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CAN SIMPLE BUY AND SELL RULES INCREASE INDEX FUTURE DAY TRADING PROFITABILITY?

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Day trading index futures is popular. Two common strategies are trend-following and gap-reversal. This paper uses these strategies as "base strategies" and asks whether simple intraday exit rules can increase their profitability. Intraday stop-loss exit rules appear to add return to a trend-following base strategy of buying index futures at the opening and closing out the position at the close. There is no strong evidence that the same is true of profit-lock exit rules or that either works with a corresponding gap-reversal strategy.

1 Introduction

Day trading index futures is popular. Two common strategies are trend-following and gap-reversal.[1] Trend-following consists of taking a long (short) position following a previous positive (negative) index future return. Gap-reversal takes a long (short) position in response to a previous negative (positive) index future return. Trend-following works if there is a positive correlation between future and past returns. Gap-reversal works if the correlation between future and past returns is negative.

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Over the period examined in this paper, there is mostly:

- a positive correlation between a day's intraday index future return and the previous day's return measured from the opening to the close;
- a negative correlation between a day's intraday index future return and the return from the previous day's close to today's opening.

In this environment, the following versions of trend-following and gap-reversal strategies should be profitable.

- *Trend-following*: Buy (sell) at the opening and sell (buy) at the close whenever yesterday's index future return is positive (negative). In order to reduce the trading frequency to about once weekly and improve the signal to noise ratio, take a position only if the magnitude of yesterday's return exceeds 1.1%. This minimum magnitude results in 367 long positions and 376 short

positions during the period from 9/1/88 to 6/30/03.

- *Gap-reversal*: Sell (buy) at the opening and buy (sell) at the close whenever the overnight index future return is positive (negative). In order to reduce the trading frequency to about once weekly and improve the signal to noise ratio, take a position only if the overnight return's magnitude exceeds 0.5%. This minimum magnitude results in 348 long positions and 346 short positions during the period from 9/1/88 to 6/30/03.

This paper uses these strategies as "base strategies" and asks whether the following three intraday exit rules can increase their profitability.

- A stop-loss order with a trigger price based on a percent change, a change equal to a number of daily return standard deviations, or a change equal to a fractile of the return distribution. The stop-loss order's price is below or above the initial price according to whether the position taken is long or short.
- A profit-lock limit order that locks in a profit with a trigger price based on a percent change, a change equal to a number of daily return standard deviations, or a change equal to a fixed fractile of the return distribution. The stop-loss order's price is above or below the initial price according to whether the position taken is long or short.
- Both of the above exit rules.

Many investors believe that a stop-loss order increases expected return by eliminating large losses and retaining gains.[2] However, price paths that end up, even strongly, often pass through the stop-loss price. Hence, many gains, even large ones, are foregone. Another common belief is that a profit-lock limit order increases expected return by closing out profitable positions that subsequently become unprofitable. This ignores price paths that end up much more than the profit-lock price. Finally, most investors believe that if two trading rules each provide performance, then, using both results in greater performance than when either one is used separately.

One issue with the above exit rules is how to select their triggers. For a stop-loss exit rule, a sensitive trigger leads to no large loss, a substantial probability of a small loss, and a substantial probability of a foregone profit (possibly large). Suppose, for example, a symmetric return distribution around zero. Then, roughly, a stop-loss order just below the initial price will cut all paths that end down and a large proportion of the paths that end up.[3] An insensitive trigger leads to a substantial probability of small to moderate losses, no chance of a large loss, and a small probability of a missed opportunity. For a profit-lock exit rule, a sensitive trigger leads to no large profit, a substantial probability of a small profit, and a substantial probability of a loss. An insensitive trigger leads to a substantial probability of a small to large profit and only a small reduction in the probability and size of a loss.

On average, both exit rules, singly or in combination, leave the investor out of the security part of the time. In the absence of timing efficacy, this reduces (increases) expected return for positions in securities that have positive (negative) expected returns. A long (short) position in index futures has a positive (negative) expected return.[4] This suggests that a reasonable null hypothesis, as long as trading is not dominated by either long or short positions, is that the exit rules do not provide performance improvements to the base strategies. This requirement is met for this paper's trading. Consequently, this null hypothesis is used in the analysis.

Stop-loss and profit-lock limit order exit rules can be considered crude dynamic strategies. A long position in a security plus a stop-loss order corresponds to bill plus call or stock plus put. A long position in a security plus a profit-lock limit order corresponds

to stock less call. Both together correspond to bill plus bull-spread. Corresponding associations exist for short positions in a security plus a stop-loss order and/or a profit-lock limit order.

The option position analogy provides insight about the upper limit that these exit rules, suitably modified, could provide without timing efficacy. A stop-loss rule could be replaced with a stop-loss (sell after a drop)-start-gain (buy after a rise) rule that creates a synthetic security plus put. This makes clear that there is a cost/benefit tradeoff associated with a stop-loss exit rule. Similarly, a profit-lock exit rule could be replaced with a sell-after-a-gain buy-after-a-drop rule that creates a synthetic security less call. There is a clear cost/benefit tradeoff here, too.

Some of the paper's results are given below.

- All the intraday exit rules materially improve the returns of the trend-following base strategy. Many of these incremental returns are highly statistically significant. Others are not. The average statistical significances (one tail *t*-test) of the intraday return increments range from 4.7% to 20.6%. In addition, the patterns of the incremental returns are inconsistent with randomness. This is inconsistent with the null hypothesis that the exit rules provide no benefit. The intraday exit rules probably add return to the trend-following strategy.
- The results for the gap-reversal base strategy are less clear. The stop-loss exit rule provides positive incremental performance on average in all three of its forms. Average statistical significances only range from 21.3% to 34.0%. However, a number of the individual rules have a statistically significant performance. The profit-lock exit rule provides only negative incremental performance. The performance pattern is consistent with randomness. When both rules are used together, the poor performance of the profit-lock exit rule dominates.

