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Intraday price reversals in the US stock index futures market: A 15-year study

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Abstract

This paper gives a long-term assessment of intraday price reversals in the US stock index futures market following large price changes at the market open. We find highly significant intraday price reversals over a 15-year period (November 1987–September 2002) as well as significant intraday reversals in our yearly and day-of-the-week investigations. Moreover, the strength of the intraday overreaction phenomenon seems more pronounced following large positive price changes at the market open. That being said, the question of whether a trader can consistently profit from this information remains open as the significance of intraday price reversals is sharply reduced when gross trading results are adjusted by a bid–ask proxy for transactions costs.

JEL classification: G14
Keywords: Index futures; Overreaction; Market efficiency

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1. Introduction and literature review

One of the benefits of using stock index futures to assess market anomalies is that the phenomena can be studied in a relatively low transactions cost environment (Cornell (1985) and reiterated by Fung et al. (2000)). In this study, we use the "lead" contract on S&P 500 Futures to assess the question of intraday price reversals following large price changes at the market open. We use a time period (November 1987–September 2002) which is considerably longer than that used before to study the intraday overreaction hypothesis. We test for consistency of intraday price reversals on both a yearly basis and a day-of-the-week basis. Moreover, we examine whether it is "profitable" to execute an intraday contrarian strategy on stock index futures after consideration of a bid–ask proxy for transaction costs.

Intraday price reversals following large price changes at the market open have been studied in several papers: Atkins and Dyl (1990) find evidence of strong price reversals on common stocks after a large change in price before considering transaction costs. Fabozzi et al. (1995) use large price changes as proxies for the arrival of unobservable information and employ a standard event study methodology to examine the theory. Also, Fung et al. (2000) find strong support for the intraday overreaction theory on the Hong Kong HSI Futures, but less significant support on the S&P 500 Futures contract using a considerably shorter period of time than our study. [1]

Ederington and Lee (1995) examine investor reaction to information in the futures markets from a different perspective. They investigate the intraday price movement after scheduled macroeconomic news releases. In effect, their study examines how efficiently the market incorporates the new publicly available information into futures prices, Ederington and Lee find that prices are adjusted in a series of small but speedy steps, and that the whole price adjustment process is completed within 1 minute of the news release.

Intraday price movements after the market open may also relate to uncertainty involved in determining the opening price. Most studies find the existence of higher volatility associated with market openings and closings. Ekman (1992) provides evidence on the S&P 500 Futures contract. Daigler (1997) further demonstrates the existence of such a pattern not only on the S&P 500, but also on the MMI (Major Market Index) and the T-bond futures contracts. French and Roll (1986) use stock market data to demonstrate the link between return variances and the arrival of information as well as the subsequent reaction of traders. Moreover, Webb and Smith (1994) argue that the existence of higher variance during the opening is attributable to the use of the open outcry auction system without market makers.

One testable implication of the overreaction theory is that any "significant" change in security price should be followed by a correction. By focusing on the S&P 500 Futures contract, we hypothesize that any significant movement between

[1] Specifically, we use a 15-year time period to study the consistency *and* trading implications of intraday price reversals in US stock index futures compared with 2.75 years studied in Fung et al., 2000.

the previous day's closing price and the opening price can be attributed to the combined effect of investors' revised expectation after receiving new information, and their presumed "overreaction". If the overreaction argument holds, then one should observe a significant price reversal when the futures market opens with a large change in price from the previous close.

A pattern of significant intraday price reversals constitutes *gross* support for the overreaction hypothesis. However, one still needs to put the theory to a more stringent test before refuting the notion that the stock index futures market is efficient. If returns during the reversal period are less than the usual round-trip transaction cost, including a bid–ask spread, market impact, and commissions, then this provides evidence of weak-form market efficiency. Along this line, Atkins and Dyl (1990) point out that the magnitude of the bid–ask spread in the stock market results in severe bias in estimating the return to a contrarian strategy. Frino and Hill (2001) conclude that quoted spreads may enlarge around information announcements as a consequence of adverse selection costs. Finally, Chan (1988) finds that after adjusting for risk, only small abnormal returns persisted following the implementation of a contrarian strategy.

The remaining sections of this paper are organized as follow: Section 2 explains the characteristics of the data, particularly the development of the minute-by-minute pricing interval. Section 3 explains the event study research methodology, which includes the intraday average cumulative return calculation and formulation of the cumulative return *t*-test. Section 4 reports the empirical results for the 15-year sample period; including our statistical findings on intraday price reversals in US stock index futures in yearly and day-of-the-week investigations. After considering transactions costs, a brief conclusion is presented in Section 5.

