure, we divide the full sample into two sub-periods, one prior to July 1, 2002, and the other after that date. The *Taiwan Economic Journal* (TEJ) database provides minute-by-minute intraday data on the MSCI-TW spot index, as well as the trade-by-trade price and volume for every individual stock listed on the TSE.

This study assesses the expiration-day effects by comparing the volume, volatility, and price reversals of the MSCI-TW index stocks on expiration days to the same measures for five non-expiration-day samples comprising (i) all non-expiration days; (ii) one trading day before expiration (E–1); (iii) one trading day after expiration ($E+1$); (iv) five trading days before (E–5); and (v) five trading days after ($E+5$).

THE OVERALL MARKET EFFECTS

Abnormal Volume

Trading activity on expiration days is measured by the cross-sectional average trading volume of the MSCI stocks for every five-minute interval, t, as in the following equation:

$$MV_t = \frac{1}{N}\sum_{i=1}^{N} V_{it}^{IS} \tag{1}$$

where MV_t is the cross-sectional mean volume at interval t; V_{it}^{IS} is the volume (in 1,000s of shares) for index stock i at interval t; and N is the number of MSCI index stocks. It should be noted that greater weights are assigned to the

[6]There are a total of 2,332 trading days in our sample period. Data are missing from the TEJ database on a total of five days trading, and all 51 Saturday trading days are discarded because these occurred only prior to 2001. A further nine days, including one expiration day, are discarded as a result of missing data. The final sample comprises 2,267 trading days.

large-cap stocks in the calculation of cross-sectional average volume. To overcome this "size effect," we also express the five-minute volume as a fraction of the volume for the entire trading day, using the following equation:

$$M\%\ V_t = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{V_{it}^{IS}}{V_i^{IS}}\right) \qquad (2)$$

where $M\%V_t$ is the cross-sectional percentage mean volume at interval t; and V_i^{IS} is the volume for index stock i on that particular day.

Figure 1 plots the intraday pattern of the cross-day average of the mean percentage volume ($M\%V_t$) for both expiration days and the five non-expiration-day samples, with the overnight interval being situated in the center of the graph.

A large spike occurs in the last five minutes prior to the market close on expiration days, during which the volume is twice that exhibited on non-expiration days. Apart from this abnormal volume at the market close, the intraday pattern of expiration days closely resembles that of non-expiration days, showing a frequently observed intraday pattern, with higher volume at market open and close than during the rest of the day. Thus, the figure clearly suggests the

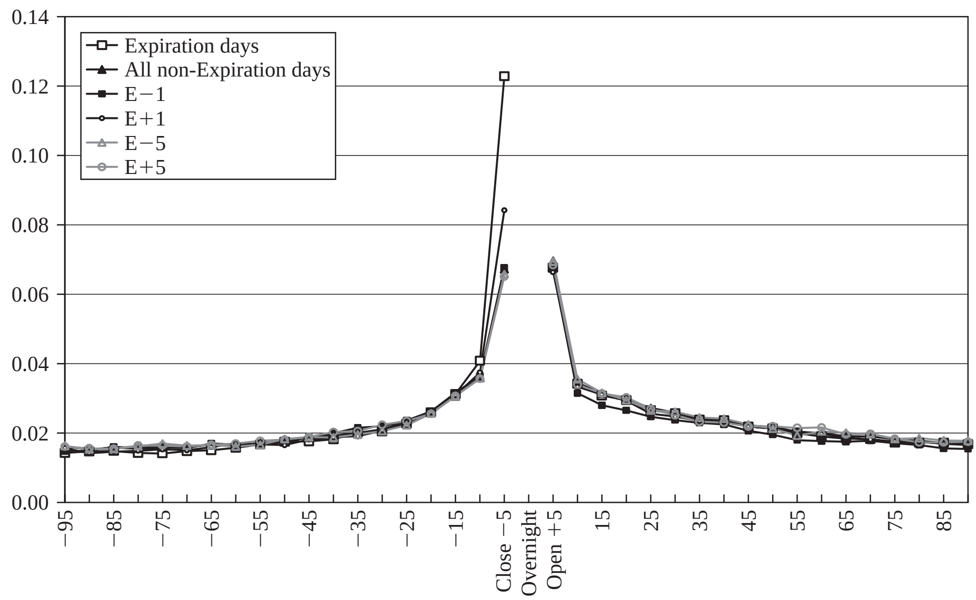

FIGURE 1
Mean percentage volume of the MSCI-TW index for each five-minute interval on expiration and non-expiration days.
Percentage volume is the ratio of the volume in interval t to the whole day volume. A five-minute time series of percentage volume is first created for each stock; the percentage volume is then averaged across stocks by interval to create a market time series of percentage volume for each of these daily intervals. The intraday pattern in the figure is calculated by averaging the five-minute percentage volume across both expiration days and non-expiration days.

presence of abnormal volume for MSCI stocks on expiration days, which is only discernible in the five-minute period immediately prior to futures expiration.

Table I presents the significance tests for the abnormal volume of the MSCI portfolio in the last five-minute interval. The last five-minute volume on expiration days (1,307) is almost twice that for non-expiration days (763), with the difference being statistically significant. The percentage volume shows that transactions taking place in the last five minutes account for an average of 12.3% of the total daily volume on expiration days, which is nearly double the 6.7% on regular days.

As a result of splitting the sample into two sub-periods, we find that the abnormal volume is particularly significant during the second sub-period, the period immediately after the adoption of the closing call procedure in the TSE. Following this regulatory change, the average volume in the last five-minute interval on expiration days (2,029) is almost three times that recorded for

TABLE I

Mean Volume of MSCI Stocks During the Last Five Minutes of Trading Days

Volume Measures	*Expiration Days*	*All Non-Expiration Days*	*E – 1*	*E + 1*	*E – 5*	*E + 5*
Whole period (107 expiration days, 2,159 non-expiration days)						
Last five-min volume	1,307.50	763.10	732.54	894.05	766.68	797.15
Pooled *t*-test	–	16.35**	6.16**	4.21**	5.76**	5.41**
Paired *t*-test	–	–	6.41**	4.72**	6.02**	5.82**
Percentage volume	0.123	0.067	0.068	0.084	0.066	0.065
Pooled *t*-test	–	23.58**	8.99**	5.84**	9.34**	9.55**
Paired *t*-test	–	–	8.79**	6.24**	8.63**	9.16**
January 1, 1997–June 30, 2002 (65 expiration days, 1,330 non-expiration days)						
Last five-min volume	841.06	756.24	746.62	810.70	768.43	794.18
Pooled *t*-test	–	2.49*	1.72	0.55	1.36	0.83
Paired *t*-test	–	–	2.38*	0.88	1.60	1.01
Percentage volume	0.091	0.074	0.075	0.087	0.073	0.071
Pooled *t*-test	–	7.10*	4.07**	0.93	4.85**	5.39**
Paired *t*-test	–	–	5.39**	1.13	4.93**	5.50**
July 1, 2002–December 31, 2005 (42 expiration days, 829 non-expiration days)						
Last five-min volume	2029.30	774.10	710.75	1,019.70	763.97	806.77
Pooled *t*-test	–	21.38**	7.71**	5.41**	7.29**	7.08**
Paired *t*-test	–		8.02**	5.51**	7.69**	7.74**
Percentage volume	0.172	0.056	0.056	0.079	0.055	0.056
Pooled *t*-test	–	31.52**	11.16**	7.76**	11.24**	11.29**
Paired *t*-test	–	–	12.25**	9.15**	11.29**	12.19**

Note. Two volume measures, share volume and percentage volume (of whole-day volume), are used to assess the trading activity of the MSCI component stocks in the last five-minute interval of expiration days. Each measure is computed for every stock day and averaged, first within a day to produce a daily cross-sectional mean, then across days. This table reports the cross-day mean over expiration days for each volume measure, as well as over five groups of comparison days: all non-expiration days, the day before ($E - 1$), the day after ($E + 1$), five days before ($E - 5$), and five days after ($E + 5$) the expiration days. The pooled *t*-statistics and paired-*t* statistics are reported for the difference between the expiration-day sample and each of the comparison-day samples. *and **indicate significance at the 5 and 1% confidence levels, respectively.

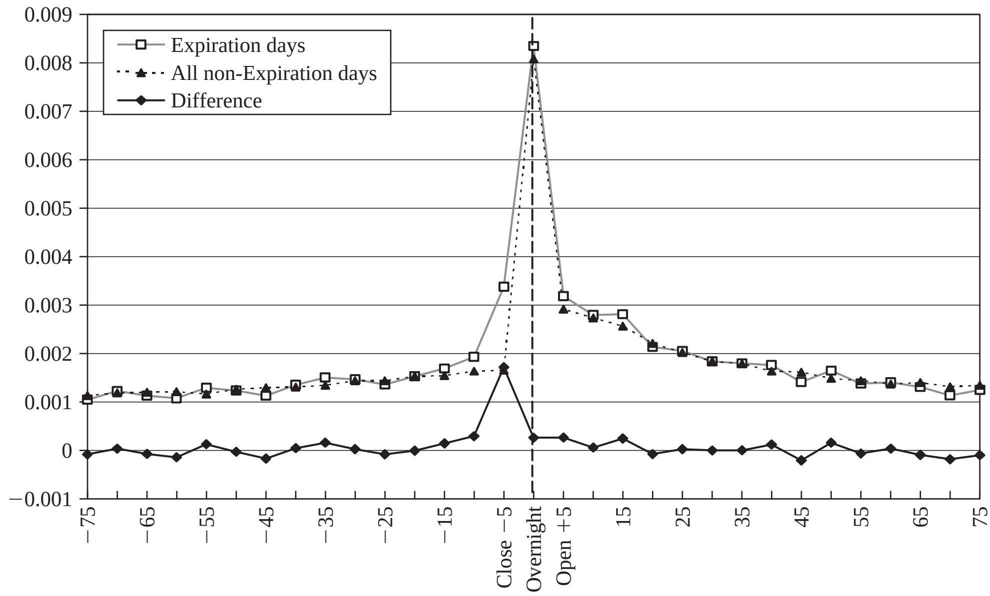

FIGURE 2
Mean volatility of the MSCI-TW index return for each five-minute interval on expiration and non-expiration days.
Intraday volatility is measured by the absolute return of the MSCI index for each five-minute interval. The index volatility within each five-minute interval is averaged across both expiration and non-expiration days. The bold solid line shows the difference between volatility on expiration and non-expiration days.

non-expiration days (774), whereas prior to the change, the difference was only marginal (841 versus 756). The percentage volume on expiration days also exhibits significant growth, from 9.1% in the first sub-period, to 17.2% in the second sub-period.

Although this dramatic increase in volume in the second sub-period may or may not be directly related to the implementation of the closing call procedure, it nevertheless suggests that the adoption of the five-minute call auction was ineffective in reducing the concentrated trading during the last five minutes of expiration days.

Abnormal Volatility

The intraday volatility of the index is assessed by the five-minute absolute return (|ret|), and the ratio of the five-minute absolute return to the whole day range return (%|ret|). Both measures are first calculated for each five-minute interval in every trading day, and then averaged across days by intervals.[7]

Figure 2 shows the intraday patterns of |ret| surrounding the overnight interval for the expiration days and for the "all non-expiration days" sample.

[7]We also use return standard deviation and the volatility measure of Parkinson (1980) to measure five-minute volatility; the results are qualitatively similar to those shown here.

Volatility rises sharply during the last five-minute interval of expiration days as compared to non-expiration days, resulting in a spike in the difference between expiration and non-expiration days (the bold solid line). Apart from this obvious peak, intraday volatility remains at almost the same level on both expiration and non-expiration days for every other interval, including the overnight interval.

Details of the cross-day average volatility during the last five-minute interval on both expiration and non-expiration days are provided in Table II. For the whole sample period, the mean absolute return on expiration days (0.00338) is over twice that for all non-expiration days (0.00166). The difference is found to be significant using both the variance ratio test and the Wilcoxon rank sum test. The results of %|ret| show that the last five-minute volatility, from 0.9528 to 0.1296, accounts for approximately 10% of daily volatility on non-expiration days, whereas the %|ret| increases to 20% on expiration days.

TABLE II

Mean Volatility in the MSCI Index During the Last Five Minutes of Trading Days

Volatility Measures	*Expiration Days*	*All Non-Expiration Days*	*E − 1*	*E + 1*	*E − 5*	*E + 5*
Whole period (107 expiration days, 2,159 non-expiration days)						
|ret|	0.00338	0.00166	0.00179	0.00220	0.00173	0.00196
Variance ratio (*F*-test)	–	3.65**	19.47**	11.02**	23.17**	19.27**
Wilcoxon rank sum	–	6.67**	4.74**	3.23**	4.59**	3.66**
%|ret|	0.20157	0.10127	0.09528	0.12963	0.09615	0.12347
Variance ratio (*F*-test)	–	3.43**	4.13**	2.24**	3.42**	2.19**
Wilcoxon rank sum	–	6.22**	4.82**	2.89**	4.88**	3.36**
January 1, 1997–June 30, 2002 (65 expiration days, 1,330 non-expiration days)						
|ret|	0.00281	0.00191	0.00223	0.00202	0.00199	0.00216
Variance ratio (*F*-test)	–	2.23**	1.66*	3.91**	3.94**	2.84**
Wilcoxon rank sum	–	2.95**	1.77	1.59	2.03*	0.79
%|ret|	0.14684	0.10065	0.10371	0.11022	0.09539	0.12080
Variance ratio (*F*-test)	–	2.43**	2.34**	2.22**	3.05**	1.98**
Wilcoxon rank sum	–	2.74**	1.84	1.37	2.15*	0.87
July 1, 2002–December 31, 2005 (42 expiration days, 829 non-expiration days)						
|ret|	0.00426	0.00126	0.00111	0.00248	0.00133	0.00165
Variance ratio (*F*-test)	–	7.65**	31.26**	7.08**	26.65**	20.22**
Wilcoxon rank sum	–	6.68**	5.05**	3.02**	4.60**	4.34**
%|ret|	0.28627	0.10226	0.08224	0.16075	0.09732	0.12880
Variance ratio (*F*-test)	–	3.42**	5.54**	1.88*	2.83**	1.81*
Wilcoxon rank sum	–	6.32**	5.12**	3.06**	4.79**	3.91**

Note. Two volatility measures, absolute returns (|ret|) and proportional absolute returns (%|ret|), are used to assess the MSCI index return volatility in the last five-minute interval on expiration days as well as on five groups of comparison days. The |ret| is the close-to-close return of the index in the last five-minute interval, and %|ret| is the ratio of |ret| to the daily range return defined as the highest minus lowest index divided by the daily average index. $E-1$, $E+1$, $E-5$, and $E+5$, respectively, stand for one day before, one day after, five days before, and five days after futures expiration. This table reports the mean volatility across sample days. The *F*-statistics for the variance ratio test and *z*-statistics of the Wilcoxon rank sum test are used for the difference in volatility between expiration and non-expiration days. *and **indicate significance at the 5 and 1% confidence levels, respectively.

We also find that abnormal volatility became stronger after the frequent call procedure was superseded by the five-minute closing call procedure in the TSE. Both |ret| and %|ret| are smaller in the first sub-period than in the second sub-period on expiration days. The difference between the volatility measures for expiration and non-expiration days is more significant in the second sub-period than in the first.

By consolidating liquidity at specific times, a closing call auction is expected to improve price discovery and thereby reduce volatility (Madhavan, 1992; Pagano & Schwartz, 2003); thus, the finding of increased expiration-day effects after the implementation of the closing call procedure comes as something of a surprise.

A number of factors may contribute to this result. Firstly, the performance of a call mechanism is sensitive to its design of pre-trade transparency (Madhavan, 1992; Stoll, 1988; Stoll & Whaley, 1997). The five-minute closing call procedure in Taiwan is designed such that information on the state of the limit order book is undisclosed until the final clearing price is determined. The mechanism therefore fails to encourage the provision of liquidity during periods of significant order imbalance. Secondly, as suggested by Comerton-Forde and Rydge (2006), the closing call prices are vulnerable to manipulation. The significant volatility effects found in the second sub-period may be, in part, ascribed to the attempt of price manipulation.[8] Thirdly, the stronger expiration-day effects in the second sub-period may simply be a consequence of more active index arbitrage in a mature market. Nevertheless, the results suggest that if the closing call auction, which was implemented in Taiwan, has not in fact exacerbated the expiration-day effects, it has clearly failed to mitigate the situation.

Abnormal Price Reversals

Stoll and Whaley (1987, 1990, 1997) suggest that if the unwinding of index arbitrage leads to a temporary order imbalance, which drives the price away from the equilibrium level, the index will tend to reverse at the next open when all of the pressure has dissipated. We apply the three measures of return reversals (*REV*0, *REV1*, and *REV*2), as proposed by Stoll and Whaley (1987). Reversals are calculated between the last five-minute interval (R_t) and the overnight close-to-open returns (R_{t+1}), because significant abnormal volume and volatility are observed only during these intervals. The three reversal measures are specified as

[8]The same view is shared by Chung and Hseu (2007), who document greater TAIEX index volatility after the TSE adopted the closing call procedure.

$$\begin{aligned} REV0_t &= R_{t+1} \quad \textit{if}\; R_t < 0 \\ REV0_t &= R_{t+1} \quad \text{if}\; R_t \geqslant 0 \end{aligned} \tag{3}$$

$$\begin{aligned} REV1_t &= |R_{t+1}| \quad \text{if sign}(R_t) \neq \text{sign}(R_{t+1}) \\ REV1_t &= 0 \qquad \text{otherwise} \end{aligned} \tag{4}$$

and

$$\begin{aligned} REV2_t &= |R_t| \quad \text{if sign}(R_t) \neq \text{sign}(R_{t+1}) \\ REV2_t &= 0 \qquad \text{otherwise} \end{aligned} \tag{5}$$

We report the mean reversal for expiration days and the five non-expiration day samples in Table III. For the sample period as a whole, *REV*0, *REV*1, and *REV*2 are all positive on expiration days, indicating that the price movements during the last five minutes of the expiration day tend to be reversed during the overnight interval. Significant results are, however, only discernible for *REV*2, and not for *REV*0 or *REV*1. The significant *REV*2 on expiration days over the whole sample period is mainly attributable to the substantial reversals during the second sub-period, whereas the first sub-period shows only a marginal tendency for reversals. This result echoes our previous findings of more pronounced abnormal volume and volatility in the second sub-period.

We carry out an alternative test to examine the frequency of reversals on expiration days vis-)-vis non-expiration days; the results are presented in Table IV, from which it shows that there were 66 reversals on 107 expiration days. The percentage of reversals on expiration days, at 62%, is significantly higher than that for the "all non-expiration days" sample. Expiration-day price reversals tend to be more clustered in the second sub-period, with a reversal rate of 69%, as compared to the first sub-period, where the reversal rate is 57%.

Although the findings of the present study confirm the statistical significance of the abnormal volatility and moderate price reversals on expiration days, the economic significance of the price effect should be evaluated against the normal bid–ask spreads, as suggested by Stoll and Whaley (1987). Studies have shown that the average percentage quote spreads in the Taiwan stock markets is about 0.5%.[9] If the selling (buying) pressure results in all stocks being pushed to trade at the bid (ask) price upon futures expiration, the index will fall (rise) by half the spread, an approximate amount of 0.25%.

[9]Brockman, Chung, and Perignon (2008) report an average relative effective spread of 0.53% for the top 289 firms in Taiwan. Ke, Jiang, and Huang (2004) show respective spreads of 0.34 and 0.97% for stocks traded under two different tick-size categories.