2. Data

We utilize the S&P 500 Futures contract (traded on the Chicago Mercantile Exchange) to test the overreaction hypothesis as discussed in Section 1. Our sample spans November 1987–September 2002 (to avoid bias, the sample commences after the October Crash of 1987). The dataset consists of the price and time (in the format of *hhmm*) of every transaction with price change that occurs within each trading day. Transactions with no price change are excluded, and multiple trades in any minute are kept in the right order as they were recorded. We use transaction prices rather than bid–ask prices because bid and ask prices are sometimes not updated as quickly as the trading prices move. [2]

Consequently, the day's closing price reflects the last transaction price rather than the settlement price. We chose the S&P 500 Futures contract because it is one of the most widely traded and closely watched stock index futures contract and has a long

[2] According to the original data tape that we received, it includes bid, ask and actual trades. The bid/ask quotes are much less frequent than the actual trades during the regular trading hours.

history of trading information. As a word of background, the expiration dates for the S&P 500 Futures are scheduled on a quarterly basis: March, June, September, and December. The S&P Futures is a cash-settled contract. In addition, we employ pit-session data in our research and discard the electronic-session (Globex session on CME) data for liquidity reasons. The general trading hours for the S&P 500 Futures contract are from 8:30 a.m. to 3:15 p.m. Central Time, except for a brief period of time in 1997. [3] Since our study is conducted on an ordinal basis, for example the first minute of the day, 5 minutes after the first minute, etc., our findings are robust to different opening hours.

Also, because the intraday CME trading volume was not available, we use the number of trades as proxy. Only trades during the regular pit-trading hours are included in the trading count. Notably, the CME regularly designates one contract as the "lead" (or dominant) contract to handle the problem of multiple contracts being traded simultaneously on any given day. The lead contract is the most heavily traded contract. The futures exchange usually designates the nearby contract to be the dominant contract until a few days before its official expiration day when the exchange selects the second-to-expire contact as the new "lead" contract. At the same time traders begin to rollover their futures positions and the concentration of trading volume shifts toward the second-to-expire contract.

For our purpose, a rollover scheme is needed because we do not have a history of the CME designation schedule. The common practice is to find the date when the trade volume switches significantly from the nearby futures contract to the second-to-expire futures contract. Our data indicate that the switch usually happens a week before the official last day of trading. The average percentage drop in trades of the nearby contract after the designated trading day is around 75% for the S&P 500 Futures contracts over our sample period. We exercise caution when switching to a new contract for the first time. Specifically, we make sure that both the previous day's closing price and the opening price come from the same contract.

To facilitate the analysis, we convert the transaction data into minute-by-minute intervals. We also identify each trading day's opening price and the previous trading day's closing price. In turn, we use four different methods of computing minute-by-minute prices. They are: the single prices, the five-trade average prices, the three-trade highest prices, and the three-trade lowest prices. The three-trade lowest and highest prices are used at a later point in our contrarian strategy as proxies for the true bid and ask prices in any given minute of trading.

At the start of each trading day, the opening price and previous trading day's closing prices are immediately available. A market's opening gap (or opening change) is

[3] From October 6, 1997 to November 15, 1997, the S&P 500 Futures opened at 8:15 a.m. This impacts only the December 1997 contract in our study. In addition, as a result of the September 11th, 2001 tragedy, trading on the S&P 500 Futures was halted until September 17th, 2001. Since our study requires the previous trading day's closing prices, we excluded September 17th from the regular trading days, even though its closing price is still used in evaluating the trading for September 18th.

defined as the natural logarithm of the division of the opening price over the previous day's close:

$$\text{Opening gap} = 100 \times \log(\text{Opening price}/\text{Previous closing price}). \quad (1)$$

The futures contract can open higher or lower than the previous close, and thereby generate a positive or a negative opening gap.

3. Research methodology

A standard event-study methodology is used in this research. An "event day" appears when the opening price gap is equal to or wider than a given filter size. Our study covers three filter sizes: ±0.10%, ±0.20%, and ±0.30%. However, due to similarity of results, and for the purpose of simplifying the presentation of the results, we report only the ±0.20% (20 bp) filter results in this paper. Trading results for other filters are available from the authors upon request.

In formal terms, the cumulative return of the S&P 500 Futures, $\text{CAR}_{i,t}$, at time t minutes after the opening minute of an event day, i, is defined as

$$\text{CAR}_{i,t} = \log(P_{i,t+1}) - \log(P_{i,1}), \quad (2)$$

where $P_{i,t+1}$ and $P_{i,1}$ and are the traded futures price on event day i at time t minutes after the opening minute and the traded price of the first minute, respectively.

In turn, the average cumulative return at t minutes after the opening minute across all event days is calculated as

$$\text{ACAR}_t = 1/N^* \Sigma_{i=1 \text{ to } N} \text{CAR}_{i,t}, \quad (3)$$

where N is the total number of event days satisfying a given filter size. A price reversal is said to exist if the sign of the intraday average cumulative return is different from the sign of the opening change. Moreover, a standard t-test is used to test whether ACAR_t is significantly different from zero. The formula for the t-calculation is given as

$$t_{\text{calc}} = (\text{Sample mean} - 0)/(\text{Sample standard deviation}/\sqrt{N}). \quad (4)$$

We compute the average cumulative returns and then conduct the t-tests (the p-values are presented) for the entire sample period. The null hypothesis is that the average cumulative return for any given minute after the market open is not significantly different from zero; meaning that the t-statistic on the average cumulative return in a contrarian investment strategy is statistically insignificant. After testing the significance of the intraday overreaction hypothesis for the entire period – namely, our 15-year reporting period – we apply the event-study methodology on both a yearly basis and a "day of the week" basis. By providing evidence on various sub-periods, we shed light on the consistency of the intraday overreaction hypothesis.

4. Empirical results

4.1. Event days

The number of event days for the ±0.20% filter is tabulated in Part A of Table 1 for the 15-year sample period and in each calendar year. [4] As shown, the number of event days varies widely between years: so too does the average abnormal opening gap in stock index futures prices. For example, the absolute value of the average excess opening price gap (meaning price gaps that satisfy the ±0.20% filter) ranged from about 0.4 during the 1991–1995 period up to around 0.64 during the three years ending 2000. In addition, Part A of the table reveals that the +0.20% filter is associated with 13% (980/864) more observations than the −0.20% filter.

In contrast, Part B of Table 1 shows that the period studied by Fung et al. (2000) – September 1993 to June 1996 – has fewer yearly observations and smaller average excess opening gaps than we report in the broader sample. For instance, the average opening gaps on the negative and positive side of the filter in our 15-year sample are −0.57% and 0.51%, respectively. The corresponding average excess opening gaps in their sample period are −0.45% and 0.35%. With a longer time frame – spanning November 1987–September 2002 – we hope to provide new insights on the magnitude and consistency of intraday price reversals in the US stock index futures market.

4.2. Average cumulative return (%)

The average cumulative returns of the S&P 500 Futures, as t runs from 5 minutes to the closing time after the opening minute are graphed in Fig. 1 for the entire sample consisting of November 1987–September 2002. Fig. 1 shows that the average cumulative returns in event days satisfying the −0.20% filter continue to fall for a 10 minute period after the opening minute before they revert and move above zero. In turn, the average cumulative returns of the +0.20% filter continue to rise for about 10 minutes after the opening minute before they then revert and become negative.

Graphically, both lines in Fig. 1 are consistent with the intraday overreaction hypothesis. The price movements of the first 10 minutes in those event days seem to match with the notion that traders may need to close their positions in a hurry after observing large price movement at the market open. Price reversals then appear after the *first* 10 minutes and can last beyond the first hour of trading. However, the strength of the reversal in prices ebbs and both lines eventually cross the 0% gridline line as the trading day comes to an end.

Table 2 presents the average cumulative returns, percentages of positive cumulative returns for negative (and positive) filter size, and the results of t-tests in a 15-minute sequence, except for the first 15 minutes and the market on close. In the case of the +0.20%

[4] When the sample is expanded to include October 1987 (which includes Black Monday, October 19th), the average excess opening gap for 1987 becomes −2.22% on the negative side and 2.02% on the positive side. Additionally, the average excess opening gap for the October 1987–September 2002 period is −0.61% and 0.54%, respectively.

Table 1
Event days and average opening gaps in the S&P 500 index futures

	Filter sizes			
	Number of event days		Average opening gaps (%)	
	−0.20%	+0.20%	−0.20%	+0.20%
Part A: November 1987–September 2002				
Whole period	864	980	−0.57	0.51
1987	16	15	−1.16	0.70
1988	61	68	−0.49	0.55
1989	44	42	−0.43	0.41
1990	68	57	−0.60	0.54
1991	53	56	−0.46	0.40
1992	41	33	−0.37	0.33
1993	25	31	−0.34	0.34
1994	33	41	−0.43	0.35
1995	30	40	−0.39	0.30
1996	41	78	−0.60	0.42
1997	55	93	−0.63	0.53
1998	74	101	−0.65	0.57
1999	67	99	−0.57	0.54
2000	82	84	−0.63	0.64
2001	97	79	−0.64	0.63
2002	77	63	−0.67	0.63
Part B: September 1993–June 1996				
Whole period	90	134	−0.45	0.35
1993	7	12	−0.34	0.34
1994	33	41	−0.43	0.35
1995	30	40	−0.39	0.30
1996	20	41	−0.60	0.42

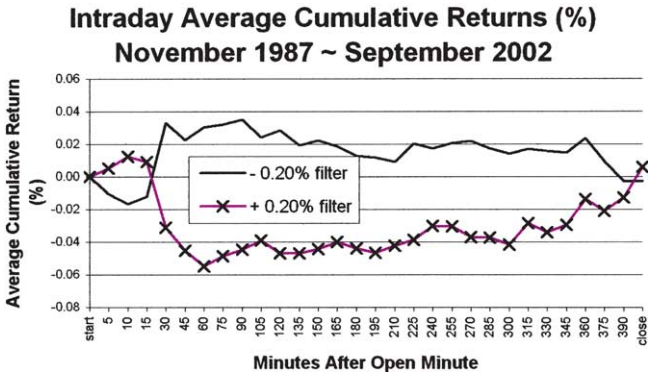

Fig. 1. Intraday average cumulative returns (%) November 1987–September 2002.

Table 2
Significance tests of average cumulative returns (ACAR%) November 1987–September 2002