TABLE III

Price Reversals in the MSCI Index During the Last Five-Minute and Overnight Intervals

Reversal Measures	*Expiration Days*	*All Non-Expiration Days*	*E − 1*	*E + 1*	*E − 5*	*E + 5*
Whole period (107 expiration days, 2,159 non-expiration days)						
*REV*0	0.00055	−0.00032	0.00063	−0.00166	0.00121	0.00074
Pooled *t*-test	–	0.72	−0.05	1.31	−0.43	−0.12
Wilcoxon rank sum	–	1.17	0.13	1.10	0.26	0.19
*REV*1	0.00445	0.00386	0.00409	0.00277	0.00412	0.00413
Pooled *t*-test	–	0.81	0.35	1.88	0.31	0.32
Wilcoxon rank sum	–	2.28*	0.86	1.99*	1.37	1.02
*REV*2	0.00217	0.00080	0.00093	0.00124	0.00080	0.00101
Pooled *t*-test	–	9.17*	3.69*	2.56*	4.43*	3.66*
Wilcoxon rank sum	–	4.94**	3.04**	2.53*	3.33**	2.74**
January 1, 1997–June 30, 2002 (65 expiration days, 1,330 non-expiration days)						
*REV*0	0.00011	−0.00042	0.00079	−0.00234	0.00218	0.00050
Pooled *t*-test	–	0.31	−0.29	1.06	−0.91	−0.17
Wilcoxon rank sum	–	0.23	−0.42	0.72	−0.70	−0.07
*REV*1	0.00495	0.00441	0.00487	0.00275	0.00517	0.00460
Pooled *t*-test	–	0.51	0.06	1.62	−0.13	0.22
Wilcoxon rank sum	–	1.07	−0.04	1.38	0.11	0.64
*REV*2	0.00154	0.00091	0.00122	0.00104	0.00092	0.00114
Pooled *t*-test	–	3.23*	0.88	1.48	2.06*	1.23
Wilcoxon rank sum	–	2.39*	0.91	1.55	1.32	1.12
July 1, 2002–December 31, 2005 (42 expiration days, 829 non-expiration days)						
*REV*0	0.00123	−0.00014	0.00039	−0.00061	−0.00028	0.00103
Pooled *t*-test	–	0.90	0.52	0.77	0.91	0.12
Wilcoxon rank sum	–	1.78	1.03	0.92	1.63	0.52
*REV*1	0.00367	0.00298	0.00289	0.00279	0.00250	0.00339
Pooled *t*-test	–	0.82	0.87	0.98	1.24	0.30
Wilcoxon rank sum	–	2.46*	1.60	1.54	2.28*	0.93
*REV*2	0.00315	0.00064	0.00050	0.00155	0.00062	0.00080
Pooled *t*-test	–	11.27**	4.40**	2.16*	4.16**	3.83**
Wilcoxon rank sum	–	4.86**	1.60	2.20*	3.51**	2.98**

Note. The average magnitude of cross-day price reversals are reported for the expiration-day sample and five comparison-day samples, with the price reversals being measured by *REV*0, *REV*1, and *REV*2 as defined in Stoll and Whaley (1987). Reversals are calculated between the last five-minute interval and the overnight close-to-open returns. *E* − 1, *E* + 1, *E* − 5, and *E* + 5, respectively, stand for one day before, one day after, five days before, and five days after futures expiration. The pooled *t*-test and Wilcoxon rank sum test are presented for the difference between the expiration-day sample and each comparison-day sample. *and **indicate significance at the 5 and 1% confidence levels, respectively.

The empirical results shown in Table II indicate that the absolute price change in the last five minutes of expiration days is 0.338%; in other words, the abnormal price effects over and above the bid–ask bounce caused by the unwinding of index arbitrage positions will be no greater than 0.1% (0.338–0.25). This result concurs with that of Stoll and Whaley (1987), showing that despite

TABLE IV

Binomial Tests for the Frequency of Reversals on Expiration and Non-Expiration Days

Reversal Measures	*Expiration Days*	*All Non-Expiration Days*	*E − 1*	*E + 1*	*E − 5*	*E + 5*
Whole period (107 expiration days, 2,159 non-expiration days)						
No. of days	107	2,159	107	107	107	107
No. of reversals	66	1,056	58	56	53	56
% Of reversal days	0.62	0.49	0.54	0.52	0.50	0.52
Binomial test	–	2.584**	1.108	1.381	1.789*	1.381
January 1, 1997–June 30, 2002 (65 expiration days, 1,330 non-expiration days)						
No. of days	65	1,330	65	65	65	65
No. of reversals	37	639	37	32	34	31
% of reversal days	0.57	0.48	0.57	0.49	0.52	0.48
Binomial test	–	1.398	0.000	0.879	0.528	1.054
July 1, 2002–December 31, 2005 (42 expiration days, 829 non-expiration days)						
No. of days	42	829	42	42	42	42
No. of reversals	29	417	21	24	19	25
% of reversal days	0.69	0.50	0.50	0.57	0.45	0.60
Binomial test	–	2.379*	1.778*	1.131	2.205*	0.911

Note. The table reports the number of days in which a price reversal is experienced by the expiration-day sample and the five comparison-day samples. $E-1$, $E+1$, $E-5$, and $E+5$, respectively, stand for one day before, one day after, five days before, and five days after futures expiration. The table also presents binomial tests for whether the percentage of the reversals is higher on expiration days than on non-expiration days. *and **indicate significance at the 10 and 1% confidence levels, respectively.

the statistically significant price movements, the expiration-related price impact on the overall market appears to have little economic significance.[10]

INDIVIDUAL STOCK EFFECTS

In the previous section, we demonstrated that the stock market as a whole is characterized by abnormally large volume and volatility on expiration days, along with some price reversal. We devote this section to the study of the abnormal behavior of individual stocks on expiration days.

Throughout our examination, we focus on how stock capitalization influences the abnormal behavior of individual stocks, with the focus on this single

[10]To check for the robustness of the results in the section "The Overall Market Effects," we also compare the expiration-day effects of the MSCI-TW index to the effects of a non-MSCI index. Essentially, stocks not subject to program trading are supposed to act "normal," even on expiration days. The non-MSCI index is constructed by value-weighting TSE-listed stocks excluded from the MSCI-TW index. The non-MSCI index comprises 283–598 stocks, which together account for about 35% of the TSE market capital. We adjust the MSCI-index measures (volume, volatility, and reversal) for the "normal" measures of the non-MSCI index, with the adjustment made by either dividing to (for volume measures) or subtracting from (for volatility and reversal measures) the corresponding non-MSCI measures. Results based on the adjusted measures are highly consistent with those reported in Tables I–IV, showing greater volume, volatility, and moderate reversals in the second sub-period. The results are available from the author on request.

dimension being essentially based upon the following two reasons. Firstly, index arbitrage activity is sometimes carried out using a subset of large-cap index stocks. It is therefore possible that stocks will be subjected to different magnitudes of impact according to their relative weights in the index. Secondly, the highest-weighted stock is, by design, most influential to the index; hence, it is most susceptible to price manipulation. Price manipulators attempting to artificially move the final settlement index can achieve the greatest impact, at the minimum cost, by concentrating their trading on the highest-weighted stock. Therefore, any excessively large volume and volatility for the highest-weighted stock may well reflect the transactions motivated by price manipulation.

In order to compare the magnitude of the expiration-day effects between high- and low-weighted stocks, we provide a ranking for all of our MSCI sample stocks on each day, from highest to lowest, according to their daily market capitalization. Individual stocks are aggregated across days by stock-size ranking, with size rank 1 containing the highest-weighted stocks from each day, rank 2 containing the second highest, and so on, up to the 63rd size rank.[11] The abnormal volume, volatility, and reversals are then summarized within each size rank. A comparison sample is formed by performing the same ranking process for stocks *not* in the MSCI index.[12] For the sake of brevity, we report only the results for the period from July 1, 2002, to December 31, 2005, a time during which the closing call procedure was adopted by the TSE; and indeed, the expiration-day effects are found to be particularly significant.[13]

Abnormal Volume of Individual Stocks

The abnormal volume for each individual stock is measured by the proportional volume in that stock during the last five-minute interval ($V_{i,-5}$) relative to the total share volume for the entire day (V_i); i.e.

$$\%V_i = \frac{V_{i,-5}}{V_i}. \qquad (6)$$

This measure determines the concentration of trading in individual stocks immediately prior to futures expiration, and is comparable across different sizes of firms.[14]

[11]The number of MSCI constituent stocks varies over time during our sample period, from 63 to 103. To avoid the problem of unequal sample size when aggregating variables across days by stock weighting, we use only the highest 63 weighted stocks.
[12]The number of non-MSCI index stocks varies from 283 to 598 in our sample period. In order to match with the MSCI sample, we only retain the largest 63 size ranks.
[13]Although moderate volume effects are discernible prior to the implementation of the closing call procedure, there is no abnormal volatility or price reversal for majority of individual stocks; the results are not included here but are available from the author on request.
[14]Other measures on trading activity, number of shares, and dollar volume, which are not shown here, provide very similar results.

Figure 3 illustrates the mean proportional volume for the MSCI stocks on both expiration days (MSCI_Exp) and all non-expiration days (MSCI_nonExp), by size ranking. The same measure for the sample of the non-MSCI stocks (nonMSCI_Exp and nonMSCI_nonExp) is also plotted by size ranking. Table V reports the pooled average of the proportional volume for (i) all 63 size ranks together; (ii) ten deciles of size ranks from rank 2 to 61; and (iii) the first size rank.

Figure 3 and Table V give rise to several interesting points. Firstly, higher proportional volume is apparent on expiration days than on non-expiration days for individual MSCI stocks, of all size ranks. This indicates that the concentrated volume in the last five minutes on expiration days is common to all index stocks, regardless of their weight in the index, thereby implying that the expiration-day effects are primarily caused by index arbitrage activities using the entire MSCI portfolio.

Secondly, there is a clear U-shaped pattern in Figure 3 in the proportional volume of MSCI stocks on expiration days, across size ranks. The same pattern is also observed across the ten size deciles, in the second column of Table V: the proportional volume monotonically declines from the first to the fifth

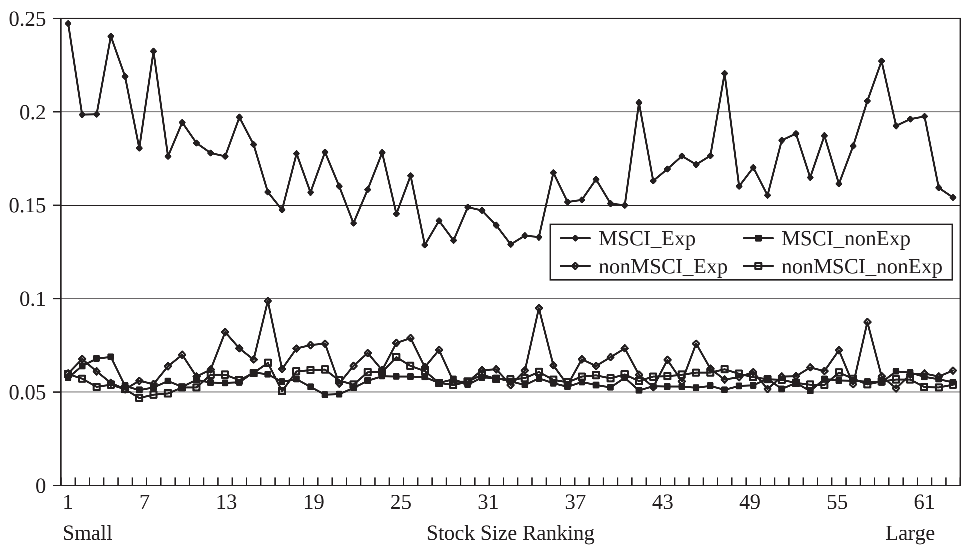

FIGURE 3

Proportional volume for sub-samples of MSCI and non-MSCI stocks on all expiration and non-expiration days, by size ranking.

The figure illustrates the mean proportional volume (the proportion of the trading volume during the last five-minute interval to the whole day volume) for the sub-samples of MSCI stocks on expiration (MSCI_Exp) and non-expiration (MSCI_nonExp) days and the sub-samples of non-MSCI stocks on expiration (nonMSCI_Exp) and non-expiration (nonMSCI_nonExp) days. The proportional volume of individual stocks is averaged across days by size rank. The stocks are ranked (and re-ranked) each day based upon their market capitalization, with rank 1 containing the highest-weighted stock from each day, rank 2 containing the second highest, and so on.

TABLE V
Pooled Mean Proportional Volume of Individual Stocks, by Size Decile

	MSCI Stocks						*Non-MSCI Stocks*	
Stock Rankings	*Expiration Days*	*All Non-Expiration days*	*E − 1*	*E + 1*	*E − 5*	*E + 5*	*Expiration Days*	*All Non-Expiration Days*
All 63 stocks	0.173+	0.056**	0.055**	0.080**	0.054**	0.056**	0.064	0.057**
size deciles								
1 (large)	0.212+	0.060**	0.054**	0.090**	0.055**	0.059**	0.058	0.052**
2	0.184+	0.055**	0.054**	0.085**	0.052**	0.058**	0.068	0.055**
3	0.167+	0.056**	0.058**	0.077**	0.058**	0.053**	0.075	0.060**
4	0.158	0.055**	0.056**	0.078**	0.053**	0.053**	0.068	0.061*
5	0.140	0.056**	0.057**	0.084**	0.055**	0.061**	0.062	0.057*
6	0.145	0.055**	0.054**	0.075**	0.057**	0.053**	0.066	0.057*
7	0.167+	0.053**	0.055**	0.070**	0.052**	0.055**	0.064	0.058**
8	0.179+	0.053**	0.054**	0.076**	0.050**	0.055**	0.062	0.060
9	0.174+	0.055**	0.054**	0.078**	0.051**	0.058**	0.061	0.056
10 (small)	0.200+	0.058**	0.057**	0.082**	0.054**	0.059**	0.062	0.055*
Highest-weighted stocks	0.247+	0.058**	0.050**	0.088**	0.061**	0.061**	0.060	0.060

Note. The proportional volume of individual stocks is measured by the proportion of the last five-minute volume to all-day volume. Stocks are ranked each day based on their market capitalization, with size rank 1 containing the highest-weighted stocks on each day, size rank 2 containing the second highest, and so on. Observations are further categorized into ten deciles according to their size rank. The proportional volume on expiration and non-expiration days coming from different populations is indicated by *at the 5% confidence level, and **at the 1% confidence level, using the Wilcoxon rank sum test. A "plus" sign in the second column indicates that the expiration-day proportional volume of the decile is significantly greater than that of the 5th decile at the 5% confidence level.

deciles, followed by a monotonic increase to the tenth decile. Evidence suggests that the magnitude of the volume impact does have relevance to firm size, with a smaller impact on medium-sized firms and a greater impact on small- and large-cap firms. The greater volume impact on large-cap firms may be the result of certain program trading strategies that use only a subset of index stocks, typically large-cap stocks.

Thirdly, the highest-weighted stocks have an average of 24.7% volume concentration on expiration days, which is the highest for all size ranks. To assess the volume impact of the highest-weighted stocks to overall market, we further calculate the ratio of dollar volume of individual stock to the entire MSCI portfolio (not shown in the table). The last five-minute trading volume of the highest-weighted stocks accounts for 11.4% of overall market volume on expiration days, which nearly doubles their 6.1% volume contribution on regular days. For any other size ranks, the volume contribution on expiration days is substantially smaller (less than 6%) and shows little incremental (less than 50%) from non-expiration days.

The greater volume impact on the largest-cap stocks is not readily attributable to the unwinding of index arbitrage positions but raises concerns of potential price manipulation. Index arbitrageurs will typically use either the entire index portfolio or a basket of large-cap index stocks. In either case, the highest-weighted stock would not exhibit such a large volume contribution disproportionate to that of other index stocks. A possible explanation is that some traders may be manipulating the final settlement index by placing heavy pressure on the highest-weighted stock, given that this is the stock with the greatest influence on the index value.

Uniformity of Price Change

We have demonstrated in the section "The Overall Market Effects" that the MSCI index becomes more volatile during the last five-minute interval on expiration days. The greater index volatility may stem from the greater volatility of individual stocks, the increased uniformity of movement of stocks, or both; it is, however, important to distinguish the source of index volatility because small investors are affected more by the increased volatility of individual stocks than by the co-movement of stocks. In Table VI, we perform an examination of whether there is a greater likelihood of index stocks moving in the same direction on expiration days as compared to non-expiration days.

In the last five minutes on expiration days, about 55% of firms move in the same direction as the MSCI index, a proportion that is significantly greater than that for non-expiration days, when it ranges between 34 and 40%. Meanwhile, fewer stocks move in the opposite direction to the index on expiration

TABLE VI

Proportion of Firms Moving in the Same or Opposite Direction to the MSCI Index

Direction Relative to MSCI Index	*Expiration Days*	*All Non-Expiration Days*	*E − 1*	*E + 1*	*E − 5*	*E + 5*
Panel A: MSCI index stocks						
% same direction	0.55	0.35**	0.34**	0.40**	0.35**	0.36**
% opposite direction	0.15	0.22**	0.22**	0.22**	0.20**	0.22**
C-S return std.	0.0068	0.0052**	0.0051**	0.0073	0.0048**	0.0052**
Panel B: Non-index stocks						
% same direction	0.28–	0.28	0.29	0.29	0.29	0.28
% opposite direction	0.27+	0.26	0.26	0.27	0.25	0.26
C-S return std.	0.0097+	0.0092	0.0090	0.0102	0.0093	0.0091

Note. The mean (across days) proportion of MSCI firms moving in the same and opposite direction to the MSCI index in the last five-minute interval on expiration and non-expiration days is reported in Panel A. The mean (across days) proportion of the non-MSCI firms moving in the same and opposite direction to the MSCI index is reported in Panel B. "C-S return std." refers to the cross-sectional standard deviation of the last five-minute returns for all MSCI index stocks. Note that the sum of the proportion of firms moving in the same and opposite directions is less than 100% because some firms have zero returns in the last five-minute interval. Significant difference between the proportion on expiration and non-expiration days is indicated by *at the 5% confidence level, and **at the 1% confidence level, using the Wilcoxon rank sum test. A "plus" ("minus") sign in the second column indicates that the expiration-day proportion of the index stocks is significantly greater (smaller) than the expiration-day proportion of the MSCI stocks at the 5% confidence level.

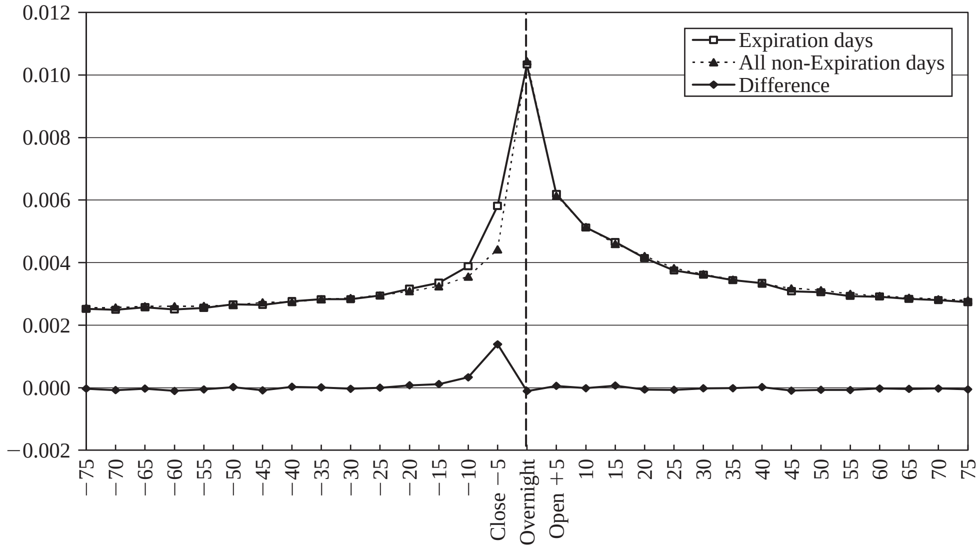

FIGURE 4
Average MSCI stock volatility on expiration and non-expiration days.
This figure illustrates the intraday pattern of average stock volatility for each five-minute interval, where volatility is measured by the absolute return for the five-minute interval. For each five-minute interval, the volatility of individual MSCI stocks is first averaged across stocks, and then across both expiration and non-expiration days. The bold line indicates the difference between the expiration-day and non-expiration-day pattern.

days (15%) than on non-expiration days (22%). Conversely, for the non-index stocks, the tendency for movement in the same and opposite directions to the index is essentially equal on both expiration and non-expiration days.

Although the evidence indicates a tendency for stock prices to move together on expiration days, the magnitude of the impact on individual stocks is less than equal. This can be observed by the greater cross-sectional standard deviation of stock returns during the last five-minute interval of expiration days, denoted as "C-S return std" in Table VI. If the magnitude of the influence of the expiration-day effect is similar for all index stocks, the cross-sectional variability should be less for expiration days than for non-expiration days; however, this is not the case. The higher cross-sectional volatility for individual stocks is consistent with the findings on the U.S. market reported by Stoll and Whaley (1990).

Abnormal Volatility of Individual Stocks

Individual stock volatility is measured by the absolute return in each five-minute interval (|ret|).[15] For every five-minute interval, we first of all calculate

[15]We also assess intraday volatility using the measure developed by Daigler (1997) and Parkinson (1980) and obtain similar results.

the equal-weighted mean volatility across stocks, then average this across both expiration and non-expiration days.

Figure 4 provides an illustration of the average individual stock volatility for each five-minute interval on both expiration and non-expiration days. The intraday pattern closely resembles the index volatility illustrated in Figure 2, with a discernible spike in the difference between the expiration day and the non-expiration day occurring only in the last five-minute interval. It is therefore clear that the expiration of MSCI-TW contracts results in an increase in the volatility of individual stocks in much the same way as it does for the portfolio of overall market.