Minute	Filter: $\leqslant -0.2\%$				Filter: $\geqslant +0.2\%$			
	ACAR%	*p*-Value (*t*-test)	% obs. (positive)	*p*-Value (proportion)	ACAR%	*p*-Value (*t*-test)	% obs. (positive)	*p*-Value (proportion)
Start	0.0000				0.0000			
5	−0.0105	(0.035)**	44.0	(0.000)***	0.0053	(0.138)	45.6	(0.007)***
10	−0.0168	(0.015)**	43.2	(0.000)***	0.0125	(0.028)**	48.7	(0.028)**
15	−0.0123	(0.114)	49.8	(0.045)**	0.0093	(0.131)	47.3	(0.104)
30	0.0330	(0.003)***	55.3	(0.000)***	−0.0313	(0.001)***	42.2	(0.000)***
45	0.0225	(0.068)*	54.5	(0.000)***	−0.0451	(0.000)***	44.5	(0.001)***
60	0.0305	(0.047)**	53.1	(0.007)***	−0.0549	(0.000)***	44.0	(0.000)***
75	0.0320	(0.059)*	52.1	(0.038)**	−0.0485	(0.001)***	45.2	(0.003)***
90	0.0349	(0.047)**	53.1	(0.013)**	−0.0447	(0.005)***	45.8	(0.010)***
105	0.0242	(0.133)	53.0	(0.038)**	−0.0391	(0.015)**	47.6	(0.134)
120	0.0287	(0.105)	51.6	(0.072)*	−0.0470	(0.006)***	45.9	(0.012)**
135	0.0193	(0.212)	52.1	(0.096)*	−0.0467	(0.008)***	47.0	(0.069)*
150	0.0224	(0.187)	52.1	(0.126)	−0.0444	(0.015)**	47.1	(0.079)*
165	0.0188	(0.234)	51.4	(0.262)	−0.0400	(0.029)**	47.7	(0.151)
180	0.0127	(0.319)	50.5	(0.359)	−0.0441	(0.021)**	47.7	(0.151)
195	0.0116	(0.338)	50.2	(0.708)	−0.0465	(0.018)**	47.1	(0.079)*
210	0.0093	(0.374)	50.0	(0.658)	−0.0422	(0.031)**	47.1	(0.079)*
225	0.0204	(0.242)	50.6	(0.434)	−0.0388	(0.044)**	46.3	(0.024)**
240	0.0173	(0.279)	49.8	(0.658)	−0.0300	(0.095)*	46.6	(0.038)**
255	0.0205	(0.250)	50.1	(0.812)	−0.0304	(0.092)*	46.5	(0.033)**
270	0.0219	(0.237)	50.1	(0.518)	−0.0371	(0.058)*	47.0	(0.069)*
285	0.0175	(0.289)	49.9	(0.658)	−0.0375	(0.060)*	47.1	(0.079)*
300	0.0142	(0.329)	50.1	(0.760)	−0.0416	(0.048)**	47.9	(0.191)
315	0.0170	(0.303)	48.1	(0.292)	−0.0284	(0.133)	47.0	(0.069)*
330	0.0156	(0.319)	49.0	(0.563)	−0.0343	(0.101)	47.0	(0.069)*
345	0.0148	(0.336)	48.3	(0.324)	−0.0296	(0.152)	47.9	(0.191)
360	0.0236	(0.265)	49.0	(0.563)	−0.0138	(0.321)	49.8	(0.774)
375	0.0094	(0.408)	50.7	(0.518)	−0.0210	(0.255)	49.8	(0.873)
390	−0.0028	(0.473)	50.5	(0.563)	−0.0129	(0.348)	49.1	(0.587)
Close	−0.0028	(0.474)	50.6	(0.395)	0.0059	(0.431)	50.9	(0.170)

*Significant at the 0.10 level (two-tailed test).
**Significant at the 0.05 level (two-tailed test).
***Significant at the 0.01 level (two-tailed test).

filter, the *p-value* hovers below the 0.05 "two-tailed" test level for the first 225 minutes of the trading day. This means that $ACAR_t$ values are statistically significant during this trading interval. On the other hand, in the case of the −0.20% filter, the $ACAR_t$ is significantly different from zero at a 5% level some 90 minutes after the opening minute.

Table 2 also reveals that the +0.20% filter has a larger (absolute) average cumulative return most of the time. [5] In addition, the $ACAR_t$ findings in Table 2 are rein-

[5] This finding may in part be explained by momentum traders expecting a positive continuation in futures prices. In this scenario, traders are overly optimistic and surprised about having to revise their expectations downward. While important, the role of trader types in explaining the intraday overreaction phenomenon is beyond the scope of this paper.

forced by the percentage (or proportion) of positive cumulative returns for various trading intervals that are statistically different from 50%. For example, in the −0.20% filter, there are a string of significant %-positive cumulative returns (that is, above 50%) in the short trading intervals out to 105 minutes after the opening minute. [6] In the +0.20 filter, the percentage of negative cumulative returns (actually, 100 minus %-positive) is also significant in the near trading intervals (30, 60, 90 minutes) following the opening minute, and still significantly different from 50% (although variably so) some 255 minutes into the trading day.

Fig. 2 is produced by limiting the testing period to the same period used in the Fung et al. (2000) study; namely, September 1993–June 1996. According to *t*-tests (not shown [7]), the overreaction hypothesis is only weakly supported in the case of −0.20% filter, but is still supported in the case of the +0.20% filter. In contrast with those in Fig. 1, the two lines in Fig. 2 appear to converge toward the zero gridline around noontime, and then pull away from each other toward the end of the trading day. While the statistical evidence of price reversals is clear in both studies (our study and the Fung, Mok and Lam study), the longer-term evidence reveals that the conclusion about the magnitude and consistency of investor overreaction is affected by the choice of the test period. [8] Moreover, with $ACAR_t$ approaching zero by the end of the trading day in both positive and negative filter scenarios, our test results point to the possibility of intraday overreaction to the initial ''overreaction'' in stock index futures prices. [9]

4.3. Delayed trading results

We reported in Table 2 that intraday price reversals appear after a brief period of price continuation following the opening minute. On its face, this finding can be used to develop a potentially profitable contrarian investment strategy. To examine this, we conduct a series of tests using the five-trade average prices of each minute. [10] By delaying the execution of the strategy by 5, 10, and 15 minutes, respectively, and then comparing the results to the execution of the strategy *without* delay, we examine whether the overreaction exists for just the opening minute, or whether it is a more pervasive phenomenon in the stock index futures market. Additionally, the success of the ''wait-to-execute'' strategy does not depend on the investors' need to execute the strategy at the opening price.

[6] We report the relevant ''*p*-values'' in test of a proportion different from 0.5 (or 50%).

[7] To conserve space, the average cumulative returns and *t*-tests for the September 1993–June 1996 period are not shown in a separate table. These results (as well as other findings mentioned later) are available from the authors upon request.

[8] Our statistical results from the ±0.10% and ±0.30% filters are consistent with the empirical results shown in Table 2.

[9] We are grateful to a reviewer of this journal for suggesting that our long-term intraday results seem consistent with a more general over-correcting behavior in stock index futures.

[10] We use the five-trade average prices of each minute to assess the stability of the single trade results reported in Table 2.

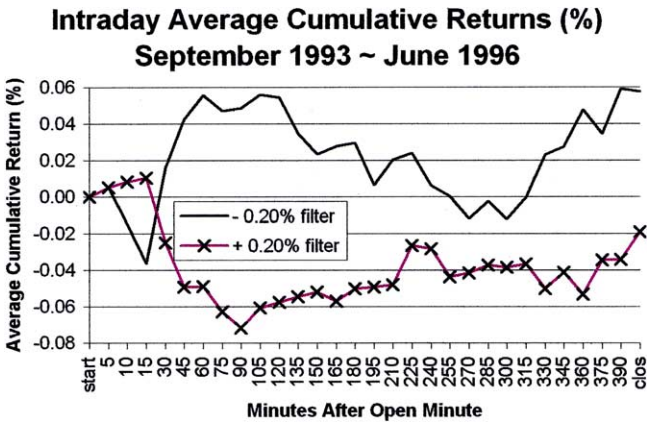

Fig. 2. Intraday average cumulative returns (%) September 1993–June 1996.

For the sake of brevity, Table 3 reports the "best" contrarian results that we obtained from the delayed trading strategy. Specifically, with a 10-minute trading delay, the average cumulative returns are significantly greater than zero some 4 hours into the trading day at a 5% level. In numerical terms, the maximum *absolute* average cumulative return to the contrarian strategy reaches 0.066% in the case of the −0.20% filter and 0.078% in the case of the +0.20% filter. Also, consistent with our findings reported in Table 2, the statistical persistency of the intraday reversal phenomenon in stock index futures lasts longer in the case of the +0.20% filter. [11]

4.4. Results on a yearly basis

To further test whether a 10-minute waiting period is meaningful, we conduct wait-to-execute tests on a yearly basis and present summary results in Table 4 (panel A and B). Table 4 (panel A) is interesting in several respects. First, the table reports that about half of the sample years have statistically significant findings at the 5% level on each side of the 0.20% filter (negative and positive). For example, after satisfying the −0.20% filter, prices revert significantly from the direction of the opening price in 7 of 15 years; including 1989, 1991, 1995, 1996, 1997, 1999, and 2000. Likewise, in the case of the +0.20% filter, Table 4 (panel A) reports significant price reversals in eight years, including 1988 through 1992, 1995, 1996, and 1999. In addition, the table shows some 10 of 15 years where significant price reversals occur on at least one side of the 5% test. This implies a yearly success rate of 67% when trading (with 10-minute delay) on intraday reversals following large price changes at the market open.

[11] Again though, the *gross* trading results should be tempered by the likelihood of observing an intraday reversal for a given filter (the % positive or negative ACAR as in Table 2) as well as transactions cost considerations including the bid–ask spread (covered shortly).

Table 3
Significance tests of average cumulative returns (ACAR%) (using each minute's five-trade average prices) trading starts 10 minutes after open November 1987–September 2002

Minutes	Filter: −0.20%		Filter: +0.20%	
	ACAR%	*p*-Value	ACAR%	*p*-Value
Start	0.0000		0.0000	
5	0.0174	(0.001)***	−0.0119	(0.003)***
10	0.0419	(0.000)***	−0.0274	(0.000)***
15	0.0539	(0.000)***	−0.0421	(0.000)***
30	0.0458	(0.000)***	−0.0585	(0.000)***
45	0.0526	(0.000)***	−0.0775	(0.000)***
60	0.0639	(0.000)***	−0.0646	(0.000)***
75	0.0659	(0.000)***	−0.0707	(0.000)***
90	0.0559	(0.002)***	−0.0570	(0.000)***
105	0.0577	(0.003)***	−0.0628	(0.000)***
120	0.0533	(0.009)***	−0.0626	(0.000)***
135	0.0496	(0.019)**	−0.0598	(0.001)***
150	0.0504	(0.019)**	−0.0605	(0.001)***
165	0.0455	(0.036)**	−0.0621	(0.001)***
180	0.0405	(0.059)*	−0.0643	(0.001)***
195	0.0374	(0.085)*	−0.0632	(0.001)***
210	0.0414	(0.069)*	−0.0548	(0.005)***
225	0.0517	(0.033)**	−0.0575	(0.004)***
240	0.0508	(0.039)**	−0.0440	(0.020)**
255	0.0471	(0.054)*	−0.0510	(0.010)***
270	0.0474	(0.055)*	−0.0579	(0.005)***
285	0.0426	(0.079)*	−0.0595	(0.005)***
300	0.0459	(0.073)*	−0.0510	(0.016)**
315	0.0483	(0.062)*	−0.0547	(0.014)**
330	0.0430	(0.098)*	−0.0479	(0.039)**
345	0.0555	(0.058)*	−0.0370	(0.094)*
360	0.0462	(0.111)	−0.0374	(0.107)
375	0.0332	(0.203)	−0.0518	(0.047)*
390	0.0271	(0.256)	−0.0208	(0.262)
Close	0.0276	(0.253)	−0.0122	(0.355)