Table VII presents the results of the statistical tests for the difference in the last five-minute |ret| between expiration and non-expiration days, along

TABLE VII
Volatility of Individual Stocks

	MSCI Stocks						*Non-MSCI Stocks*	
	Expiration Days	*All Non-Expiration Days*	*E − 1*	*E + 1*	*E − 5*	*E + 5*	*Expiration Days*	*All Non-Expiration Days*
Panel A: Average of individual stock volatility								
|ret|	0.00562	0.00331**	0.00326**	0.00467*	0.00310**	0.00342**	0.00490	0.00466*
%|ret|	0.26044	0.14018**	0.14134**	0.19843*	0.12252**	0.14099**	0.15194	0.14044*
Panel B: Pooled mean proportional volatility (%|ret|) of 63 stocks, by size decile								
All 63 stocks	0.220+	0.132**	0.134**	0.172**	0.119**	0.139**	0.139	0.128**
size deciles								
1 (large)	0.258+	0.151**	0.148**	0.204**	0.121**	0.176**	0.122	0.105
2	0.239+	0.141**	0.151**	0.193*	0.123**	0.160**	0.134	0.128
3	0.203	0.129**	0.124**	0.155*	0.127**	0.136**	0.141	0.135
4	0.211+	0.127**	0.117**	0.189*	0.117**	0.115**	0.161	0.128*
5	0.175	0.113**	0.122*	0.156	0.086**	0.119**	0.117	0.123
6	0.190	0.118**	0.116**	0.160	0.101**	0.107**	0.166+	0.131**
7	0.205	0.129**	0.128**	0.155**	0.120**	0.129**	0.146	0.137
8	0.240+	0.134**	0.141**	0.157**	0.129**	0.140**	0.137	0.133
9	0.233+	0.140**	0.153**	0.183*	0.119**	0.149**	0.127	0.123
10 (small)	0.234+	0.143**	0.145**	0.168**	0.148**	0.164**	0.116	0.128
Highest-weighted stocks	0.318+	0.141**	0.097**	0.211**	0.137**	0.178**	0.195	0.197

Note. The table reports the average volatility of individual stocks for the expiration days and for the various non-expiration day periods. Panel A assesses individual stock volatility by the absolute return in the last five-minute interval (|ret|) as well as the ratio (%|ret|) of the absolute return in the last five-minute interval over the range return for the whole day. Individual stock volatility is initially averaged across the stocks for each day, and then across both expiration and non-expiration days. Panel B ranks the stocks on each day based on their market capitalization, with size rank 1 containing the highest-weighted stocks on each day, size rank 2 containing the second highest, and so on. Observations are further categorized into ten deciles according to their size rank. The volatility on expiration and non-expiration days coming from different populations is indicated by *at the 5% confidence level, and **at the 1% confidence level, using the Wilcoxon rank sum test. A "plus" sign in the expiration-day columns indicates that the expiration-day volatility of the decile is significantly greater than that of the 5th decile at the 5% confidence level.

with the ratio (%|ret|) of the last five-minute absolute returns to the whole-day absolute range returns defined as the daily highest price minus the lowest price divided by the daily mean.

Panel A reveals that on expiration days, |ret| is 0.00562 and %|ret| is 0.26, both of which are significantly greater than the corresponding figures on non-expiration days using the Wilcoxon rank sum test. Together with the findings reported in Table VI, this result suggests that not only do the expiration-day effects cause an increase in the co-movement of the index stocks, but that they also lead to higher volatility for individual stocks. The latter of these two effects is of particular concern, essentially because it implies that retail investors engaging in transactions around the expiration period will trade at a price that may be some distance from its fair value.

In order to further explore whether these effects are more pronounced on large-cap stocks than smaller ones, we perform the same size ranking as in the section "Abnormal Volume of Individual Stocks" and report the %|ret|, by size rank, on expiration days and non-expiration days for both MSCI and non-MSCI stocks.

Figure 5 shows that across size ranks, the volatility impact on expiration days exhibits a U-shaped pattern, similar to the volume effect. This pattern is confirmed by the results reported in the second column in Panel B of Table VII,

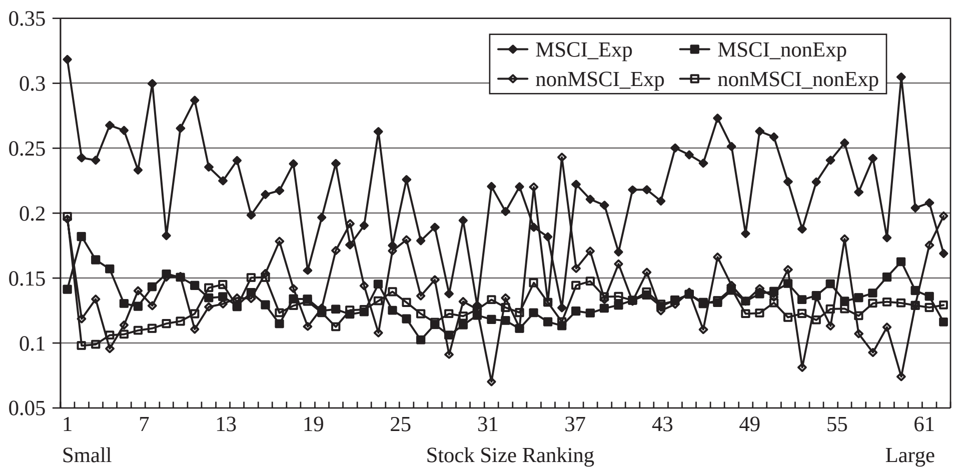

FIGURE 5

Proportional volatility for sub-samples of MSCI and non-MSCI stocks on expiration and non-expiration days, by size ranking.

This figure illustrates the cross-day mean proportional volatility for the sub-samples of MSCI stocks on expiration (MSCI_Exp) and non-expiration (MSCI_nonExp) days, and the sub-samples of non-MSCI stocks on expiration (nonMSCI_Exp) and non-expiration (nonMSCI_nonExp) days. The mean proportional volatility is the ratio of the absolute return during the last five-minute interval to the absolute return over the entire day, averaged across days, by size ranking. Stocks are ranked (and re-ranked) each day based on their market capitalization, with rank 1 containing the highest-weighted stock from each day, rank 2 containing the second highest, and so on.

from which we can see that there is a decline in the pooled mean %|ret| from 0.258 in the largest size decile, to 0.175 in the fifth size decile, and then a subsequent increase to 0.240 in the eighth decile.

Although all individual index stocks become more volatile immediately prior to futures expiration, the greatest volatility occurs in the highest-weighted stocks. As shown in the last row of Table VII, the last five-minute price changes in the highest-weighted stocks on expiration days account for 31.8% of the whole-day price range, which is twice the level of non-expiration days and significantly greater than stocks with lower weight. Our main concern is whether the exceptionally large volatility of the highest-weighted stock can actually destabilize the entire market.

To answer the question, we propose a calculation for the volatility contribution to the index by individual stocks. We assess the volatility contribution of a stock in terms of the difference between the absolute return of the value-weighted index comprising all MSCI-TW stocks and that of the index with the stock in question having been excluded. The volatility contribution (VCB_i) of stock i, is

$$VCB_i = |R^{idx}| - |R^{idx-i}| \tag{7}$$

where R^{idx} is the return of the MSCI-TW index portfolio in the last five-minute interval and R^{idx-i} is the return of the index portfolio with stock i excluded. A positive VCB_i indicates that the inclusion of stock i increases the volatility of the index, whereas a greater VCB_i indicates a higher volatility contribution from stock i.[16]

The volatility contribution is calculated on a daily basis for individual stocks, and then averaged out, first of all across stocks by their daily size ranks, and then across days. Figure 6 provides a graphical illustration of the mean volatility contribution on expiration days (gray and black bars) and non-expiration days (white bars), by stock size ranking. A black bar indicates that the volatility contribution of a particular stock size is significantly higher on expiration days than on non-expiration days.

The highest capitalization stock, as expected, is the major contributor to volatility within the index on both regular days and expiration days, as the first white bar is the highest among all white bars and the first black bar is the highest among all black and gray bars. What is interesting is that the first black bar (0.000237) is three times greater than the first white bar (0.000067), indicating a substantial rise in the volatility contribution of the highest-weighted stocks on expiration days as compared to that on non-expiration days. This suggests that

[16]The interpretation of the volatility contribution of individual stocks is analogous to that of the incremental VAR, which measures the change in portfolio VAR attributable to a new position by the difference in VARs between portfolios with and without the position in question.

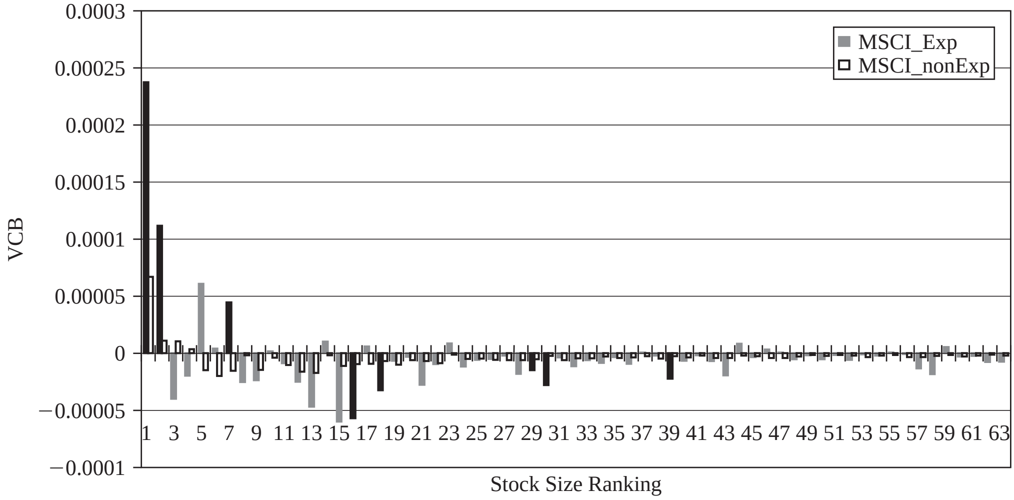

FIGURE 6
Volatility contribution of individual MSCI stocks on expiration and non-expiration days, by size ranking.
The volatility contribution of an individual stock is the difference between the last five-minute absolute returns of two value-weighted indexes, one that includes and the other that excludes the stock. Stocks are ranked (and re-ranked) each day based upon their market capitalization, with the mean volatility contribution being calculated across days by size ranking. A gray (white) bar in the figure represents the expiration (non-expiration) cross-day mean volatility contribution for a particular size ranking. A black bar indicates that within the particular size ranking, the expiration day volatility is significantly greater than the non-expiration day volatility.

the abrupt movement of the single stock on expiration days causes considerable disturbance in the overall market, a finding that is consistent with potential market manipulation through the use of the highest-weighted index stocks.

Return Reversal of Individual Stocks

Following the abnormal price pressure experienced by individual stocks prior to futures expiration, the prices of these stocks will tend to reverse once the pressure subsides. Table VIII reports the magnitude and frequency of *REV1* reversals for individual stocks by size ranking.[17]

Individual stock reversals are significantly larger on expiration days than on non-expiration days. This is true for all but the smallest size decile, as shown in Panel A of Table VIII. Furthermore, the frequency of the reversals is also found to be significantly greater on expiration days (33.3%) than on non-expiration days (22.2%); this is confirmed for all of the non-expiration day sub-samples and for most of the size deciles in Panel B.

[17]For the sake of brevity, we do not report the results using *REV*0 and *REV*2. The reversals measured using *REV*2 provide results, which are almost identical to those using *REV*1, whereas the reversals on expiration days for individual stocks are less apparent using *REV*0.

TABLE VIII

Pooled Mean Frequency of Reversals in Individual Stocks, by Size Decile

	MSCI Stocks						*Non-MSCI Stocks*	
	Expiration Days	*All Non-Expiration Days*	*E − 1*	*E + 1*	*E − 5*	*E + 5*	*Expiration Days*	*All Non-Expiration Days*
Panel A: Pooled mean individual stock reversal (REV1), by size decile								
All 63 stocks size deciles	0.00339	0.00242**	0.00234**	0.00295**	0.00223**	0.00213**	0.00276	0.00257
1 (large)	0.00337	0.00228**	0.00232**	0.00217	0.00246**	0.00219*	0.00231	0.00260
2	0.00326	0.00222**	0.00221**	0.00313	0.00181**	0.00184**	0.00302	0.00270
3	0.00323	0.00234**	0.00206**	0.00255	0.00242	0.00167**	0.00275	0.00268
4	0.00394	0.00258**	0.00208**	0.00315**	0.00218**	0.00229**	0.00293	0.00254
5	0.00335	0.00256**	0.00254**	0.00331	0.00219**	0.00247**	0.00339	0.00256
6	0.00367	0.00244**	0.00234*	0.00366	0.00206**	0.00202**	0.00343	0.00241**
7	0.00290	0.00240**	0.00277	0.00285	0.00255*	0.00214*	0.00236	0.00262
8	0.00324	0.00235**	0.00250*	0.00284	0.00223**	0.00243*	0.00259	0.00250
9	0.00388	0.00249**	0.00250**	0.00328	0.00227**	0.00180**	0.00254	0.00269
10 (small)	0.00255–	0.00241	0.00193	0.00266	0.00234	0.00217	0.00217	0.00256
Highest-weighted stocks	0.00759+	0.00333**	0.00287*	0.00448	0.00252**	0.00494*	0.00189	0.00178
Panel B: Pooled mean frequency of reversal on individual stocks, by size decile								
All 63 stocks size deciles	0.333	0.222**	0.224**	0.275**	0.207**	0.216**	0.236	0.223
1 (large)	0.341	0.234**	0.222**	0.278	0.198**	0.238*	0.230	0.213
2	0.337	0.222**	0.206**	0.310	0.206**	0.230**	0.238	0.231
3	0.317	0.223**	0.218*	0.238*	0.250	0.206**	0.266	0.239
4	0.429	0.229**	0.246**	0.286**	0.194**	0.210**	0.230	0.225
5	0.377	0.228**	0.238**	0.302	0.218**	0.222**	0.246	0.217
6	0.310	0.226**	0.218*	0.306	0.222*	0.206**	0.274	0.210*
7	0.313	0.214**	0.242	0.254	0.198**	0.234*	0.222	0.233
8	0.333	0.217**	0.222**	0.270	0.190**	0.250*	0.226	0.221
9	0.329	0.211**	0.194**	0.254	0.187**	0.167**	0.206	0.228
10 (small)	0.234–	0.220	0.230	0.258	0.238	0.190	0.187	0.218
Highest-weighted stocks	0.500+	0.231**	0.238*	0.333	0.214**	0.286*	0.190	0.229

Note. The table presents the pooled average of the individual stock reversals on expiration and non-expiration days. A reversal is recognized if stock prices move in the opposite direction between the last five-minute interval and the overnight interval. Panel A reports the magnitude of the reversals measured by *REV*1 as defined in Stoll and Whaley (1987). Panel B reports the frequency of the reversal proportionate to all days. Stocks are sorted and regrouped each day according to their market capitalization, with size rank 1 containing the highest-weighted stock on each day, size rank 2 containing the second highest, and so on. Observations are further categorized into ten deciles according to their size rank. The reversals on expiration and non-expiration days coming from different populations are indicated by *at the 5% confidence level, and **at the 1% confidence level, using the Wilcoxon rank sum test. A "plus" ("minus") sign in the expiration-day columns indicates that the expiration-day reversal of the decile is significantly greater (smaller) than that of the 5th decile at the 5% confidence level.

It should be noted that the price reversals for the individual stocks reported in Table VIII are much more pronounced than the moderate index reversals reported in Tables III and IV. The abnormal transactions on expiration days appear to affect individual stock prices in a way that cannot be observed by the examination of the index in isolation. This further emphasizes the need for evidence from individual stocks before drawing any concrete conclusion.

There is an L-shaped pattern across size deciles for return reversals, with the highest-weighted stocks exhibiting a larger magnitude and a greater probability of reversals in excess of the level for the remaining stocks. The average reversal for the highest-weighted stocks is 0.00759, a return that is over twice the stocks' normal level on non-expiration days (0.00333) and also over twice the average level on expiration days for all stocks (0.00339). This magnitude of reversals, when evaluated against the quoted half-spread (which is approximately 0.15% for the highest-weighted stocks) is of economic significance: about 0.6% of the abnormal return reversal (0.00759–0.0015) cannot be attributed to the normal bid–ask bounce.[18] When evaluated by the frequency of reversals, stocks of the highest index weight reverse on 50% of the expiration days, a probability level that is significantly greater than that for all the other size deciles.

Our evidence suggests that the expiration-day effects have much greater impacts on the highest-weighted stocks than on any other stocks. Such concentration of impact on a single stock cannot be easily explained by program trading, which trades in either all index stocks or a basket of large stocks. On the other hand, however, the disproportionate impact on the largest stocks is consistent with the notion that some traders use such stocks as a vehicle to manipulate the index on expiration days. Although a thorough analysis of the price manipulation hypothesis is beyond the scope of this study, our results do point to an important source of expiration-day effects. A surveillance mechanism focusing on large-cap stocks may be necessary if we are to provide appropriate protection for retail investors trading in individual stocks.

CONCLUSIONS

In this study, we provide extensive evidence on the expiration-day effects on the overall MSCI-TW index futures market in Taiwan, as well as on individual stocks. Abnormally large volume and volatility are revealed during the last five-minute trading interval on expiration days for both individual stocks and for the overall market. Close to the contract expiration period, stocks of all size are found to experience higher volatility, and also have a tendency to move in the same direction as the index, with large and small stocks being affected

[18]The average return reversal is 0.00427 if assessed by *REV*2, with the price impact remaining substantial after deducting the size of the half bid–ask spread.

more than medium-sized stocks. Price reversals are found to be more significant in individual stocks than within the index as a whole, a finding that suggests that the expiration-day effects have greater impact on small investors trading in individual stocks, than on institutional traders trading large baskets of stocks.

The expiration-day effects of volume, volatility, and reversals are found to have become more pronounced after the change, on July 1, 2002, from a more continuous auction procedure to a discrete call auction for market close in the TSE. This suggests that if the closing call procedure implemented in Taiwan has not in fact exacerbated the expiration-day effects, then it has certainly failed to mitigate the situation.

Finally, we find evidence that attempts at price manipulation in Taiwan may well have amplified the expiration-day effects. The highest-weighted index stocks experienced substantial volume, volatility, and price reversals at a magnitude that is far above that of the remaining index stocks. There is a discernible surge in the influence of the highest-weighted stock on the index around the expiration period, an effect that is not readily attributable to the unwinding of index arbitrage; however, it may well be the result of trading by price manipulators in their attempts to affect the final settlement index by concentrating the price pressure on the most influential stocks.

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Stock Price Clustering on Option Expiration Dates*

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Abstract

This paper presents striking evidence that option trading changes the prices of underlying stocks. In particular, we show that on expiration dates the closing prices of stocks with listed options cluster at option strike prices. On each expiration date, the returns of optionable stocks are altered by an average of at least 16.5 basis points, which translates into aggregate market capitalization shifts on the order of $9 billion. We provide evidence that hedge re-balancing by option market-makers and stock price manipulation by firm proprietary traders contribute to the clustering.

JEL classification: G12; G13; G24

Keywords: Stock price clustering; Option expiration; Hedging; Manipulation

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1. Introduction

Exchanged-based trading of options commenced in the United States in 1973 when the Securities and Exchange Commission (SEC) authorized the Chicago Board Options Exchange (CBOE) to undertake a pilot program to trade calls on 16 underlying common stocks (Securities and Exchange Commission, 1978, pp. 1–2.) In June 1977 the SEC first permitted the listing of puts, but only on an experimental basis (Whaley, 2003, p. 1134, n. 6.) Later in 1977, however, the SEC proposed a moratorium on new option introductions while it investigated exchange-listed option trading.[1] An important factor in the SEC's initial caution in allowing exchange-based trading of calls and puts and its subsequent moratorium on new option listings was a concern that underlying stock prices would be perturbed. Despite this longstanding concern, little evidence has emerged that option trading has much impact on underlying stock prices.

One set of studies examines option introductions to see whether option trading influences underlying stock prices.[2] Some of the earlier papers (Skinner (1989), Conrad (1989), and Bansal, Pruitt, and Wei (1989)) indicate option introductions produce a decrease in the price volatility of underlying stocks. However, Lamoureux and Panikkath (1994), Freund, McCann, and Webb (1994), and Bollen (1998) provide evidence that this effect is likely due to market-wide volatility changes, as similar changes occur in samples of matched control firms. Conrad (1989) and Detemple and Jorion (1990) investigate whether option introductions change the price levels of underlying stocks and find positive effects. Recent evidence, however, suggests that this result is not robust. Sorescu (2000) finds a positive price impact during Conrad's data period (i.e., prior to 1980), but a decrease in stock prices after 1980. Ho and Liu (1997) obtain similar results. Mayhew and Mihov (2004) find that—like the volatility effects—the apparent price level effects largely vanish when a comparison is made to an appropriate set of control firms.[3]

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[1] By 1977 options were trading at several US exchanges. These exchanges voluntarily complied with the proposed moratorium until the SEC signaled its approval to resume option introductions in 1980.

[2] There is also a large theoretical literature on how the introduction of derivatives might impact stock prices. The results of this literature are ambiguous in that different models, and sometimes the same model with different parameter values, imply different impacts. Mayhew (2000) provides a recent survey of this literature.

[3] Some of the option introduction studies also examine the impact on the trading volume or microstructure level characteristics of the underlying stock. Kumar, Sarin, and Shastri (1998) is an example of this type of research.