*Significant at the 0.10 level (two-tailed test).
**Significant at the 0.05 level (two-tailed test).
***Significant at the 0.01 level (two-tailed test).

Moreover, the yearly evidence (Table 4, panel A) on intraday price reversals in US stock index futures shows that overreaction occurs *across* periods of abnormal increases and decreases in the underlying stock market. For example, significant intraday price reversals in stock index futures occur on at least one side of the test during 1989 and 1990 (abnormally high, followed by negative year for US stock market) and in the bull market run up of 1995–1999, followed by a stock market decline in 2000. Interesting though, significant intraday price reversals in stock index futures are generally not observed in 2001 and 2002.

When looking at sub-period analyses of one year or less, it is also helpful to report the profit or loss for each period. Specifically, if there are many years of gains, it

Table 4
Significance tests of average cumulative returns (ACAR%) using five-trade average prices and delaying 10 minutes by year: 1988–2002 (panel A). Number of years with positive/negative ACAR (period 1988–2002) (panel B)

Year	Minute	Filter: −0.20%		Filter: +0.20%	
		ACAR%	*p*-Value	ACAR%	*p*-Value
Panel A					
1988	30	0.0347	(0.228)	−0.1075	(0.001)***
	60	−0.0001	(0.499)	−0.1346	(0.002)***
	90	−0.0337	(0.294)	−0.1161	(0.012)**
1989	30	0.1127	(0.003)***	−0.0714	(0.008)***
	60	0.1243	(0.060)*	−0.0748	(0.056)*
	90	0.0830	(0.145)	−0.0277	(0.257)
1990	30	0.0312	(0.162)	−0.1269	(0.000)***
	60	0.0052	(0.469)	−0.1742	(0.000)***
	90	0.0221	(0.380)	−0.1762	(0.002)***
1991	30	0.1051	(0.001)***	−0.0913	(0.001)***
	60	0.1095	(0.016)**	−0.0601	(0.104)
	90	0.1056	(0.052)*	−0.0644	(0.136)
1992	30	0.0260	(0.222)	−0.0536	(0.034)**
	60	0.0241	(0.331)	−0.0015	(0.485)
	90	0.0034	(0.485)	−0.0017	(0.485)
1993	30	0.0135	(0.382)	−0.0546	(0.050)*
	60	0.0260	(0.345)	−0.0576	(0.081)*
	90	0.0201	(0.368)	0.0174	(0.367)
1994	30	0.0423	(0.135)	−0.0441	(0.109)
	60	0.0771	(0.062)*	−0.0120	(0.382)
	90	0.0984	(0.052)*	0.0141	(0.387)
1995	30	0.0801	(0.004)***	−0.0677	(0.004)***
	60	0.1176	(0.017)**	−0.0385	(0.154)
	90	0.0822	(0.065)*	−0.0864	(0.050)**
1996	30	0.0805	(0.018)**	−0.0646	(0.004)***
	60	0.0959	(0.020)**	−0.1381	(0.000)***
	90	0.0955	(0.062)*	-0.1248	(0.002)***
1997	30	0.1247	(0.004)***	−0.0288	(0.182)
	60	0.1968	(0.011)**	−0.0409	(0.149)
	90	0.2149	(0.015)**	−0.0624	(0.092)*
1998	30	0.0684	(0.066)*	−0.0516	(0.154)
	60	0.1083	(0.056)*	−0.0907	(0.056)*
	90	0.0880	(0.120)	−0.0756	(0.099)*

Table 4 (*continued*)

Year	Minute	Filter: −0.20%		Filter: +0.20%	
		ACAR%	*p*-Value	ACAR%	*p*-Value
1999	30	0.0767	(0.026)**	−0.1001	(0.001)***
	60	0.0337	(0.251)	−0.0626	(0.077)*
	90	0.0698	(0.123)	0.0090	(0.431)
2000	30	0.0957	(0.012)**	−0.0044	(0.459)
	60	0.1338	(0.011)**	0.0330	(0.271)
	90	0.1185	(0.041)**	0.0320	(0.323)
2001	30	−0.0382	(0.174)	0.0196	(0.344)
	60	−0.0080	(0.456)	0.0047	(0.469)
	90	−0.0229	(0.375)	0.0300	(0.345)
2002	30	−0.0567	(0.157)	−0.0428	(0.229)
	60	0.0050	(0.474)	−0.0927	(0.139)
	90	−0.0275	(0.362)	−0.1677	(0.048)**
Panel B					
		Average ACAR%	Count of ACAR > 0	Average ACAR%	Count of ACAR < 0
	30	0.0531	13	−0.0593	14
	60	0.0699	13	−0.0627	13
	90	0.0612	12	−0.0534	10
Total years		15		15	