A smaller number of studies investigate stock price behavior around expiration dates.[4] An early CBOE (1976) report found no evidence of abnormal price behavior in the two-week period leading up to option expirations. Klemkosky (1978) examines 14 option expiration dates in 1975 and 1976 and finds an average abnormal return of –1% in the week leading up to option expiration and of +0.4% in the week following option expiration. The finding for the week leading up to expiration is more reliable.[5] Cinar and Vu (1987) also study the impact of impending option expiration on six underlying stocks over a longer six and one-half year period from January 1979 to June 1985. They find that the return from the Thursday to Friday of expiration week when compared to non-expiration weeks is significantly positive for one stock, significantly negative for one stock, and insignificant for the other four stocks. Although a joint test of the returns for the six stocks was not performed, it would not be surprising if it failed to show a significant expiration-week difference. None of the six stocks had volatilities from Thursday to Friday on expiration weeks that were significantly different from other Thursday to Friday time periods.

All in all, the option introduction and expiration literature has not shown that equity option trading significantly impacts the prices of underlying stocks. The present paper, by contrast, provides striking evidence that option trading alters the distribution of underlying stock prices and returns. In particular, we show that over the 1996-2002 period optionable stocks (i.e., stocks with listed options) cluster at option strike prices on expiration dates. There is no corresponding expiration date change in the distribution of the closing prices of non-optionable stocks. Nor are optionable stocks more likely to close near a strike price on the Fridays before or after expiration

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[4] There is a larger body of research on expiration effects for stock index options or futures (e.g., Stoll and Whaley (1986, 1987, 1991, 1997), Edwards (1988), Feinstein and Goetzmann (1988), Herbst and Maberly (1990), Hancock (1991), Chen and Williams (1994), Karolyi (1996), Diz and Finucane (1998), Bollen and Whaley (1999), Alkebäck and Hagelin (2002), and Chow, Yung, and Zhang (2003).) Mayhew (2000; p. 32) surveys much of this literature, and concludes that “there is little evidence of a strong, systematic price effect around expiration.” It may be the case that expiration effects for index derivatives have been more widely studied because (unlike stock options) they are cash-settled. Whaley (2003, Section 7.2) argues that cash-settled derivatives are more likely to have expiration effects in the prices of their underlying assets.

[5] The negative return in the week leading up to expiration is significant at the 5% level for seven of the 14 expiration dates. The positive return in the week following option expiration is significant at the 5% level for only three of the fourteen expiration dates. Klemkosky (1978) does not examine volatility changes in the underlying stock around expirations. In a non-US study, Pope and Yadav (1992) find similar, though smaller, return effects in the U.K.

Fridays. Hence, it appears that the increased likelihood that the stock prices close near option strike prices is indeed attributable to the expiration of the options written on them.[6]

Unsurprisingly, the changes in expiration Friday closing stock prices are associated with return differences on expiration relative to non-expiration Fridays. On expiration Fridays optionable stocks are more likely to experience returns that are small in absolute value and less likely to experience returns that are large in absolute value. This difference suggests that the expiration date clustering is produced primarily from cases in which Thursday stock prices that are close to option strike prices remain in the neighborhood of the strike rather than from cases in which Thursday stock prices that are distant from the strike price move to the neighborhood of the strike.

We derive an expression that provides a lower bound on the expiration date return deviations. Using this expression, we estimate that optionable stocks have their returns altered on average by at least 16.5 basis points (bps) per expiration date. In addition, we are able to determine that on a typical expiration date at least two percent of optionable stocks have their returns altered. Since at any point during our data period there are roughly 2,500 optionable stocks, the 16.5 bps lower bound on average return impact implies that if all 2,500 optionable stocks are impacted the average deviation in returns is 16.5 bps, if half or 1,250 are impacted the average deviation is 16.5/0.5 = 33 bps, if five percent or 125 are impacted the average deviation is 16.5/0.05 = 330 bps, and if two percent or 50 are impacted the average deviation is 16.5/0.02 = 825 bps. Regardless of the percentage of optionable stocks that are impacted, our estimates imply that on average the return deviations shift market capitalizations of optionable stocks by at least $9.1 billion per expiration date.

The expiration day stock price deviations lead to wealth transfers in both the option and the stock market. For example, there are wealth transfers in the option market insofar as investors who have purchased expiring options make exercise decisions based on expiration Friday closing stock prices. The changed exercise decisions have welfare implications both for the option purchasers and for the option writers whose probability of getting assigned varies with the exercise decisions.[7]

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[6] Krishnan and Nelken (2001) provide a related piece of evidence. They show that shares of Microsoft (which is an optionable stock) close near integer multiples of $5 more frequently on expiration Fridays than on other trade dates.
[7] It is, of course, possible that all option purchasers are aware of the clustering phenomenon and successfully account for it when making exercise decisions at option expiration. This possibility seems remote.

There will also be wealth transfers when non-expiring options trade near expiration, because option prices vary with the prices of underlying stocks. In addition, transfers will occur among stock market investors who do not participate in the option market but who happen to be trading optionable stocks near expiration.

Our results naturally raise the question of what produces the strike price clustering on option expiration dates. We investigate four potential explanations. Here we indicate their general nature, deferring to the body of the paper a more detailed discussion of the mechanism by which each might cause the clustering. The first is proposed by Avellaneda and Lipkin (2003), who develop a model in which stock trading undertaken to maintain delta-hedges on existing net purchased option positions pushes stock prices toward strike prices as expiration approaches. The second is that the clustering is induced by delta-hedging (with the underlying stock) particular types of changes in option positions on the day of expiration. The third potential explanation is that the clustering results from investors unwinding certain combined stock and option positions on expiration dates. A final possible explanation is that investors with written options intentionally manipulate the underlying stock price at expiration so that the options finish at-the-money (ATM) or just out-of-the-money (OTM) and consequently are not exercised.[8]

We investigate these potential explanations in several ways. First, we re-examine the strike price clustering around option expiration dates for subsamples of underlying stocks where likely delta-hedgers have net purchased or net written option positions. We find that when the likely delta-hedgers have net purchased option positions, the clustering increases in the days leading up to expiration and spikes on the expiration date. On the other hand, when likely delta-hedgers have net written option positions, the clustering decreases in the days leading up to option expiration, but still increases on the expiration date. These findings suggest that the clustering is produced by hedge re-

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[8] A fifth potential explanation is that since strike prices are usually round numbers such as integer multiples of $5.00 or $2.50, our findings may be just another manifestation of the asset price clustering that is known to pervade financial markets (e.g., Harris (1991).) An earlier version of this paper included an in-depth empirical investigation of this possibility and found no evidence that it contributes to the expiration date clustering. Since it seems somewhat implausible that the explanation plays an important role – because it would require that investors switch to a coarser grid of transaction prices on expiration Friday and then switch back the following Monday – we omit the analysis of this explanation from the paper.

balancing combined with one or more of the other mechanisms, because hedge re-balancing predicts increasing (decreasing) clustering leading up to the expiration date when delta-hedgers have net purchased (written) option positions, while the other mechanisms predict in both cases an increase in clustering on the expiration date. Second, we perform logistic regressions to determine which of the explanations' predictions about increased likelihood of stock prices closing near strike prices on expiration dates are realized in the data. We find that the clustering is significantly elevated when the delta-hedge re-balancing and stock price manipulation explanations predict that it should be greater, but that the clustering does not increase as predicted by the delta-hedging of new option position or unwinding of combined stock and option position explanations. Third, we examine the option writing in the week leading up to expiration of a group of investors who are natural candidates for manipulating stock prices. In accordance with the hypothesis that these investors manipulate stock prices, we find that the written option positions turn out to be quite profitable and that when calls (puts) are written there is an elevated probability that on the expiration date the underlying stock price crosses below (above) the strike price so that the options finish OTM.

In summary, our investigation of these four explanations provides evidence that the hedge re-balancing described by Avellaneda and Lipkin (2003) and stock price manipulation by option writers both contribute to the clustering, while suggesting that the two other potential factors do not play an important role. These findings are interesting not only because they provide insight into the clustering phenomenon, but also because they indicate more generally that hedging and manipulation each impact underlying stock prices.

The remainder of this paper is organized as follows. The next section describes the data. Section 3 documents underlying stock price clustering at strike prices on option expiration dates. The fourth section presents four potential explanations for the clustering. Section 5 provides empirical evidence on these explanations. The sixth section concludes, and an appendix contains the proof of a technical result.

2. Data

The primary data used in this paper are the Ivy DB data from OptionMetrics LLC. This data set includes end-of-day bid and ask quotes, open interest, and daily trading volume on every call and put option on individual stocks traded at any U.S. exchange from January 4, 1996 through September 13, 2002. It also provides daily price, return, dividend, and split data on all stocks that trade on U.S. exchanges. For the paper's main tests we use the Ivy DB data to determine on each trade date the universes of optionable and non-optionable stocks. We also use this data set to get daily closing stock prices, stock returns, and stock trading volumes.

The second data set that we use was obtained from the CBOE. These data include daily open interest and trading volume for each option that trades at the CBOE from the beginning of 1996 through the end of 2001. When a CBOE option also trades at other exchanges, the open interest data reflect outstanding contracts from all exchanges at which the option trades. The volume data, on the other hand, are only for transactions that actually occur at the CBOE. The open interest data are broken down into four categories defined by purchased and written open interest and two types of investors,[9] while the trading volume data are broken down into eight categories defined by four types of volume and two types of investors. The four volume types are volume from buy orders that open new purchased positions (open buy volume), volume from sell orders that open new written positions (open sell volume), volume from buy orders that close existing written positions (close buy volume), and volume from sell orders that close existing purchased positions (close sell volume).

The two investor types are public customers and firm proprietary traders. The Option Clearing Corporation (OCC) assigns one of three origin codes to each option transaction: *C* for public customers, *F* for firm proprietary traders, and *M* for market-makers. The CBOE data include all non-market-maker open interest and volume broken down into public customer and firm proprietary trader categories according to the OCC classification.[10] Investors trading through Merrill

[9] While aggregate purchased open interest must equal aggregate written open interest, this generally will not be true for each type of investor.

[10] The CBOE further subdivided the public customer category into customers of discount brokers, customers of full-service brokers, and other public customers. This further subdivision of the public customer category is not employed in any of the results reported in this paper. It was used in some untabulated robustness checks.

Lynch or Etrade are examples of public customers while an option trader at Goldman Sachs who trades for the bank's own account is an example of a firm proprietary trader.

Exchange listed options expire at 10:59 pm Central Standard Time on the Saturday immediately following the third Friday of each month. The options do not trade between the close of the markets on Friday and the expiration on Saturday night, and we treat the third Friday of each month as the option expiration date. There are 80 option expiration dates during our data period that extends over the 80 months from January 1996 through August 2002. On a given trade date, a stock is considered to be optionable if it has at least one option listed on it and a strictly positive closing price in the Ivy DB database. From January 1996 through August 2002, there are 4,395 stocks that are optionable on at least one trade date, and there are a total of 184,449 optionable stock-expiration date pairs across the 80 option expiration dates. On a given trade date, a stock is considered non-optionable if it has a strictly positive closing price but no options listed on it. There are 12,001 stocks that are non-optionable on at least one expiration date during our data period from January 1996 through August 2002. Across the 80 expiration dates, there are a total of 417,007 non-optionable stock-expiration date pairs.

Daily stock closing prices and numbers of shares outstanding from the Center for Research in Security Prices (CRSP) are used to compute market capitalizations of optionable stocks. CRSP daily stock returns are also used for a robustness check reported in a footnote.

3. Stock price clustering on option expiration dates

This section of the paper investigates stock price clustering on option expiration dates. In the first subsection, we show that optionable stocks are more likely to close at or near strike prices on expiration dates. The second subsection provides two pieces of evidence that the clustering is actually related to option expiration. First, we show that there is no expiration date clustering for the universe of non-optionable stocks. Second, we show that the expiration date clustering appears when non-optionable stocks become optionable and disappears when optionable stocks become non-optionable. In the third subsection, we compare the closing price and return distributions of optionable stocks on expiration and non-expiration Fridays. The final subsection estimates a lower bound on the magnitude of the expiration Friday changes in the returns of optionable stocks.

3.1. Closing prices of optionable stocks

We begin our investigation by examining the probability that optionable stocks close near a strike price as a function of the number of trade dates before or after expiration. Panel A of Figure 1 displays the percentage of optionable stocks that have a daily closing price within \$0.25 of a strike price (of one of its own options) for each of the 21 trade dates from ten trade dates before to ten trade dates after an option expiration Friday.[11] In the figure, trade date –10 is ten trade dates before the option expiration date (i.e., typically two Fridays before option expiration), trade date 0 is the option expiration Friday, and trade date 10 is ten trade dates after the option expiration Friday (i.e., typically two Fridays after option expiration.) Panel A shows that more than 19 percent of optionable stocks close within \$0.25 of a strike price on option expiration Fridays while less than 18 percent do so on the Fridays before and after expiration (i.e., on trade dates –5 and +5.) It is clear from the plot that the percentage on trade date zero is well outside of the range of the percentages on the other (i.e., non-expiration) trade dates. We test formally for a difference on trade date zero by computing a z-statistic for the null hypothesis that the percentage on the expiration Friday is drawn from the same population as the percentage on the non-expiration dates. We estimate the mean and the standard deviation of this population by the sample mean and standard deviation from the 20 non-expiration dates. The resulting z-statistic is a highly significant 8.15.[12] It is also worth noting that the percentages appear to be increasing in the week leading up to expiration (i.e., on trade dates –5 through –1.) We will return to this observation when we consider various explanations for the expiration date clustering.

[11] Here and for the remainder of the paper *within* \$$x$ of a strike price means *less than or equal to* \$$x$ from a strike price.

[12] A large part of the variability on the non-expiration dates is attributable to the few days immediately prior to expiration. As discussed below, clustering on these dates appears to be due to one of the phenomena that explain clustering on the expiration date. Thus, this z-statistic (and the others reported below) understate the statistical significance of the results.

Panels B and C of Figure 1 are constructed like Panel A except that they depict the percentage of optionable stocks that close, respectively, within \$0.125 of a strike price or exactly on a strike price. As expected, the percentages are lower in Panel B than Panel A and lower still in Panel C. The overall shapes of the three plots, however, are very similar. In all three cases, the percentages seem to be increasing in the week leading up to expiration and there is a pronounced spike on the expiration date. The percentage on trade date zero is different than the other dates with high significance in both Panels B and C. In particular, the *z*-statistics for Panels B and C are, respectively, close to nine and seven. For brevity, in the rest of the paper we will focus on the case of stock prices closing within \$0.125 of a strike price. None of the conclusions are sensitive to this choice.

3.2. Is the clustering related to option expiration?

If the clustering that we just documented is indeed related to the presence of expiring options, then it should not be observed on non-optionable stocks. In addition, the clustering should materialize when stocks become optionable and vanish when they become non-optionable. We next investigate these implications of the clustering indeed being related to option expiration.

Obviously, non-optionable stocks do not have associated strike prices.[13] As a result, in order to compare clustering of optionable and non-optionable stocks, we investigate the extent to which these two universes of stocks congregate around integer multiple of \$5. We do this because exchanges introduce equity options in such a way that there are usually options with exercise prices at integer multiples of \$5 that lie near the current price of an underlying stock.[14] Consequently, if the closing price of an optionable stock is near an integer multiple of \$5, it is most likely near a strike

[13] Strictly speaking, non-optionable stocks also do not have option expiration dates. We use the expiration date the stock would have if it were optionable—all U.S. exchange-traded equity options expire on the Saturday following the third Friday of the month.

[14] Exercise prices below \$20 include odd integer multiples of \$2.50. Occasionally exercise prices that are not integer multiples of \$2.50 also occur, typically when options are adjusted for stock splits or stock dividends. (The practice of regularly listing options with strike prices that are integer multiples of \$1 began after the end of our data period.) Not every integer multiple of \$5 is an option strike price because even though new option series are typically added when the underlying stock trades through the highest or lowest strike price available, this is generally not done when there would be only a short time remaining until expiration. Also, option strike prices greater than \$200 are at \$10 intervals.

price. Panel A of Figure 2 displays percentages of optionable stocks that have a daily closing price within $0.125 of an integer multiple of $5, while Panel B displays these percentages for non-optionable stocks. The plot for the optionable stocks has a conspicuous spike at the option expiration date while there is no expiration date increase for the non-optionable stocks. Indeed, for the optionable stocks the *z*-statistic for the expiration date percentage being different than the non-expiration date percentages has a highly significant value of about nine, while for the non-optionable stocks the expiration date percentage is right in the middle of the percentages from the non-expiration dates. It is also interesting that while the main features of optionable stock clustering around integer multiples of $5 (i.e., Panel A of Table 2) are similar to those for clustering around strike prices (i.e., Panel B of Table 1), the clustering around integer multiples of $5 is somewhat less distinct. That is, the size of the expiration date spike is a bit smaller and the increase in clustering through the expiration week is not as clear. We attribute this to integer multiples of $5 being a somewhat noisy proxy for the prices about which optionable stocks actually are clustering, namely, option strike prices.

We next investigate whether there are changes in clustering when stocks become optionable or non-optionable. In our sample, there are 2,628 stocks that first become optionable between February 1996 and August 2002. These stocks yield 47,134 observations on option expiration dates before they become optionable, and 81,170 observations on option expiration dates while they are optionable. Panel A of Figure 3 reports the percentages of their prices that close within $0.125 of an integer multiple of $2.50 before the stocks become optionable.[15] The average percentage is around 11.0 percent, and there is not much variation as a function of the number of trade dates from the option expiration date. In particular, the percentage on the option expiration date is typical of all of the percentages that are observed. Panel B of Figure 3 reports the percentage of closing stock prices within $0.125 of an integer multiple of $2.50 after the stocks become optionable. Once the stocks are optionable, the average percentage on non-expiration dates increases from 11.0 percent to 11.5

[15] We use integer multiples of $2.50 for Figures 3 and 4 instead of the integer multiples of $5 used earlier, because the stocks that become non-optionable during the sample period tend to have lower prices. Option strike prices below $20 are typically integer multiples of $2.50.

percent and the percentage on the expiration date jumps to 12.3 percent. The *z*-statistic for the difference between the expiration and non-expiration dates is close to 6.

In our sample, there are 1,079 optionable stocks that subsequently became non-optionable. These stocks have 30,149 expiration date observations during the time they are optionable and 20,412 expiration date observations when they no longer have listed options. Panel A of Figure 4 shows the percentages of these stocks that have closing prices within \$0.125 of an integer multiple of \$2.50 during the time period when they are optionable, while Panel B shows the percentages that have closing prices within \$0.125 of an integer multiple of \$2.50 after their options have been delisted. Because of the smaller sample size, these graphs display more variability than the previous ones. It is still the case, however, that when the stocks were optionable the percentage on the expiration date is greater than on any other trade date, with a *z*-statistic slightly above 4. After the stocks were no longer optionable, the percentage on the option expiration date is well within the range of the percentages from the other trade dates.

3.3. Price and return distribution differences between expiration and non-expiration Fridays

We have established that on expiration Fridays optionable stocks are more likely to close near strike prices than on other dates.[16] The expiration Friday change in the distribution of optionable stock prices farther away from the strike prices is also of interest. In order to abstract from any potential day-of-the-week effects, we compare the distribution of closing prices for optionable stocks on expiration Fridays to the distribution on the Fridays before and after expiration. The comparison is made by computing for optionable stocks the absolute difference (*AD*) between closing prices and nearest strike prices and sorting these absolute differences into 20 non-overlapping adjacent intervals: $AD \leq \$0.125$, $\$0.125 < AD \leq \$0.25$, $\$0.25 < AD \leq \$0.375$, …, $\$2.375 < AD \leq \$10.00$.[17] We then compute the percentage of optionable stocks that close in each of the twenty intervals on expiration Fridays and the percentage of optionable stocks that close in each of the

[16] We also computed the percentage of closing stock prices near strike prices for each year from 1996 to 2002 and for each month from January to December. Optionable stocks are more likely to close near strike prices on option expiration dates in every year and every month.
[17] The small number of observations with $AD > \$10.00$ are omitted.

twenty intervals on the Fridays before and after expiration. Panel A of Figure 5 plots for each of the 20 intervals the percentage from the expiration Fridays minus the percentage from the Fridays before and after expiration.

The plot has a large positive bar of about 1.3 percent in the first (i.e., $AD \leq \$0.125$) interval. This bar indicates that optionable stocks are about 1.3 percent more likely to close near a strike price on expiration Fridays than on the Fridays before or after expiration. Although this is already known from the previous figures, this bar underscores that the effect is not related to the fact that expirations occur on Fridays. By construction, the bars in the panel must sum to zero. It is interesting, however, that the large positive bar in the first interval is not offset by negative bars evenly distributed across the other 19 intervals. Instead, the negative bars are concentrated around an absolute difference of about $0.50 to $1.00. Consequently, on expiration Fridays more optionable stock prices close near a strike price and fewer close from $0.50 to $1.00 away from the nearest strike price. This fact is consistent with optionable stocks that would have otherwise closed between $0.50 and $1.00 from the nearest strike price on non-expiration Fridays instead closing within $0.125 of a strike price on expiration Fridays. However, this need not be the case. For example, the plot is equally consistent with some optionable stocks that would have closed between $0.50 and $1.00 from the nearest strike price instead closing about $0.25 from the nearest strike price and an equal number that would have closed about $0.25 from the nearest strike price instead closing within $0.125 of a strike price.