*Significant at the 0.10 level (two-tailed test).
**Significant at the 0.05 level (two-tailed test).
***Significant at the 0.01 level (two-tailed test).

suggests that a contrarian strategy may be profitable to a trader in economic terms. In this context, the average ACAR% across the 15 years offers further support for the overreaction hypothesis. Table 4 (panel B) demonstrates a count of 12–13 years with positive ACAR% in the negative filter for the first 90 min and a count ranging from 10 to 14 years with negative ACAR% in the positive filter during this trading interval. Indeed, the yearly ACAR counts imply at least a 67% (positive filter: 10/15) to 80% (negative filter: 12/15) chance of economic success for the derived trading strategies.

4.5. Day-of-the-week considerations

We now report the results of our investigation concerning intraday price reversals in US stock index futures on a day-of-the-week basis. To examine this, we conduct the intraday price reversal tests on each weekday, plus a combination of *non*-Monday (Tuesday through Friday) trading days. We retrieved from each set of tests

the $ACAR_t$ for the first 30, 60, 90, 120, 150, and 180 minutes of each weekday and non-Monday trading days. The empirical results are shown in Table 5.

Price movements following large opening price changes are quite different on Mondays than non-Mondays. [12] In fact, price continuations instead of reversals following the opening prices prevail on Mondays, especially after a −0.20% or stronger opening gap. Opening errors exist on both Mondays and *non*-Mondays, but in an opposite direction. Thus, Monday trading of the S&P 500 Futures contract deserves a special examination by the trader because it presents a potentially different trading opportunity. That being said, the "day of the week" results on Wednesdays offer the strongest evidence of price reversals, followed by the results from Fridays. At the very least, the trader should consider initiating the contrarian strategy on *non*-Mondays as the intraday pricing pattern in stock index futures is fundamentally different from that observed on Monday.

We also performed an overnight volatility test to see if information arrival might account for the statistically significant findings of overreaction on Wednesdays and Fridays. Specifically, we examine if volatility over Tuesday close to Wednesday open and Thursday close to Friday open is higher or lower than other days of the week. This test (not shown) reveals that volatility of opening gaps on Wednesday and Friday is actually *lower* than the volatility of opening gaps observed on Tuesday and Thursday, and about the same as that observed on Monday. Hence, at least on a statistical basis, the overreaction phenomenon remains intact on Wednesdays and Fridays, where overnight information arrival seems relatively low.

4.6. Role of transactions costs

Up to this point we have said nothing about transactions costs. While an intraday overreaction pattern is clearly evident in future prices during our 15-year sample period (especially, Table 3) and in our yearly and day-of-the-week investigations (Tables 4 and 5), it is possible that the cost of transacting could overwhelm the gross profits in a contrarian trading strategy. In this closing section, we assess transactions costs in terms of the three-trade lowest and highest prices of each minute to represent the possible bid and ask prices of each minute. Under this "worst-case scenario" the trader is forced to sell futures at the presumed lower bid price and buy futures at the higher ask price. However, since this version of our test does not include the commission cost which is about $6 per round-trip transaction on S&P 500 Futures contract the $ACAR_t$ would weaken faster than we show here.

We duplicate the previously successful, 10-minute delay strategy shown in Table 3 under a more stringent transactions-cost test. The revised test results for the entire sample period (November 1987–September 2002) are shown in Table 6. In this case, only the price reversal occurring after a positive 0.20% filter

[12] We realize that positive ACAR following the market open on Mondays is statistically insignificant.

Table 5
Significance tests of average cumulative returns (ACAR%) by weekday: Monday–Friday plus non-Monday November 1987–September 2002