We next examine the difference in returns of optionable stocks on expiration Fridays and the Fridays before and after expiration. We proceed by considering the 20 absolute return intervals, $0 \text{ bps} \leq |r| < 50 \text{ bps},\ 50 \text{ bps} \leq |r| < 100 \text{ bps}, \ldots,\ 950 \text{ bps} \leq |r| < 1{,}000 \text{ bps},$ and compute the percentage of optionable stocks with positive option volume that have absolute returns in each interval on expiration Fridays and on the Fridays before and after expiration. For each interval, Panel B of Figure 5 plots the percentage of returns from the expiration Fridays minus the percentage from the Fridays before and after expiration.[18] All of the bars from 0 bps to 300 bps are positive while all of those from 300 bps to 1,000 bps are negative.[19] This pattern indicates that on expiration Fridays

[18] For both Panels in Figure 5, the plots are similar if the non-expiration Fridays are limited to only the Fridays before or only the Fridays after expiration.
[19] As in the previous panel the bars must sum to zero by construction.

optionable stocks are more likely to experience returns that are small in absolute value and less likely to experience returns that are large in absolute value, and suggests that the clustering is due more often than not to cases in which Thursday stock prices close to the strike are prevented from leaving the neighborhood of the strike rather than cases in which Thursday stock prices distant from the strike are pushed to the strike.[20] The 0 bps to 50 bps interval shows the greatest increase and the 350 bps to 500 bps intervals show the greatest decrease (although there is also a noticeable increase in the 50 bps to 100 bps interval and a noticeable decrease over the entire 300 bps to 750 bps range.) The plot is consistent with optionable stocks that would have had returns with absolute values of 350 bps to 500 bps on non-expiration Fridays instead having returns with absolute values of less than 50 bps on expiration Fridays. As with Panel A, however, the plot in Panel B does not force this conclusion. It is also consistent, for example, with some optionable stocks that would have had absolute returns of 350 bps to 500 bps instead having returns of about 200 bps and an equal number of optionable stocks that would have had returns of about 200 bps instead having returns of fewer than 50 bps. It should also be noted that the figure does not entail that the effect arises solely from absolute returns shifting toward zero; all that is required is that the frequency with which absolute returns are decreased exceeds the frequency with which they are increased.

3.4. Implications of differences in expiration day returns

In order to understand more fully the expiration day alteration in the movement of optionable stock prices, we next develop an expression that provides a lower bound on the average deviation in the absolute returns of optionable stocks on expiration dates. Let $\hat{r}_i$ denote the return on the stock in the *i*-th optionable stock-expiration date pair on expiration Friday and r_i denote what the return would have been in the absence of the expiration day effect, i.e., let r_i denote the unaltered stock return. We are interested in the quantity $E\left|\hat{r}_i - r_i\right|$, which measures the average effect on returns. The following proposition, derived in the appendix, provides a lower bound for $E\,|\,\hat{r}_i - r_i\,|$.

[20] It should be borne in mind that if expiration Friday returns are altered by phenomena other than clustering, these alterations will also be reflected in the return distribution difference as well.

Proposition 1. *Define* $\hat{a}_i \equiv \left|\hat{r}_i\right|$ *and* $a_i \equiv \left|r_i\right|$. *Then*

$$E\left|\hat{r}_i - r_i\right| \geq \left|E\left(\hat{a}_i\right) - E\left(a_i\right)\right|. \tag{1}$$

The quantities $E(\hat{a}_i)$ and $E(a_i)$ can be interpreted as the average distances of $\hat{r}_i$ and r_i from zero, so the right-hand side of (1) can be interpreted as the change in the average distance. Interpreting the right-hand side this way, the proposition says that if the average distance from zero changes, then on average returns were shifted by at least the same amount. The right-hand side of (1) provides a lower bound on the average shift in returns rather than an estimate of it due to the existence of shifts in returns that do not affect the average distance from zero. For example, consider three returns $0 \leq x < y < z$. If one stock has its return shifted from *y* up to *z* and another stock has its return shifted from *z* down to *x*, the bound $| E(\hat{a}_i) - E(a_i) |$ only includes the net effect of a single shift from *y* down to *x*, and thus understates the alteration of returns on option expiration dates. The bound also underestimates $E | \hat{r}_i - r_i |$, because it does not account for cases in which a return *x* is shifted to *y* and another return *y* is shifted to *x* and for the greater change in return when a stock with return *y* ($\geq x > 0$) has its return shifted to $-x$ rather than to *x*. The bound provided by the right-hand side of (1) can be crudely estimated from Panel B of Figure 5, and estimated accurately from a version of the figure that uses a smaller bin size. To see this, note that Panel B of Figure 5 shows the differences in the probabilities of each of the bins. If one multiplies the differences in the probabilities by the midpoints of the bins and sums the products, the result is an estimate of the differences in average distances $E(\hat{a}_i) - E(a_i)$, but with an error stemming from the relatively large bin sizes. In order to develop a more accurate estimate, let $\hat{f}(\bullet)$ and $f(\bullet)$ be the density functions of, respectively, $\hat{a}_i$ and a_i. We can then re-write the right hand side of inequality (1) as

$$\left|E\left(\hat{a}_i\right) - E\left(a_i\right)\right| = \left|\int_0^\infty \left[\hat{f}\left(u\right) - f\left(u\right)\right] u \, du\right| \tag{2}$$

and approximate it as

$$\left|E\left(\hat{a}_i\right)-E\left(a_i\right)\right| \approx \left|\sum_{b=1}^{B}\left[\hat{p}\left(b\right)-p\left(b\right)\right]a\left(b\right)\right| \tag{3}$$

where $b = 1,...,B$ indexes B absolute return intervals, $a(b)$ is the absolute return of interval *b*, and $\hat{p}(b) - p(b)$ is the difference in the probability that an optionable stock's absolute return will fall in interval *b* on expiration and non-expiration Fridays.[21] The *B* absolute return intervals should be non-overlapping and cover the range of absolute returns for which there is a non-trivial difference in the expiration and non-expiration densities. In order to illustrate the components of the right hand side of approximation (3), consider Panel B of Figure 5. In this panel *B* is 20, $a(b) \in$ $[(b-1)\times 50 \text{ bps}, b\times 50 \text{ bps})$, and $\hat{p}(b) - p(b)$ is equal to the value of the *b*th bar. The quality of the approximation in expression (3) is governed by the width of the absolute return interval. In the limit where the width of the intervals goes to zero, the approximation becomes exact (provided that the *B* intervals cover the range of absolute returns where the expiration and non-expiration densities are not identical.)

We estimate a lower bound for $E\left|\hat{r}_i - r_i\right|$ by computing the right hand side of approximation (3) from optionable stocks with positive option volume. We set $B = 1{,}000{,}000$ and use 0.01 bps absolute return intervals to cover the range from 0 bps up to 10,000 bps (i.e., up to 100%). For each of the 1,000,000 intervals, we set $a(b)$ to the average of the absolute returns that fall within the interval. The resulting lower bound for $E\left|\hat{r}_i - r_i\right|$ is 16.57 bps. This estimate is not sensitive to the choices we make when computing it. For example, if the bin width is changed from 0.01 bps to 1 bp, the lower bound is still 16.57 bps (i.e., there is no change to two decimal place accuracy.) If we keep the bin width at 0.01 bps but limit the absolute return intervals to the range 0 bps to 5,000 bps, then the lower bound decreases only from 16.57 bps to 15.88 bps.[22]

The 16.57 bps lower bound on $E\left|\hat{r}_i - r_i\right|$ implies that across optionable stocks the average expiration date alteration in absolute return is at least 16.57 bps. This lower bound suggests that the total impact is consequential regardless of the percentage of optionable stocks that are influenced on

[21] We estimate the probabilities $p(b)$ from the returns on optionable stocks on the Fridays before and after expiration.

[22] We also performed the lower bound calculations using CRSP rather than OptionMetrics returns. The results were very similar.

a typical expiration date. For example, if ten percent of the optionable stocks (or about 250) have their returns altered, the average absolute return deviation of the impacted stocks is at least 165.7 bps. Return deviations of this magnitude are large, especially in light of the fact that option expirations occur twelve times per year.[23] Since the positive bars in Panel B of Figure 5 sum to about two percent, we know that at least two percent of optionable stocks are influenced on a typical expiration date. We doubt that only two percent are impacted, because that would imply there are no cases in which a large absolute return is shifted to an intermediate absolute return and an intermediate absolute return is shifted to a small absolute return. If it, nonetheless, turns out that only two percent of optionable stocks (or about 50) have their returns altered, then the lower bound on the average absolute return deviation of the impacted stock is an enormous 828.5 bps. Although it also seems unlikely, it is possible that nearly all optionable stocks (or about 2,500) are impacted on each expiration date. In this case, the lower bound on the average absolute return deviation is 16.57 bps. This is still an impressive number, because during our data period optionable stocks comprised the great majority of U.S. stock market capitalization.

As is common with many financial market phenomena, the lower bound on the average absolute return effect varies with market capitalization. We document this variation by grouping the optionable stocks on each expiration date into deciles based on their market capitalizations, and then computing the lower bound for each decile separately. The estimates of the lower bounds ranged from 24.30 bps and 28.52 bps, respectively, for deciles 1 and 2 (the deciles with the smallest market capitalization stocks), to 13.63 bps and 6.70 bps for deciles 9 and 10 (the deciles with the largest market capitalization stocks). Note that this sort into size deciles is based on only the optionable stocks, and the market capitalizations of optionable stocks tend to be larger than those of non-optionable stocks. For example, the median stocks in deciles 1 and 2 fall into the second and third deciles of NYSE market capitalizations, and the 13.63 bps and 6.70 bps lower bounds apply to some of the largest market capitalization stocks traded in the U.S.

[23] That is, if ten percent of optionable stocks are impacted on each expiration date, in expectation each optionable stock will be impacted every year.

We can also use the lower bounds on $E\left|\hat{r}_i - r_i\right|$ for the deciles to estimate the average expiration day impact on the market capitalization of optionable stocks. We do so by multiplying the lower bound and average market capitalization for each decile and then summing these products across the deciles. This procedure yields a lower bound on the impact on the market capitalization of optionable stocks of $9.1 billion per expiration date. Hence, it appears that each month at expiration there are large shifts in market capitalization associated with the changes in the returns of optionable stocks. Note that the $9.1 billion approximation for the lower bound is invariant to the percentage of optionable stocks that typically have their returns altered on expiration dates.

4. Potential sources of the clustering

This section of the paper describes four potential explanations for the expiration date strike price clustering of optionable stocks documented above. The next section will provide empirical evidence on these explanations. The explanations are not mutually exclusive, so more than one may contribute to the clustering.

4.1. Re-balancing of delta-hedges on existing option positions

Avellaneda and Lipkin (2003) propose a model in which expiration date stock price clustering at strike prices is produced by the delta-hedging activity of option market participants with existing net purchased option holdings. A delta-hedging option investor attempts to maintain a stock position that is opposite to the delta of his net option position. Consequently, as the deltas of his existing portfolio of options change, he trades in the underlying stock in order to keep his overall option and stock position close to delta-neutral. Specifically, when the delta of his net option position increases (decreases), a delta-hedger sells (buys) stock in order to remain delta-neutral. If the elasticity of the underlying stock price with respect to selling and buying volume is non-zero (which Avellaneda and Lipkin assume), then the re-balancing of delta hedges will affect stock prices.

In order to understand how re-balancing by investors with net purchased option positions pushes stock prices toward strike prices as expiration approaches, recall that the Black-Scholes delta of a call option on a non-dividend paying stock is $N\left(d_1\right)$, where $N(\bullet)$ is the standard normal distribution function,

$$d_1 \equiv \frac{\ln(S/K)+(r+\sigma^2/2)(T-t)}{\sigma\sqrt{T-t}}, \tag{4}$$

S is the stock price, *K* is the strike price, *r* is the risk-free rate, σ is the volatility of the underlying stock, *T* is the expiration date, and *t* is the current date. A straightforward application of put-call parity shows that the corresponding put delta is $N\left(d_1\right)-1$. These formulas imply that the time derivatives of the call and put deltas are the same:

$$\frac{\partial N(d_1)}{\partial t} = \frac{\partial\left(N(d_1)-1\right)}{\partial t} = N'(d_1)\frac{1}{2\sigma(T-t)^{3/2}}\left[\ln(S/K)-(r+\sigma^2/2)(T-t)\right], \tag{5}$$

where $N'\left(\bullet\right)$ is the standard normal density function.

If we disregard the term $\left(r+\sigma^2/2\right)\left(T-t\right)$, which is small relative to $\ln(S/K)$ as $t \to T$ provided that $S \neq K$, the remaining component of the time derivative is greater than or less than zero depending on whether *S* is greater than or less than *K*. That is, denoting the time derivative of the option delta by $\partial\Delta/\partial t$, for both a put and a call as $t \to T$

$$\frac{\partial\Delta}{\partial t} \approx \frac{N'(d_1)}{2\sigma(T-t)^{3/2}}\ln(S/K) > 0 \quad \text{if } S > K, \tag{6}$$

$$\frac{\partial\Delta}{\partial t} \approx \frac{N'(d_1)}{2\sigma(T-t)^{3/2}}\ln(S/K) < 0 \quad \text{if } S < K. \tag{7}$$

This time derivative of the option Δ plays a key role in the analysis of Avellaneda and Lipkin (2003).

In particular, consider an agent who has purchased options on *n* shares of stock, and thus has a position with a delta of $n\Delta$. If the agent continuously re-hedges the option position, then at each instant of time the stock position is $-n\Delta$ shares. The previous analysis implies that if $S > K$ as expiration approaches, then the time derivative $\partial\Delta/\partial t > 0$. The positive time derivative of Δ, in turn, implies that $\partial(-n\Delta)/\partial t < 0$, or that as time passes the agent sells stock driving *S* down toward *K*. On the other hand, if $S < K$, then $\partial(-n\Delta)/\partial t > 0$ which implies that as time passes the agent buys stock driving *S* up toward *K*. That is, the hedge re-balancing of an agent who has net purchased option positions tends to push the stock price toward the option strike price. A directly analogous argument, however, shows that a delta-hedging agent with a net written option position trades in the opposite direction, and, thereby tends to push the stock prices away from a strike price. Thus, the Avellaneda and Lipkin (2003) model implies that stock prices should tend to cluster at option strike prices when delta-hedging option market participants have net purchased option positions and to de-cluster when they have net written option positions.

Avellaneda and Lipkin (2003) suppose that market-makers are the heaviest delta-hedgers in the option market and that they sometimes have net purchased option positions. Below we establish that although it is not unusual for market-makers to have net written option positions, they most often have net purchased positions. Hence, the Avellaneda and Lipkin (2003) model of hedge re-balancing is capable of explaining stock price clustering at option strike prices. In our empirical analysis below, we also make use of the fact that the model predicts de-clustering at strike prices when likely delta-hedgers have net written option positions.

4.2. Delta-hedging of changes in option positions

Investors who delta-hedge their net option positions will buy and sell the underlying stock not only to re-balance when the deltas of their existing options change as discussed above, but also to establish or remove hedges when they open or close option positions. This fact may lead to clustering through the following mechanism suggested in Anders (1982). Suppose that some non-trivial portion of non-delta-hedging (e.g., public) option investors do not like to exercise and take delivery of shares if their purchased call options expire in-the-money (ITM). These customers will then sell their ITM purchased calls in the days leading up to expiration. However, for those calls close to the money, it is not clear until expiration Friday whether they will expire ITM. For these calls, the non-delta-hedging investors wait until expiration Friday and sell if the stock price is above the strike price. When the non-delta-hedging option customers sell their calls, they are typically purchased by market-makers who delta-hedge the increase in their call position by selling stock. The stock sale tends to push the stock price down toward the strike price. Analogously, if non-delta-hedging investors do not like to deliver shares, then on expiration Fridays they will sell their purchased slightly ITM puts to market-makers who will delta-hedge the increase in their put position by buying stock. The stock buying will push the stock price upward toward the strike price.

In addition to the specific mechanism just described, there may be other option market practices that result in likely delta-hedgers buying calls (or selling puts) when the stock price is slightly above the strike price on expiration Fridays or buying puts (or selling calls) when the stock price is slightly below the strike price on expiration Fridays. Consequently, below we test for a relation between clustering and these changes in the option positions of likely delta-hedgers.

4.3. Stock trading by non-delta-hedging option investors

Investors who do not delta-hedge still sometimes enter into stock positions in combination with option positions. If these investors unwind these combined positions on expiration Fridays, then their transactions in the underlying stock may contribute to the clustering.[24] Two common positions are covered calls, which are written call positions combined with long stock positions, and protective puts, which are purchased put positions combined with long stock positions. Investors may be more likely to unwind OTM covered calls or protective puts. The reason is that when the options finish ITM the stock can just be delivered to the counter-party upon assignment (in the case of a covered call) or exercise (in the case of a protective put.) If the options finish OTM, on the other hand, then the investor is left with a naked stock position over the weekend if he does not sell his long stock position on expiration Friday. Since the unwinding of covered calls and protective puts by non-delta-hedgers both involve selling stock, it has the potential to push the stock price downward and thereby contribute to clustering when close to expiration the stock price is above the strike price.

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[24] Unwinding these positions also involves buying or selling options to market-makers who will generally transact in the underlying stock to delta-hedge the changes in their option positions. This delta-hedging by the market-makers will be accounted for in the empirical work via the changes in the option positions of likely delta-hedgers (which was discussed in the previous subsection.)

Consequently, in the empirical tests below, we check whether the clustering is positively related to the purchased OTM put and written OTM call open interest of investors who are relatively less likely to be delta-hedging their option positions when shortly before expiration the stock price is greater than the nearest strike price.

4.4. Option investor manipulation of underlying stock prices

If the option market is populated by sophisticated and unsophisticated investors, then stock price manipulation by a subset of the sophisticated investors is another possible explanation for the greater propensity of optionable stocks to close on or near strike prices at expiration dates. Suppose that sophisticated traders have the resources to manipulate underlying stock prices and that at expiration unsophisticated investors follow the simple rule of exercising their purchased options when the closing stock price on expiration Friday indicates that the option is ITM. In this case, sophisticated option writers have an incentive to manipulate underlying stock prices so that unsophisticated option buyers do not exercise their options. In particular, sophisticated option writers have an incentive to manipulate underlying stock prices so that ITM options become OTM and OTM options are prevented from becoming ITM. When a sophisticated option writer prevents exercise through such manipulation, he avoids a liability equal to the (absolute) difference between the unmanipulated underlying stock price and the strike price.

Of course, some option buyers will be drawn from the pool of sophisticated option market participants. They might recognize that other sophisticated option market participants with written options sometimes manipulate the underlying stock price and may exercise their positions even if they are not ITM according to the closing price of the underlying stock. Although this would lessen the incentive to manipulate, it would not eliminate it provided that some option buyers are unsophisticated.[25] Further, even if sophisticated option buyers are aware that underlying stock prices are sometimes manipulated, they will not know with certainty whether manipulation occurred in

[25] Some option writers will be drawn from the pool of unsophisticated investors. They will not manipulate underlying stock prices, and their existence does not alter the incentive that sophisticated option writers have to manipulate.

particular cases, so they will still sometimes fail to exercise options when manipulation has actually occurred.[26]

Finally, since artificially moving or constraining stock prices is costly, sophisticated option writers have no further incentive to manipulate once an initially ITM option becomes OTM or when an OTM option is not just about to become ITM. Thus, stock price manipulation by option traders with written positions will tend to increase the frequency with which optionable stock prices close on or near strike prices on expiration dates.

While it might seem that traders with purchased option positions would have similar incentives to manipulate the prices of underlying stocks leading up to expiration, they do not. Suppose a sophisticated trader who has purchased a call manipulates the stock price upward so that exercise seems optimal. If he then exercises the call on the expiration date, he will receive shares of overpriced stock. These shares may well be difficult to sell at their inflated value, reducing or eliminating the apparent profit. Likewise, if a sophisticated trader who has purchased a put manipulates the stock price downward and then exercises the put, he will deliver shares of undervalued stock. The fact that the delivered shares are undervalued will also reduce or eliminate the apparent profit.[27] Written and purchased option positions do not provide symmetric incentives to manipulate the underlying stock price, because the sophisticated option writer gains when an unsophisticated purchaser is "tricked" into making an exercise decision based upon the manipulated price; an option purchaser cannot profit by tricking himself into making an incorrect exercise decision.[28]

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[26] It should also be noted that if non-manipulating sophisticated investors could identify manipulation with a high degree of accuracy, they might choose to bet against it directly in the stock market. However, given the difficulty that non-manipulating investors would face in identifying manipulation with confidence, it would not be surprising if such betting does not occur.

[27] This argument that a trader who has purchased options cannot benefit from manipulating the price of the underlying asset does not apply to cash-settled index options. Of course, manipulating a stock index is likely to be more difficult than manipulating the price of an individual stock.

[28] Even if investors with purchased option positions do engage in manipulation, they would have no reason to stop manipulating the stock price once the option becomes ITM. Consequently, their manipulation would not produce strike price clustering. Manipulators with written option positions, on the other hand, will stop manipulating once the option is more than slightly OTM, because manipulating is costly and they receive no additional benefits as the option goes further OTM.

It is also worth noting that the argument above implies that any stock position held by option traders, for example a “delta-hedge,” will not affect the incentives to manipulate created by the existence of written option positions. Any apparent gain or loss on the stock position from the manipulation will reverse when the stock price reverts to its non-manipulated level.

Of course, the fact that option market participants have incentives to manipulate the prices of the underlying stocks does not imply that they do so. There are also costs to manipulating, including the cost of artificially moving or constraining the stock price and the possibility of penalties if the manipulation is detected. A trader contemplating manipulation must assess whether the benefit is likely to exceed the cost. The benefit will be increasing in the size of the short option position, while the cost of the manipulation is not directly related to the size of the option holdings. This fact suggests that traders who undertake larger option positions are more likely candidates for manipulating the underlying stock price at expiration.

Evidence that investors manipulate prices in two other contexts lends plausibility to the notion that investors in exchange traded options may manipulate underlying stock prices at expiration dates. First, Carhart, Kaniel, Musto, and Reed (2002) provide evidence that mutual fund managers manipulate the prices of the stocks in their portfolios on the last days of quarters and years in order to obtain top rankings and benefit from the resulting inflow of investments. It seems at least as likely that option traders or option trading desks would manipulate stock prices, because stock price manipulation produces immediate profits for option investors. The benefits to mutual fund management companies, by contrast, are delayed until after future increased investment flows into funds. In addition, the benefit to mutual fund managers is attenuated by the fact that increasing returns in one period through stock price manipulation comes at the cost of reducing returns in the next period. Second, in late November 1994 a hedge fund operated by well-known fund manager Michael Steinhardt bought from Merrill Lynch $500 million of “knock in” put options on Venezuelan Brady bonds that expired in early January. By early December there was open warfare between the hedge fund that was trying to drive the price of the underlying bonds up to the knock-in level and Merrill Lynch, which was trying to keep the price of the bonds below the knock-in level. On December 9 as much as $1.5 billion of the $6.5 billion of face value outstanding changed hands.

The head of emerging-market debt trading at a big European bank remarked "nobody could have imagined the amount of money" that each side would spend to muscle the market in its favor. (Sesit and Jereski, 1995) Although the market for listed equity options is clearly different along a number of dimensions than the over-the-counter market for barrier options on Brady bonds, this incident lends credence to the idea that traders of exchange listed options may engage in stock price manipulation.

5. Evidence on potential explanations for clustering

In order to provide an empirical assessment of the potential explanations, we need to separate cases where there is more delta-hedging of options on an underlying stock by investors with purchased options from those where there is more delta-hedging by investors with written options. Although the numbers of purchased and written option positions on an underlying stock are necessarily identical, certain types of investors are more likely than others to delta-hedge. Avellaneda and Lipkin (2003) maintain that the clustering in their model would be produced by option market-makers with net purchased option positions. Cox and Rubinstein (1985) likewise contend that market-makers are the option market participants who are most likely to delta-hedge their net option positions on underlying stocks. They write:

> … many Market Makers attempt to adhere quite strictly to a delta-neutral strategy. However, a delta-neutral strategy usually requires relatively frequent trading. As a result, it is not advisable as a consistent practice for investors with significant transaction costs. While public investors fall into this category, Market Makers do not. (p. 308)

Hull (2000, pp. 307, 319) similarly maintains that market-makers and firm proprietary traders but not public customers are likely to delta-hedge their net option positions. He explains that delta-hedging is relatively more attractive to investors who hold large portfolios of options on an underlying stock. These investors can delta-hedge their entire portfolios with a single transaction in the underlying stock and thereby offset the hedging cost with the profits from many option trades. Delta-hedging by investors who hold only a small number of options on an underlying asset, on the other hand, is extremely expensive. McDonald (2003) devotes an entire chapter of his textbook to "Market-

Making and Delta-Hedging." Based on the widely held view that non-public investors are the predominant delta-hedgers in the option market, we assume either that delta-hedging is concentrated in the market-makers or that it is concentrated in the market-makers plus firm proprietary traders. The results of the test conducted below are quite similar regardless of which assumption is made. Consequently, for brevity, we report results only for tests that assume delta-hedging is concentrated in the market-makers.

5.1. Clustering and net purchased or written positions of likely delta-hedgers

The implications of hedge re-balancing for expiration date clustering at strike prices depend crucially upon the net option position of market participants who delta-hedge with the underlying stock. When delta-hedgers have net purchased positions in the expiring options of an underlying stock with a particular strike price, hedge re-balancing will push the stock price toward the strike price and thereby tend to produce clustering. When delta-hedgers have net written option positions, on the other hand, hedge re-balancing will push the stock price away from the strike price and thereby tend to produce de-clustering (i.e., lower probabilities of closing near the strike price.)

Based on the assumption that market-makers are the predominant delta-hedgers in the option market, Figure 6 uses the CBOE open interest data to investigate the extent to which clustering depends on the net option position of market-makers from January 1996 to December 2001. The CBOE data contain the total purchased and written open interest for all non-market makers on every CBOE traded option on every trade date.[29] We obtain market-maker net open interest for an underlying stock-trade date from these data in the following way. First, we compute non-market-maker net open interest as non-market-maker purchased open interest in the closest to expiration call and put with strike price nearest to the trade date's closing stock price minus non-market-maker written open interest in these options. We then set the market-maker net open interest to the negative of the non-market-maker net open interest. When this quantity is positive on a trade date for an underlying stock, the stock-trade date is classified as one on which market-makers have net

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[29] The public customer and firm proprietary traders together constitute all non-market-makers. Recall that when CBOE listed options also trade at other markets, the open interest data reflect the positions across all markets.

purchased open interest. When the quantity is negative the stock-trade date is classified as one on which market-makers have net written open interest. Market-makers have net purchased open interest on 62% of the stock-trade date pairs and net written open interest on 38% of the stock-trade date pairs.

Panel A of Figure 6 shows the percentage of optionable stocks closing within $0.125 of a strike price as a function of the number of trade dates before or after option expiration when market-makers have a net purchased position in the closest-to-expiration options on an underlying stock with strike price nearest to the closing stock price. This plot has two important features. First, the spike at trade date zero is very pronounced. It is nearly 2 percent higher than on the non-expiration dates, which is about double the size of the spike when there is no conditioning on whether the market-makers have net written or purchased option positions (i.e., Panel B of Figure 1.) Second, the percentages before expiration are larger than those after expiration.[30] That is, there is elevated clustering leading up to the expiration date. Consequently, the evidence in Panel A of Figure 6 is consistent with the hedge re-balancing explanation which predicts that when delta-hedgers have net purchased option positions clustering will be elevated leading up to expiration and will peak at expiration. It should be noted, however, that since some of the other explanations considered in the previous section predict increased clustering right at expiration, the evidence is also consistent with hedge re-balancing plus one or more of the other mechanisms producing the expiration date clustering.

Panel B of Figure 6 is like Panel A except that it is constructed from stock-trade date pairs for which option market-makers have a net written (rather than a net purchased) position in the closest to expiration options on an underlying stock with strike price nearest to the closing stock price. This plot also has two important features. First, although there is still a spike on the expiration date, it is now less pronounced than when there is no conditioning on the market-maker net option position (i.e., Figure B of Panel 1). Second, the percentages before expiration are now lower than those after

[30] A binomial test shows that the difference in percentages between the three trade dates before expiration (i.e., dates –3 to –1) and the three trade dates after expiration (i.e., dates +1 to +3) is highly significant with a *p*-value of less than 0.000001.

expiration.[31] That is, there is de-clustering leading up to the expiration date. Neither hedge re-balancing nor any of the other explanations in isolation can account for both of the features of this plot. The hedge re-balancing explanation predicts the de-clustering leading up to the expiration date but cannot explain the positive spike at expiration. Indeed, the hedge re-balancing explanation predicts that de-clustering should be most conspicuous at expiration. The other explanations can account for the spike at expiration, but do not predict de-clustering leading up to expiration. It seems that the expiration date clustering is produced by hedge re-balancing combined with at least one of the other potential explanations.[32]

5.2. Logistic regressions

We now perform logistic regressions to investigate further the contributions of the potential explanations to the expiration date clustering. We use a fixed-effects logistic regression model with a dependent variable that is set to one when the underlying stock price closes within $0.125 of an option strike price, and otherwise is set to zero.[33] The unit of observation in the regressions is a stock-expiration Friday pair, e.g., Microsoft on Friday, September 21, 2001. Observations that meet the following conditions are included: (1) the stock has strictly positive closing prices on both the expiration Friday and the preceding Thursday;[34] (2) the distance between the Thursday closing stock price and the strike price nearest the Friday closing stock price is less than $10; and (3) the CBOE data include written open interest (which may be zero) for both the firm proprietary traders and the

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[31] Once again, a binomial test shows that the difference in percentages between the three trade dates before expiration (i.e., dates –3 to –1) and three trade dates after expiration (i.e., dates +1 to +3) is highly significant with a *p*-value of less than 0.000001.

[32] We believe that the main features of Figure 6 do not result from error in our measure of delta-hedger's net option positions, because we obtain a similar figure if we assume that market-makers plus firm proprietary traders (rather than market-makers alone) are the predominant delta-hedgers in the option market. Hedge funds are another group of investors who may tend to delta-hedge their net option positions. Our data do not allow us to separate out the purchased and written option positions of hedge funds. Nonetheless, given that our results are robust to using either market-makers alone or market-makers combined with firm proprietary traders as the assumed delta-hedgers, we doubt that including hedge funds as well would make much of a difference. Even if there is non-trivial noise in our proxy for the delta-hedgers, it is difficult to see how one could account for the evidence in the figure without appealing to both hedge re-balancing and at least one other explanation.

[33] We also performed the logistic analysis with pooling and with random effects. The results were similar to those reported below.

[34] Here and throughout the discussion of the logistic regressions, "Thursday" and "Friday" always refer to the Thursday and Friday of expiration week.

public customers. There are observations on 2,585 different stocks and 75,690 stock-expiration Friday pairs in the period from January 1996 through December 2001 that satisfy these conditions.

The first independent variable measures clustering pressure from the hedge re-balancing activities of likely delta-hedgers. We again assume that market-makers are the primary delta-hedgers in the option market, and set the first independent variable to the *market-maker net purchased open interest*. This variable is computed from the open interest data at the close of trading on Thursday in the expiring put and call whose strike prices are nearest to the Thursday closing stock price.[35] As in the previous subsection, we compute the market-maker net purchased open interest by using the fact that it is equal to the negative of the non-market-maker net purchased open interest. The hedge re-balancing explanation predicts a positive coefficient on this variable.

The next variable measures clustering pressure from the delta-hedging of changes in option positions (as opposed to delta-hedging that results from the changing deltas of existing option positions.) That is, it measures delta-hedging of changes in market-maker option positions which requires selling stock on Friday when the stock price is greater than the strike price or buying stock on Friday when the stock price is less than the strike price:

$$New\ delta\ hedging \equiv sign\left(S_{Thur} - K\right) \times (DeltaAdjChgOI_{Call}^{MM} + DeltaAdjChgOI_{Put}^{MM})\,. \tag{8}$$

In this expression, $sign\left(S_{Thur} - K\right)$ takes the values +1, 0 and -1 when the Thursday closing stock price is, respectively, greater than, equal to, or less than the nearest strike price. $DeltaAdjChgOI_{Call}^{MM}$ is the delta-adjusted Thursday to Friday change in net market-maker open interest aggregated across all calls on the underlying stock, and $DeltaAdjChgOI_{Put}^{MM}$ is a similar variable for the puts on the

[35] If there is a large stock price change on Friday the option strike price nearest the Thursday closing stock price may no longer be the strike price nearest the intra-day stock price on Friday, and net purchased open interest at the strike price nearest the Thursday closing stock price may not be the best measure of the potential effect of hedge re-balancing. A separate issue is that when $S_{Thurs} = K$ clustering pressure from delta-hedging changes in option positions may be negative, but the expression in equation (8) below treats it as zero. We address these issues by re-estimating the regressions including only those observations for which: (4) the option strike price closest to the stock's closing prices is the same on both Thursday and Friday; and (5) the Thursday stock closing price is not equal to a strike price. There are observations on 2,236 different stocks and 62,121 stock-expiration Friday pairs in the period from January 1996 through December 2001 that satisfy these conditions in addition to (1)–(3) above. Re-estimating the logistic regressions with this smaller sample results in coefficient estimates that are similar in magnitude and significance to those reported below.

underlying stock. In order to understand how this variable measures clustering pressure from delta-hedging of new option positions, consider the situation where the Thursday closing stock price is greater than the nearest strike price. In this case, $sign\left(S_{Thur}-K\right)$ is equal to +1. Since increases (decreases) in net long call positions are delta-hedged by selling (buying) stock, increases (decreases) will lead to hedging which pushes the stock price toward (away from) the strike price. For this reason, the changes in call net open interest enter positively. Analogous considerations for puts indicate that the $DeltaAdjChgOI_{Put}^{MM}$ variable should also enter the expression with a positive sign. A positive coefficient on the *new delta hedging* variable indicates that delta-hedging of changes in option positions contributes to the clustering.

The third independent variable measures the unwinding by non-delta-hedgers of positions that combine options and the underlying stock. As discussed in Subsection 4.3, non-delta-hedger unwinding of OTM covered call and OTM protective puts will tend to push the stock price toward the strike price when the stock price is greater than the strike price. For this reason we define a covered call and protective put unwinding variable by

$$\begin{aligned} Covered\ call\ and\ protective\ put\ unwinding \equiv I\left(S_{Thur}-K\right)\times\Big[&OTMPurchasedOI_{Put}^{Firm+Public} \\ &+OTMWrittenOI_{Call}^{Firm+Public}\Big], \end{aligned} \tag{9}$$

where $I\left(S_{Thur}-K\right)=1$ if the Thursday closing stock price is greater than the strike price nearest the Thursday closing stock price, and $I\left(S_{Thur}-K\right)=0$ otherwise. The variable $OTMPurchasedOI_{Put}^{Firm+Public}$ is the purchased open interest of expiring OTM puts at the close on Thursday by firm proprietary traders and public customers, while $OTMWrittenOI_{Call}^{Firm+Public}$ is the written open interest of expiring OTM calls at the close on Thursday by firm proprietary traders and public customers. Although it is possible that stock activity related to non-delta-hedgers unwinding combined option positions other than covered calls or protective puts could be in the right direction to induce clustering, we doubt that it would have a meaningful impact on the results if unwinding related to covered calls and protective puts is not important.[36]

Two sets of independent variables are included to provide evidence on whether the clustering is related to attempts by either the firm proprietary traders or the public customers to manipulate underlying stock prices on expiration Friday so that their written option positions finish OTM. First, we include the option volume that opens new written positions on the Tuesday through Thursday leading up to expiration for both firm proprietary traders and public customers. As we explain below, we do not include expiration Friday volume, because doing so would introduce an endogeneity problem. The second set of independent variables consists of the written open interest for firm proprietary traders and public customers at the close of trading on Thursday. Both of these sets of variables are constructed only from the currently expiring call and put with strike price nearest to the Thursday closing stock price. These variables provide measures of either the possible intention or the incentive of the different investor types to engage in stock price manipulation. That is, investors who intend to manipulate stock prices at expiration would be inclined to write options in the days leading up to expiration, while investors with larger written option open interest have a larger incentive to manipulate the stock price at expiration regardless of the original motivations for entering into those positions. If stock price manipulation contributes to the stock price clustering, then we would expect a positive relation between the clustering and the option writing volume or open interest of investors who have the resources and knowledge necessary to manipulate stock prices. Firm proprietary traders are the most likely candidates for manipulating stock prices, because they have both the ability to enter into sizeable written option positions for which the benefit to manipulation is large and the wherewithal to manipulate the prices of the underlying stocks. Although market-makers have the resources and knowledge to manipulate stock prices, they are unlikely to do so because their trading in underlying stocks is carefully monitored.[37]

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[36] In results that are not reported, we included a measure of total open interest to control for unwinding of other combined stock and option positions by non-delta-hedgers. The coefficient on the control variable was insignificant and its inclusion had little impact on the magnitudes or significance of the coefficient estimates on any of the other variables.

[37] Cox and Rubinstein (1985, p. 89) argue that market-makers are unlikely to manipulate stock prices at expiration in order to make options expire OTM, because their trading in underlying stocks is monitored by exchange officials on a daily basis.

The final independent variable measures the (absolute) distance between the Thursday closing stock price and the strike price nearest the Friday closing stock price. It is included to control for the fact that the stock price is more likely to close on or near an option strike price on an expiration Friday if it closed near that strike price on the preceding trade date. It is crucial to include this control, because option market activity in short-term options may be higher when the stock price is close to the option strike price. Consider the open written volume variables that are included to measure stock price manipulation. It is plausible that trading volume in expiring options is higher on Friday when the stock price is closer to the option strike price (and thus trading volume is likely to be positively correlated with the probability that the stock price closes on or near an option strike price) even if no traders are manipulating the stock price. Because the control variable consists of the distance between the Thursday closing stock price and the option strike price closest to the Friday closing stock price, it will not control for the fact that Friday's volume in the currently expiring option may be higher when the intra-day stock price is closer to the option strike price. For this reason, we do not include volume from the expiration Friday in our variables that measure option trading volume from transactions that open new written option positions. This is also the reason that the market-maker net purchased open interest, the covered call and protective put unwinding, and the written open interest variables are all constructed from open interest at the close of trading on Thursday.

Table 1 reports summary statistics for the independent variables. The first column of numbers in Table 2 reports the logistic regression results under the assumption that market-makers are the predominant delta-hedgers in the option market. Standard errors are included in parentheses below the point estimates.

Three variables have coefficient estimates that are significant at the one percent level. (And no other variable is significantly different from zero at even the five percent level.) First, as expected, the variable which measures the absolute distance between the Thursday closing stock price and the strike price nearest the expiration Friday closing stock price is significantly negative. The negative sign indicates that it is more likely that the stock price closes on or near an option strike price on the expiration Friday when the distance between the Thursday closing stock price and the strike price is smaller. Second, consistent with the hedge re-balancing explanation (and Figure 6) the coefficient on market-maker net purchased open interest is positive and significant. Third, the coefficient on the firm proprietary trader option volume that opens new written option positions on Tuesday through Thursday of expiration week is significantly positive. This positive and significant coefficient estimate is consistent with the firm proprietary traders opening written option positions with less than one week to expiration and then manipulating the underlying stock price to ensure that the options expire OTM.

It is not surprising that we find evidence of stock price manipulation in the firm proprietary trader open written volume but not in their written open interest. After all, it is not obvious what other than the manipulative strategy would motivate the firm proprietary traders to write very many new options during expiration week.[38] Consequently, the signal about manipulation from firm proprietary traders establishing new written option positions during expiration week has the potential to be relatively strong. Firm proprietary trader written open interest on the Thursday of expiration week, on the other hand, is more reflective of the full range of reasons that firm proprietary traders write options. Consequently, it is likely to provide a relatively weaker signal about manipulation. Put differently, if only a subset of firm proprietary traders engage in the manipulation, then we would expect their share of new written option volume during expiration week to be larger than their share of written open interest. In the next subsection of the paper, we present further evidence that firm proprietary traders who write new option positions during expiration week subsequently manipulate the underlying stock price so that the options finish OTM.

Turning to the remaining variables, there is no evidence that delta-hedging of changes in option positions or unwinding of combined stock and option positions by non-delta-hedgers contributes to the clustering. The fact that neither the open written volume nor the written open interest for the public customers are significant implies that there is no evidence that stock price manipulation by these investors contributes to the clustering of stock prices at strike prices on

[38] It seems unlikely that firm proprietary traders write the options in order to exploit information that the underlying stock prices will decrease or increase, because this hypothesis does not explain the result that option writing by firm proprietary traders predicts clustering at option strike prices. Further, because the profit potential is limited to the option premia, call and put writing are not the most natural strategies to use to profit from information about the direction of future price movements.

expiration days. We also estimated specifications in which the open written volumes and written open interest of three sub-groups of public customers (customers of discount brokers, customers of firm-proprietary traders, and other public customers) were included separately. The estimated coefficients on these variables were not significantly different from zero at conventional levels, and the estimated coefficients on the other variables were similar to those reported in Table 2.