Weekday	Minute	Filter: −0.20%		Filter: +0.20%	
		ACAR%	*p*-Value	ACAR%	*p*-Value
Monday	30	−0.0039	(0.453)	0.0075	(0.370)
	60	−0.0543	(0.149)	0.0248	(0.231)
	90	−0.0599	(0.134)	0.0279	(0.258)
	120	−0.0968	(0.064)*	0.0323	(0.237)
	150	−0.1105	(0.040)**	0.0354	(0.234)
	180	−0.1395	(0.020)**	0.0337	(0.253)
Tuesday	30	0.0062	(0.395)	0.0025	(0.423)
	60	−0.0596	(0.074)*	−0.0128	(0.341)
	90	−0.0363	(0.234)	0.0024	(0.475)
	120	−0.0308	(0.270)	−0.0108	(0.394)
	150	0.0138	(0.398)	−0.0345	(0.232)
	180	0.0152	(0.396)	−0.0507	(0.167)
Wednesday	30	0.0685	(0.003)***	−0.0777	(0.001)***
	60	0.1008	(0.001)***	−0.1601	(0.001)***
	90	0.1113	(0.005)***	−0.1580	(0.001)***
	120	0.1451	(0.002)***	−0.1683	(0.001)***
	150	0.1583	(0.003)***	−0.1556	(0.001)***
	180	0.1457	(0.007)***	−0.1436	(0.003)***
Thursday	30	0.5020	(0.016)**	−0.0343	(0.091)*
	60	0.0552	(0.058)*	−0.0400	(0.117)
	90	0.0462	(0.114)	−0.0275	(0.242)
	120	0.0035	(0.468)	−0.0368	(0.199)
	150	−0.0025	(0.479)	−0.0387	(0.209)
	180	−0.0375	(0.241)	−0.0489	(0.174)
Friday	30	0.0393	(0.086)*	−0.0507	(0.005)***
	60	0.0947	(0.010)***	−0.0821	(0.002)***
	90	0.0988	(0.018)**	−0.0670	(0.015)**
	120	0.1074	(0.014)**	−0.0547	(0.061)*
	150	0.0690	(0.114)	−0.0354	(0.170)
	180	0.0682	(0.134)	−0.0212	(0.292)
Non-Monday	30	0.0413	(0.001)***	−0.0399	(0.001)***
	60	0.0494	(0.004)***	−0.0727	(0.001)***
	90	0.0562	(0.006)***	−0.0610	(0.001)***
	120	0.0567	(0.009)***	−0.0648	(0.001)***
	150	0.0521	(0.028)**	−0.0622	(0.003)***
	180	0.0467	(0.054)*	−0.0615	(0.005)***

*Significant at the 0.10 level (two-tailed test).
**Significant at the 0.05 level (two-tailed test).
***Significant at the 0.01 level (two-tailed test).

Table 6
Significance tests of average cumulative returns (ACAR%) allow for bid–ask spread and market impact delay by 10 minutes November 1987–September 2002

Minute	Filter: −0.20%		Filter: +0.20%	
	ACAR%	*p*-Value	ACAR%	*p*-Value
Start	0.0000		0.0000	
5	−0.0319	(0.000)***	0.0244	(0.000)***
10	−0.0067	(0.219)	0.0089	(0.094)*
15	0.0072	(0.222)	−0.0066	(0.194)
30	−0.0015	(0.453)	−0.0228	(0.019)**
45	0.0056	(0.358)	−0.0433	(0.000)***
60	0.0190	(0.145)	−0.0306	(0.015)**
75	0.0199	(0.147)	−0.0364	(0.007)***
90	0.0114	(0.280)	−0.0238	(0.076)*
105	0.0129	(0.270)	−0.0299	(0.040)**
120	0.0085	(0.351)	−0.0302	(0.043)**
135	0.0052	(0.413)	−0.0262	(0.077)*
150	0.0065	(0.394)	−0.0278	(0.075)*
165	0.0021	(0.467)	−0.0291	(0.073)*
180	−0.0027	(0.458)	−0.0320	(0.060)*
195	−0.0070	(0.397)	−0.0307	(0.071)*
210	−0.0030	(0.457)	−0.0224	(0.145)
225	0.0074	(0.394)	−0.0244	(0.129)
240	0.0077	(0.394)	−0.0109	(0.308)
255	0.0029	(0.460)	−0.0183	(0.203)
270	0.0029	(0.461)	−0.0244	(0.140)
285	−0.0022	(0.471)	−0.0252	(0.138)
300	0.0009	(0.489)	−0.0178	(0.229)
315	0.0025	(0.467)	−0.0206	(0.206)
330	−0.0025	(0.470)	−0.0133	(0.314)
345	0.0084	(0.406)	−0.0020	(0.472)
360	−0.0016	(0.483)	−0.0027	(0.465)
375	−0.0124	(0.378)	−0.0180	(0.282)
390	−0.0171	(0.338)	0.0117	(0.360)
Close	−0.0037	(0.465)	0.0081	(0.404)

*Significant at the 0.10 level (two-tailed test).
**Significant at the 0.05 level (two-tailed test).
***Significant at the 0.01 level (two-tailed test).

seems promising at a 5% significance level; since, the −0.20% test results (excepting one) are statistically insignificant. Of course, the conclusion may differ among traders facing different commission cost structures. We also conducted another run of tests utilizing the five-trade highest and lowest prices by min and, as before, the results deteriorate and cannot (statistically) warrant a successful contrarian trading strategy. Although the gross pattern of intraday price reversals during the November 1987–September 2002 period is clearly inconsistent with futures market efficiency, we take the transactions-cost-adjusted findings reported in Table 6 to imply a different, and more favorable, interpretation of stock index futures efficiency.

5. Conclusion

Our long-term investigation shows that intraday stock index futures prices revert following large price changes at the market open. Following the opening price, we find 10 minutes of significant price continuation on S&P 500 Futures and then a long series of significant price reversals. Additionally, the intraday reversal phenomenon in US stock index futures is evident in both our yearly and day-of-the-week investigations. The yearly evidence reveals that intraday price reversals occur across periods of abnormally high and low performance in the underlying stock market. The day-of-the-week investigation shows that intraday reversals occur primarily on *non*-Monday (particularly Wednesday and Friday) trading days. That being said, the question of whether a trader can consistently profit from this information remains open as the significance of intraday reversals in US stock index futures is sharply reduced when gross trading results are adjusted by a bid–ask proxy for transactions costs.

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