If the open written volume of the firm proprietary traders were the only independent variable in the regressions, then a positive coefficient estimate could be interpreted either as evidence that they manipulate stock prices or that they write options during expiration week in order to exploit clustering caused by other mechanisms, for example, hedge re-balancing. Since there are independent variables that control for other potential causes of the clustering, stock price manipulation by firm proprietary traders appears to be the appropriate interpretation of the positive coefficient estimate. Of course, the controls for other potential causes may be imperfect. As a check, the final column of Table 2 reports regression results when market-maker net long open interest (the variable which measures clustering pressure from hedge re-balancing) is removed. We also remove public customer written open interest, because it is highly correlated with market-maker net long open interest.[39] The magnitude and significance of the coefficient estimate for firm proprietary trader open written volume is nearly identical in these regressions. If firm proprietary traders were merely trading on knowledge of clustering caused by other factors (and not manipulating the stock price themselves), then we would expect (counterfactually) that the magnitude and significance of the coefficient would increase when a measure for one of the other important factors is removed.[40]

5.3. Further evidence on manipulation by firm proprietary traders

Subsection 5.1 demonstrates that hedge re-balancing by likely delta-hedgers and at least one other mechanism produce the clustering of optionable stocks at strike prices on expiration dates. The

[39] Firm proprietary traders are a much smaller part of the market than public customers. For this reason firm proprietary trader written open interest is not highly correlated with market-maker net purchased open interest, and we leave firm proprietary trader written open interest in the regression. Removing it, however, leads to the same conclusions.

[40] In unreported results, we re-ran the regressions from Table 2 under the assumption that market-makers plus firm proprietary traders are the predominant delta-hedgers in the option market. All of the main features of the regressions were also observed under this alternative assumption.

logistic regressions presented in the previous subsection indicate that only one other mechanism contributes to the clustering, namely, stock price manipulation by firm proprietary traders who write new options in the week leading up to expiration. We now provide further evidence on the hypothesis that firm proprietary traders who write options in the week leading up to expiration manipulate the prices of underlying stocks so that their written options expire OTM.

If the firm proprietary traders engage in such behavior, then the expiring options they write during expiration week should be profitable if held until expiration. We check their profitability by estimating the total premia that firm proprietary traders receive from writing expiring options and the total liability they would face if those written option positions were held until expiration. We estimate the total premia under the assumption that each written option is sold at the option's daily closing bid price, and compute the liability at expiration by $\max\left[0, \text{Friday Closing Stock Price } - K\right]$ for calls and $\max\left[0, K - \text{Friday Closing Stock Price}\right]$ for puts. There are three reasons that the use of closing option bid prices results in a conservative estimate of the premia received, and thus a conservative estimate of the profitability of the option writing. First, time decay of option values tends to make the closing option prices lower than the prices of the same options earlier in the day. Second, the (unknown to us) underlying stock price at the time the option is written is approximately symmetrically distributed about the closing stock price. This symmetric distribution, combined with the convexity of option values in underlying stock prices, makes the closing option prices downward-biased estimates of the prices at which the options were actually sold. This convexity effect and the time decay effect are both particularly strong for at- and close-to-the-money options with only a few days to expiration. Third, the use of bid prices results in a conservative estimate of the premia received to the extent that firm proprietary traders are skillful at transacting inside the bid-ask spread. An offsetting factor that tends to make the estimate based on bid prices less conservative is that sizable options trades will likely have some market impact.

The estimate of the total premia received by firm proprietary traders for options written on the Tuesday through Thursday of expiration weeks over the January 1996 through December 2001 period is \$118.8 million while the liability faced is only \$46.4 million. Not only do the firm proprietary traders take in about 2.6 times more in premia than they would have to pay out at expiration a few days later, but they also profit quite consistently. On 67 of the 72 expiration weeks, the premia exceeds the pay out.

Subsection 5.2 discussed the possibility that firm proprietary traders write options during expiration week in order to take advantage of strike price clustering caused by market-makers re-balancing their delta-hedges, and presented logistic regression results showing that option-writing by firm proprietary traders helps to explain strike price clustering even when the regression specification includes variables to control for the magnitude of hedge re-balancing. We provide further evidence that firm proprietary traders are not simply taking advantage of clustering caused by hedge rebalancing by re-computing premia and liabilities separately for stock-expiration date pairs where at the Thursday close of expiration week market-makers have net purchased or net written positions in expiring options with strike price closest to the underlying stock price. If the high profitability of option writing by firm proprietary traders during the expiration week comes about because they exploit knowledge of the hedge re-balancing effect, then the option writing should be more profitable when market makers have net purchased positions. When market-makers have net purchased option positions the premia is 2.5 times as great as the liabilities, while when they have net written positions the premia is 2.7 times as great. Since the profitability is greater when market-makers have net written rather than net purchased positions, it is unlikely that the profitability comes from firm proprietary traders taking advantage of clustering that results from market-makers with net purchased option positions re-balancing their delta-hedges.[41]

We next test another implication of stock price manipulation by firm proprietary traders who write new options during expiration week. The analysis of Avellaneda and Lipkin summarized in Subsection 4.1 implies that when delta-hedging option investors have net purchased (written) option positions, their stock market trading pushes stock prices toward (away from) strike prices at option expiration. It also shows that for a given net option position the attraction to (or repulsion from) a strike price is of equal intensity regardless of whether the stock price is a given distance above or

[41] The results are similar when stock-expiration date pairs are divided into net purchased or net written according to the option holdings of market-makers plus firm proprietary traders. Although the fact that the option writing of firm proprietary traders in the week leading up to expiration is quite profitable is another piece of evidence that they manipulate stock prices in order to make their written option positions more valuable, a caveat is in order: it is not clear how to benchmark the profitability of these written option positions.

below the strike price and regardless of the composition of long and short puts and calls that constitute the net option position. The stock price manipulation mechanism, on the other hand, implies an asymmetry depending upon whether the manipulators write calls or puts. In particular, when a manipulator writes calls, he will push the stock price downward to get it (or keep it) below the strike price. He will not, however, manipulate the stock price upward. Similarly, when a manipulator writes puts, he will push the stock price upward to get it (or keep it) above the strike price but will not manipulate the stock price downward.

The fact that the hedge re-balancing mechanism has symmetric implications for stock price changes and the manipulation mechanism has asymmetric implications can be used to test whether manipulation contributes to the clustering. In particular, we compute the difference in the probability that a stock price that closes above the nearest strike price on the Thursday of expiration week closes just below the strike price on the Friday of expiration week (i.e., at expiration) and the probability that a stock price that closes below the nearest strike price on the Thursday of expiration week closes just above the strike price on the Friday of expiration week. Specifically, we compute the quantity

$$P\left\{S_{Fri} \in \left[K-0.125, K\right] \middle\| S_{Thurs} > K\right\} - P\left\{S_{Fri} \in \left[K, K+0.125\right] \middle\| S_{Thurs} < K\right\}. \qquad (10)$$

According to the hedge re-balancing mechanism, this quantity will be unrelated to firm proprietary traders writing calls or puts in the week leading up to expiration, because any change in the net option positions of delta-hedgers that results from such option writing will impact both probability terms in expression (10) equally. According to the manipulation mechanism, however, expression (10) will be larger when manipulators write calls and smaller when they write puts. To see why, consider the case where a manipulator writes calls. If the stock price closes above the strike price on Thursday, then the manipulator will push the stock price down on Friday so that his written calls finish OTM. This manipulation will increase the value of expression (10) by increasing the first probability. If, on the other hand, the stock price closes below the strike price on Thursday, then the manipulator will prevent the stock price from rising above the strike price on Friday which will also increase the value of expression (10) by decreasing the second probability (which enters with a negative sign.) Similar considerations show that expression (10) will tend to be smaller when manipulators write puts.

We compute the value of expression (10) by replacing the probabilities with their sample frequencies. When firm proprietary traders write neither calls nor puts on the Tuesday through Thursday of expiration week, the estimate of expression (10) is 0.014. When firm proprietary traders write calls but not puts on the Tuesday through Thursday of expiration week, the estimate of expression (10) is 0.030 which (as predicted by the stock price manipulation hypothesis) is greater than the value when firm proprietary trader write neither calls nor puts. Using a binomial test, the difference is significant at the 5 percent level. Finally, when firm proprietary traders write puts but not calls on the Tuesday through Thursday of expiration week, the estimate of expression (10) is -0.012, which is less than the value when the firm proprietary traders write neither calls nor puts. This difference is also in accordance with the stock price manipulation hypothesis and significant at the 5 percent level.

These results about asymmetric stock price movements that differ depending on whether firm proprietary traders have written calls or puts are also consistent with the hypothesis that firm proprietary traders possess information that the underlying stock prices will decrease or increase, respectively, and write options in order to profit from such information. However, this hypothesis that firm proprietary traders write options to exploit simple directional information does not explain the result in subsection 5.2 that option writing by firm proprietary traders predicts clustering at option strike prices. Further, because the profit potential is limited to the option premia, call and put writing are not the most natural strategies to use to profit from simple directional information.

6. Conclusion

Despite substantial interest and concern that the trading of listed equity options would alter the prices of underlying stocks, to date there has been little indication of any significant impact. This paper provides striking evidence that the presence of options perturbs the prices of underlying stocks. In particular, we show that over the 1996-2002 period optionable stocks had a greater propensity to cluster around strike prices on option expiration dates than on other trade dates. This result is clearly associated with option expiration. There is no such clustering for optionable stocks on non-expiration Fridays or for the universe of non-optionable stocks. Nor is clustering present for non-optionable stocks that later become optionable or for non-optionable stocks that were once optionable.

We estimate that the returns of optionable stocks are altered by an average of at least 16.5 bps per expiration date and that at least two percent of optionable stocks have their returns changed on a typical expiration date. During our sample period, there are on the order of 2,500 optionable stocks on any given expiration date. Consequently, these estimates imply that if all optionable stocks are impacted 2,500 stocks have their returns changed by 16.5 bps, if half of the optionable stocks are impacted 1,250 have their returns changed by 33 bps, and if the minimum two percent are impacted 50 have their returns changed by 825 bps. Regardless of the percentage impacted, the associated change in the market capitalization of optionable stocks is roughly $9.1 billion per expiration date.

We investigate four possible explanations for the expiration date clustering of optionable stock prices at strike prices. Our tests indicate that delta-hedge re-balancing by investors with net purchased option positions and stock price manipulation by investors who write options in the week leading up to expiration both contribute to the clustering. We find no evidence that the clustering is related to delta-hedging of new option positions or unwinding by non-delta-hedgers of combined stock and option positions.

An interesting question, which we leave for future research, is how effectively the stock price deviations can be predicted from publicly available information prior to expiration Friday. If these predictions can be made with sufficient precision, then it may be possible to devise a trading strategy that exploits the expiration date clustering to produce abnormal profits after trading costs.

Appendix

Proof of Proposition 1. The quantity $\left|\hat{r}_i - r_i\right|$ is always greater than or equal to the quantity $\left|\hat{a}_i - a_i\right|$. Consequently,

$$E\left|\hat{r}_i - r_i\right| \geq E\left|\hat{a}_i - a_i\right|. \tag{A.1}$$

Since $\left|\hat{a}_i - a_i\right|$ is a convex function of the difference $\hat{a}_i - a_i$, Jensen's inequality implies that

$$E\left|\hat{a}_i - a_i\right| \geq \left|E\left(\hat{a}_i\right) - E\left(a_i\right)\right|. \tag{A.2}$$

Combining (A.1) and (A.2) yields the inequality (1). □

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Table 1
Summary statistics

This table provides summary statistics for the independent variables used in the logistic regressions. The data period is January 1996 through December 2001. Stock prices are from OptionMetrics LLC, while the trading volume and open interest for public customers and firm proprietary traders were obtained directly from the CBOE. There is one observation for each underlying stock and option expiration date that meet the following conditions: (1) the stock has a strictly positive closing price on both the expiration Friday and the preceding Thursday; (2) the distance between the Thursday closing stock price and the strike price nearest the expiration Friday closing stock price is less than $10; and (3) written open interest (which may be zero) for the firm proprietary traders and public customers is available in the data set. The net purchased open interest variable is calculated from open interest at the close of trading on the Thursday before expiration. The new delta hedging variable measures potential clustering pressure from delta-hedging of changes in option positions from the close of trading on Thursday to the close of trading on Friday, while the unwinding variables measure potential clustering pressure from the unwinding on Friday of covered calls and protective puts by non-delta hedging investors. The open written volume variables aggregate the daily trading volume of the different groups of investors over the Tuesday through Thursday of the expiration week. The written open interest variables are for the Thursday prior to option expiration. The Thursday stock price distance to strike variable is the absolute value of the difference between the expiration Thursday stock closing price and the strike price nearest to the expiration Friday stock closing price. Except where otherwise indicated, the units are option contracts.

Variable	Mean	Std. Dev.	Min	Max
Market-maker net purchased open interest	222.07	1,265.28	-67,153	51,214
New delta hedging	0.96	911.08	-68,937	86,467
Covered call and protective put unwinding	1,437.75	9,054.53	0	573,482
Firm proprietary trader open written volume	5.78	80.06	0	6,465
Public customer open written volume	28.47	184.43	0	10,830
Firm proprietary trader written open interest	127.38	704.51	0	35,218
Public customer written open interest	877.40	2,864.62	0	112,039
Thursday stock price distance to strike ($)	1.12	1.08	0	10
Number of observations:	75,690			

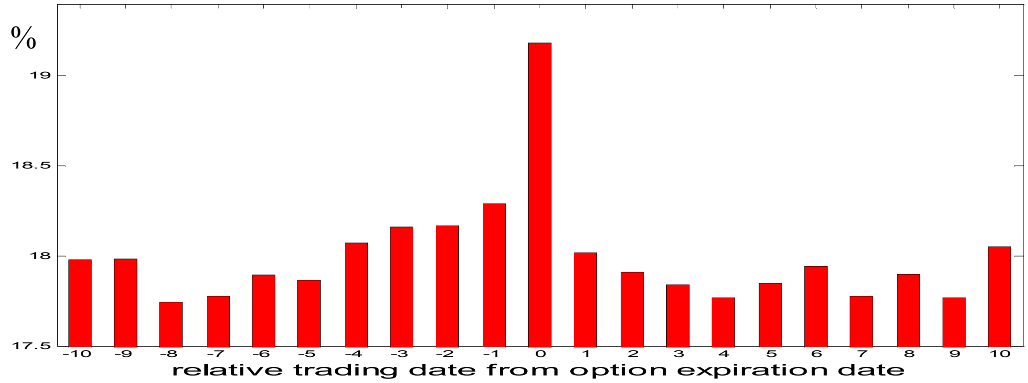
Table 2
Logistic regressions for stocks closing within $0.125 of an option strike price on an expiration Friday assuming that market-makers are the predominant delta-hedgers in the option market

This table reports coefficient estimates and estimated standard errors from logistic regressions with fixed effects in which the dependent variable takes the value one for optionable stock-expiration date pairs in which the stock closes within $0.125 of an option strike price on an expiration Friday, when it is assumed that market-makers are the predominant delta-hedgers in the option market. The numbers reported in the table are the coefficient estimates and estimated standard errors multiplied by 10,000. The data period is January 1996 through December 2001, and there are a total of 75,690 observations. Stock prices are from OptionMetrics LLC, while the trading volume and open interest for public customers and firm proprietary traders were obtained directly from the CBOE. There is one observation for each underlying stock and option expiration date that meet the following conditions: (1) the stock has a strictly positive closing price on both the expiration Friday and the preceding Thursday; (2) the distance between the Thursday closing stock price and the strike price nearest the expiration Friday closing stock price is less than $10; and (3) written open interest (which may be zero) for the firm proprietary traders and public customers is available in the CBOE data. The net purchased open interest variable is calculated from open interest at the close of trading on the Thursday before expiration. The new delta hedging variable measures potential clustering pressure from delta-hedging of changes in option positions from the close of trading on Thursday to the close of trading on Friday, while the unwinding variable measures potential clustering pressure from the unwinding on Friday of covered calls and protective puts by non-delta hedgers. The open written volume variables aggregate the daily trading volume of the two groups of investors over the Tuesday through Thursday of the expiration week. The written open interest variables are for the Thursday prior to option expiration. The Thursday stock price distance to strike variable is the absolute value of the difference between the expiration Thursday stock closing price and the strike price nearest to the expiration Friday stock closing price. Standard errors are provided in parentheses. Statistical significance at 5 and 1 percent levels is indicated by * and **, respectively.

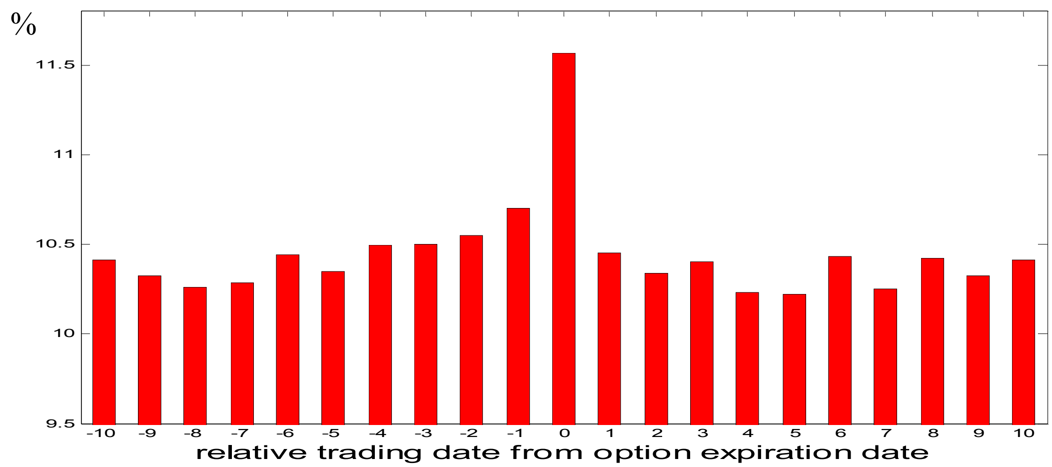
Table 2 – *Continued*

Market-maker net purchased open interest	0.27**	
	(0.11)	
New delta hedging	−0.08	−0.06
	(0.12)	(0.11)
Covered call and protective put unwinding	0.02	0.02
	(0.01)	(0.01)
Firm proprietary trader open written volume	3.15**	3.14**
	(1.26)	(1.26)
Public customer open written volume	−0.83	−0.58
	(0.78)	(0.76)
Firm proprietary trader written open interest	-0.02	0.10
	(0.19)	(0.18)
Public customer written open interest	0.04	
	(0.06)	
Thursday stock price distance to strike	−15346.00**	−15360.00**
	(259)	(259)

Panel A. Percentage of optionable stocks closing within $0.25 of a strike price



Panel B. Percentage of optionable stocks closing within $0.125 of a strike price



Panel C. Percentage of optionable stocks closing on a strike price

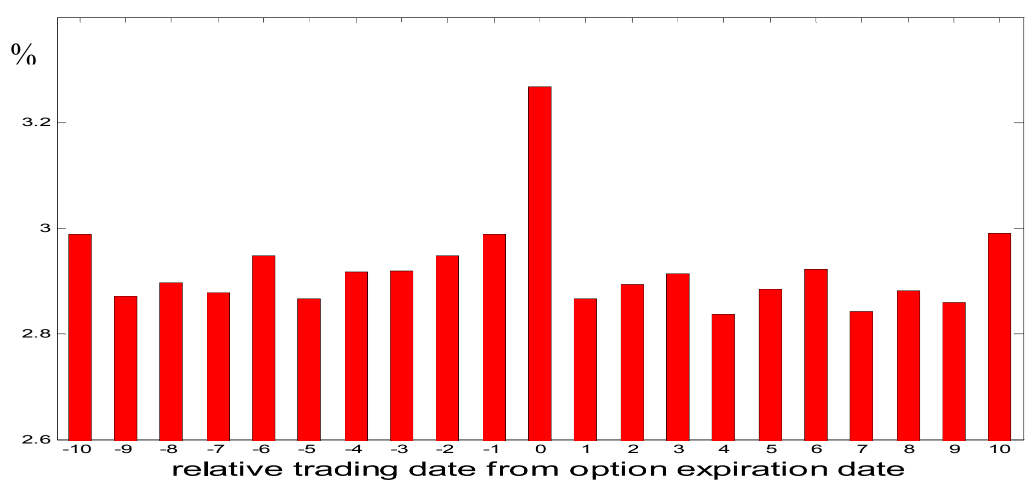
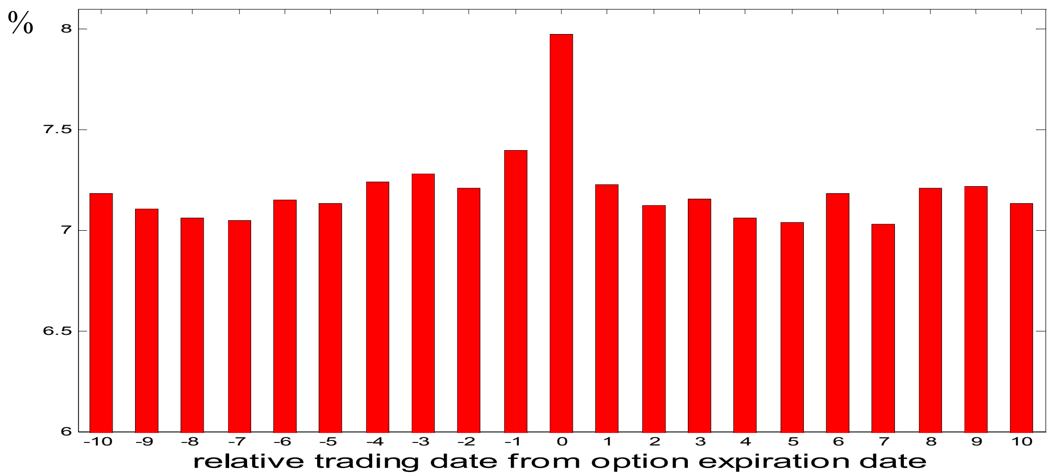


Fig. 1. Percentage of optionable stocks closing various distances from an option strike price. Expiration Fridays are trade date '0' relative to the option expiration date, the Thursdays before are trade date '−1' relative to the option expiration date, the Mondays after are trade date '1' relative to the option expiration date, etc. For each trade date relative to the expiration date, the plots give the percentage of stocks that close within a specified distance from a strike price of an option listed on the stocks. Panel A shows the percentage of optionable stocks that close less than or equal to $0.25 from a strike price of an option listed on the stocks. Panel B shows the percentage of optionable stocks that close less than or equal to $0.125 from a strike price of an option listed on the stocks. Panel C shows the percentage of optionable stocks that close on a strike price of an option listed on the stocks. The data period covers the 80 option expirations from January 1996 through August 2002.

Panel A. Percentage of optionable stocks closing within $0.125 of an integer multiple of $5



Panel B. Percentage of non-optionable stocks closing within $0.125 of an integer multiple of $5

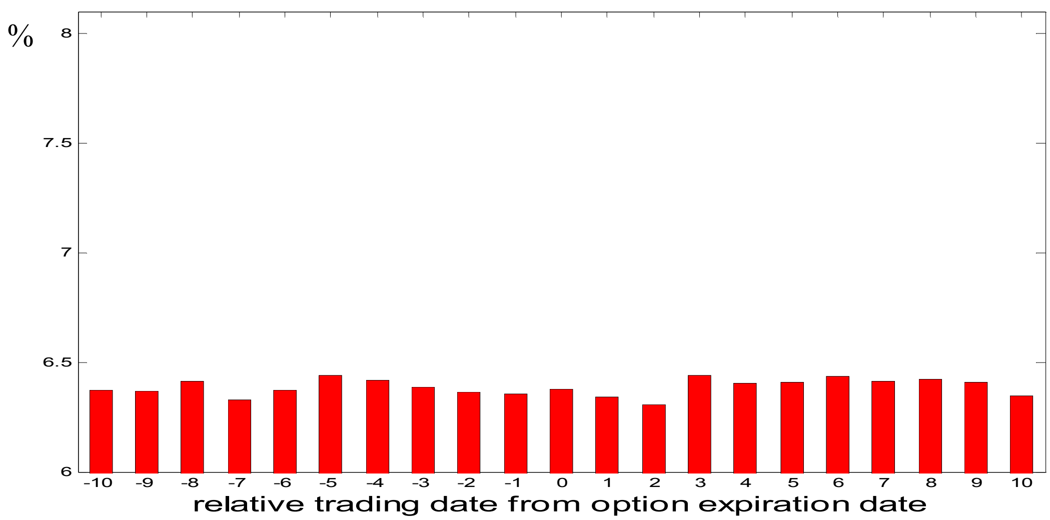
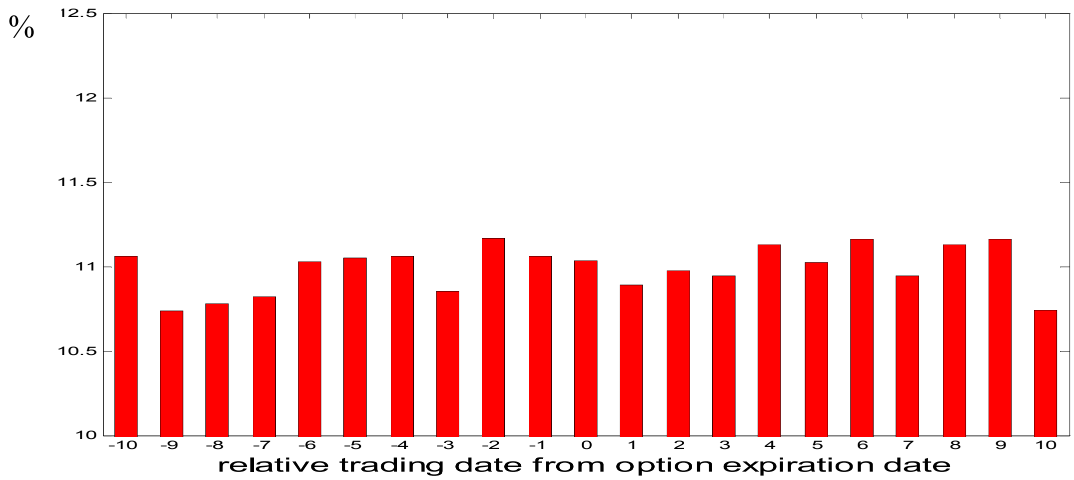


Fig. 2. Percentage of optionable and non-optionable stocks closing within $0.125 of an integer multiple of $5 as a function of the number of trade dates before or after an option expiration date. Expiration Fridays are trade date ‘0’ relative to the option expiration date, the Thursdays before are trade date ‘−1’ relative to the option expiration date, the Mondays after are trade date ‘1’ relative to the option expiration date, etc. For each trade date relative to the expiration date, the plots give the percentage of stocks that close less than or equal to $0.125 from an integer multiple of $5.00. Panel A shows the percentage of optionable stocks (i.e., stocks that have exchange listed options) that close less than or equal to $0.125 from an integer multiple of $5.00. Panel B shows the percentage of non-optionable stocks (i.e., stock that do not have exchange listed options) that close less than or equal to $0.125 from an integer multiple of $5.00. The data period covers the 80 option expirations from January 1996 through August 2002.

Panel A. Percentage of non-optionable stocks that subsequently become optionable closing within $0.125 of an integer multiple of $2.50



Panel B. Percentage of optionable stocks that were previously non-optionable closing within $0.125 of an integer multiple of $2.50

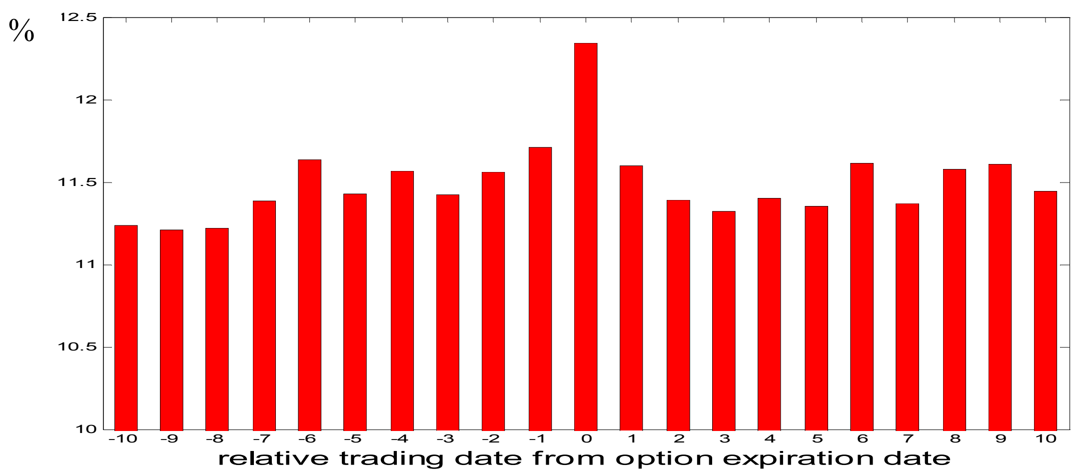
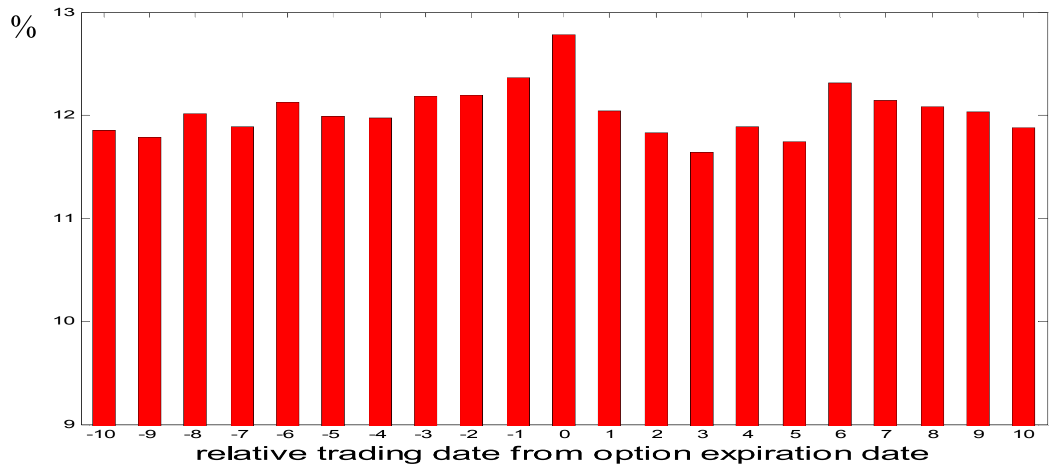


Fig. 3. Percentage of non-optionable stocks which subsequently become optionable and percentage of optionable stocks that previously were non-optionable closing within $0.125 of an integer multiple of $2.50 as a function of the number of trade dates before or after an option expiration date. Expiration Fridays are trade date ‘0’ relative to the option expiration date, the Thursdays before are trade date ‘–1’ relative to the option expiration date, the Mondays after are trade date ‘1’ relative to the option expiration date, etc. For each trade date relative to the expiration date, the plots give the percentage of stocks that have closing prices less than or equal to $0.125 from an integer multiple of $2.50. Panel A shows these percentages for stocks that are non-optionable but subsequently become optionable during the sample period. Panel B shows these percentage for optionable stocks that earlier in the sample period were non-optionable. The sample period is January 1996 through August 2002.

Panel A. Percentage of optionable stocks that subsequently become non-optionable closing within $0.125 of an integer multiple of $2.50



Panel B. Percentage of non-optionable stocks that were previously optionable closing within $0.125 of an integer multiple of $2.50

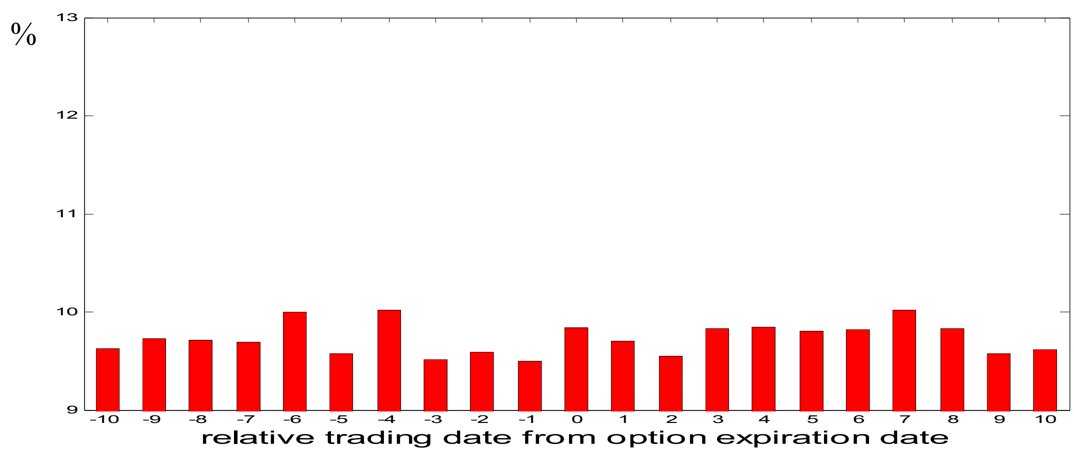
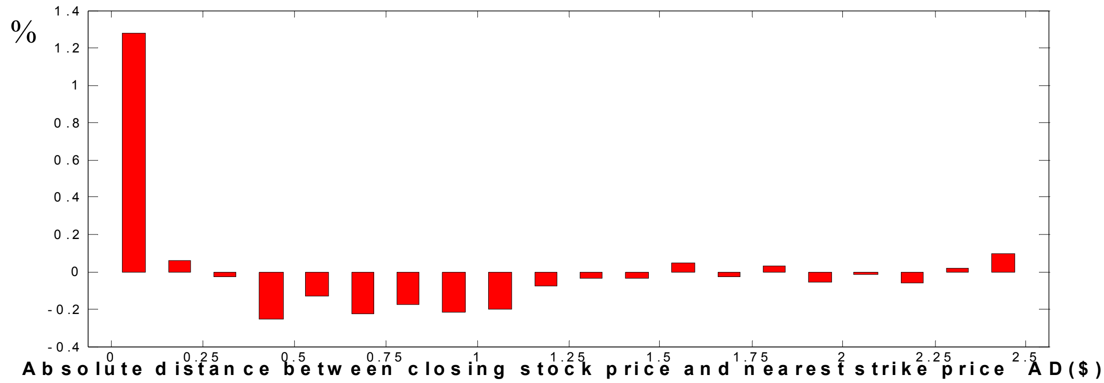


Fig. 4. Percentage of optionable stocks which subsequently become non-optionable and percentage of non-optionable stocks that previously were optionable closing within $0.125 of an integer multiple of $2.50 as a function of the number of trade dates before or after an option expiration date. Expiration Fridays are trade date ‘0’ relative to the option expiration date, the Thursdays before are trade date ‘–1’ relative to the option expiration date, the Mondays after are trade date ‘1’ relative to the option expiration date, etc. For each trade date relative to the expiration date, the plots show the percentages of stocks that have closing prices less than or equal to $0.125 from an integer multiple of $2.50. Panel A shows these percentages for stocks that are optionable but subsequently become non-optionable during the sample period. Panel B shows these percentage for non-optionable stocks that earlier in the sample period were optionable. The sample period is January 1996 through August 2002.

Panel A. Percentage of optionable stocks that close various absolute distances from a strike price on option expiration Fridays minus the percentage on the Fridays before and after option expiration



Panel B. Percentage of optionable stocks with absolute returns of various sizes on option expiration Fridays minus the percentage on the Fridays before and after option expiration

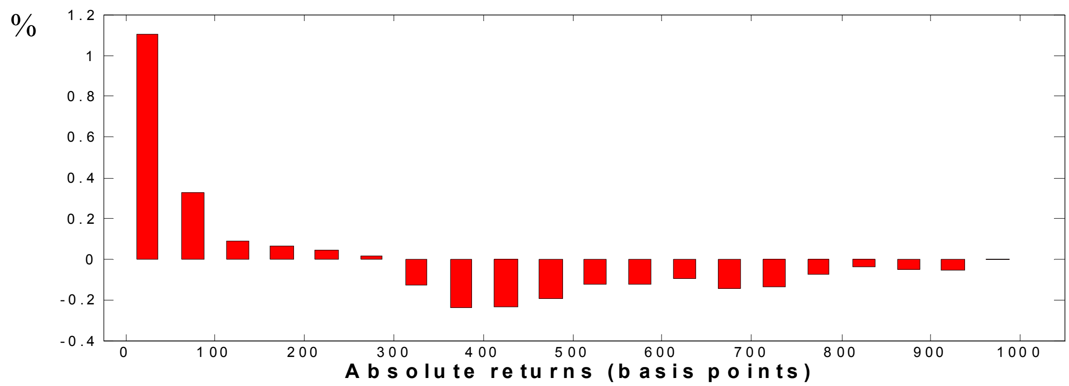
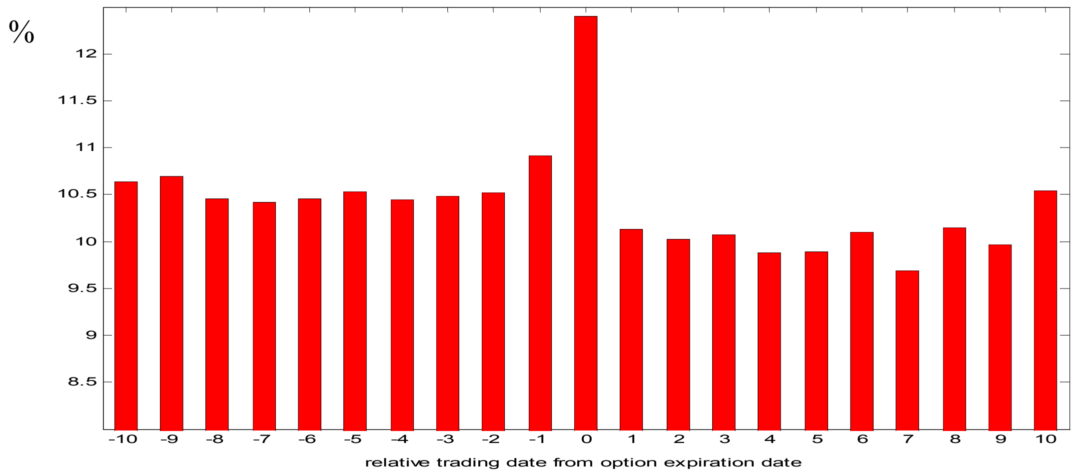


Fig. 5. Difference in optionable stock distributions on option expiration Fridays and the Fridays before and after expiration. In Panel A the absolute dollar distance (*AD*) between the closing prices of optionable stocks and the nearest option exercise price is divided into 20 disjoint intervals: $AD \leq \$0.125$, $\$0.125 < AD \leq \$0.25$, $\$0.25 < AD \leq \$0.375$, …, $\$2.375 < AD \leq \$10.00$. (Absolute dollar distances greater than \$10.00 are eliminated.) Panel A then displays the percentages of optionable stocks with closing prices in each of the intervals on option expiration Fridays minus the percentage on the Fridays before and after expiration. In Panel B the daily absolute stock returns are divided into 20 absolute return intervals: $0 \text{ bps} \leq |r| < 50 \text{ bps}$, $50 \text{ bps} \leq |r| < 100 \text{ bps}$, …, $950 \text{ bps} \leq |r| < 1{,}000 \text{ bps}$. Panel B then displays the percentage of optionable stocks with positive option volume that have returns in each interval on expiration Fridays minus the percentage on the Fridays before and after expiration. The sample period is January 1996 through August 2002.

Panel A. Percentage of optionable stocks closing within $0.125 of a strike price when market-makers have a net purchased option position



Panel B. Percentage of optionable stocks closing within $0.125 of a strike price when market-makers have a net written option positions

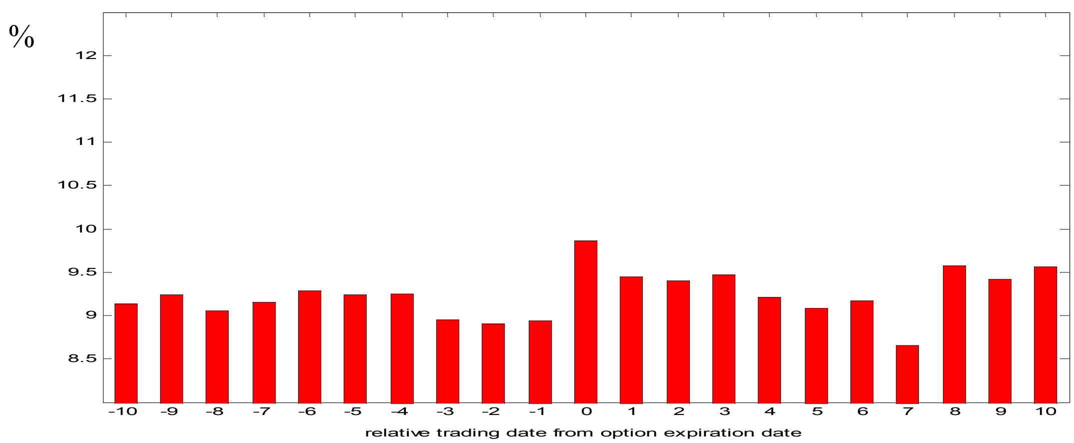


Fig. 6. Percentage of optionable stocks closing within $0.125 of an option strike price as a function of the number of trade dates before or after an option expiration date, for subsets of stock-expiration date pairs in which market-makers have net purchased or net written positions on the closest to expiration options with strike price nearest to the closing stock price. Expiration Fridays are trade date '0' relative to the option expiration date, the Thursdays before are trade date '–1' relative to the option expiration date, the Mondays after are trade date '1' relative to the option expiration date, etc. For each trade date relative to the expiration date, the plots show the percentages of stocks that close within $0.125 of a strike price of an option listed on the stocks. Panel A shows the percentages for the option expirations dates on which market-makers have a net purchased position in the closest to expiration options with strike price nearest to the closing stock price. Panel B shows the percentages for the option expiration dates on which market-makers have a net written position on these options. The data period is January 1996 through December 2001.