The paper is organized as follows.

The second section is a brief literature review. Section 3 describes the data. The methodology is discussed in Section 4. Section 5 reviews the results. The conclusion is given in Section 6.

2 Literature review

Technical trading studies usually match exit and entry rules. Balsara (2003) demonstrates how a stop-loss rule based on historical unrealized losses can improve the profitability of a conventional moving average trading system (which can be slow responding to changing market conditions). His sample consisted of 15 stocks chosen from the Dow Jones (30) Industrial Average over the period January 1986 to December 2001.

Shyy (1989) adopts techniques from stochastic processes and searches for an optimal stop-loss trading rule in the Treasury Bond Futures contracts. Shyy assumes constant volatility and risk neutrality. A trader is assumed to buy one CBOT T-bond future at the open and liquidate the position at the close, unless the position is closed out during the day.

Schalow (1996) focuses on setting the stop-loss order's price. He suggests that stop-loss prices based on the standard deviation of day-to-day percent price changes are more effective than relatively arbitrary price rules. His motivation for basing the stop-loss orders price on the daily return standard deviation is that it should provide better control over Type I (stopping out when it is best not to) and Type II errors (failing to stop out when it is advantageous).

3 Data

This paper's exit rules are tested on the S&P 500 Index Futures contract, traded on the Chicago

Mercantile Exchange (CME). The data period is from September 1, 1987 to June 30, 2003. Since 250 days of prior open-to-close data are required for determining when transactions take place, trading days range from September 1, 1988 to June 30, 2003.

Some changes in how the futures contract was traded occurred during the data period.

- Trading hours were changed. Currently, trading hours are from 08:30 to 15:15 central time. From October 6, 1997 to November 15, 1997, trading hours were from 08:15 to 15:15.
- The contract size or multiplier of the S&P 500 Index Futures contract changed from 500 to 250 on October 31, 1997.

The methodology used in this paper is not sensitive to these changes.

4 Methodology

4.1 Intraday return correlations

The futures's intraday returns for a day are correlated with their return for yesterday and last night. The intraday returns are for sixteen time periods measured from the opening (in hours and minutes: 0:15, 0:30, 0:45, 1:00, 1:30, 2:00, 2:30, 3:00, 3:30, 4:00, 4:30, 5:00, 5:30, 6:00, 6:30, Close). The result is two series of correlation coefficients, associated with the previous day and overnight. Each of the correlations in the two series is tested using a two-tail t-test with the null hypothesis that the correlation coefficient is zero.

Intraday sequences of correlation coefficients with the same sign are suggestive of smooth time dependence. However, the intraday returns used to compute successive correlation coefficients are for overlapping periods. Consequently, appearances may be deceiving. One solution is to examine the changes in the intraday correlation coefficients. Then, runs of signs do suggest time dependence. Accordingly, correlation coefficient changes were computed and their signs were tested with a single tail runs test to see if the number of runs is low enough to reject the null hypothesis of no relationship.

4.2 Costs

All the returns in the study are pre-cost. While this overstates the achievable returns of both the base strategies and the exit rules, it should have negligible impact on the incremental return provided by the exit rules. This is because there are always two trades per day corresponding to creating and liquidating a single position.

4.3 Trading return signals

Daily opening and closing prices are used to calculate the trading signals for the base strategies. In addition, intraday returns are computed to determine if the exit rules are triggered. The following three continuous return signals are computed.

$$\begin{aligned} R_{\mathrm{OC}t} &\equiv \ln\left(P_{\mathrm{C}(t-1)}/P_{\mathrm{O}(t-1)}\right) \\ R_{\mathrm{CO}t} &\equiv \ln\left(P_{\mathrm{O}t}/P_{\mathrm{C}(t-1)}\right) \\ R_{\mathrm{OT}t} &\equiv \ln\left(P_{\mathrm{T}t}/P_{\mathrm{O}t}\right) \end{aligned} \tag{1}$$

where $P_{\mathrm{O}t}$ is the opening price for day t, $P_{\mathrm{C}t}$ the closing price for day t, P_{Tt} the intraday price for day t measured at time T, $R_{\mathrm{OC}t}$ the return signal for day t used with the trend-following base strategy, $R_{\mathrm{CO}t}$ the return signal for day t used with the gap-reversal base strategy, and $R_{\mathrm{OT}t}$ the return signal for day t used with exit rules.

The trend-following base strategy buys (sells) one contract if $R_{\mathrm{OC}t}$ is up (down) by 1.1% or more. The gap-reversal base strategy sells (buys) one contract if $R_{\mathrm{CO}t}$ is up (down) by 0.5% or more. These trigger

parameters are chosen to limit trading to an average of about one trade weekly. Base strategy positions are liquidated at the close. They produce 743 and 694 trading days for the trend-following and gap-reversal strategies, respectively.

The exit rules modify the base strategies by closing out positions before the close. The stop-loss exit rule sells long positions or covers short positions if the intraday futures return, $R_{\mathrm{OT}t}$, reaches a trigger level, $R_{\mathrm{T}t}$, on the downside or upside, respectively. The profit-lock exit rule sells long positions or covers short positions if $R_{\mathrm{OT}t}$ reaches $R_{\mathrm{T}t}$ on the upside or downside, respectively. $R_{\mathrm{T}t}$ is computed in one of the following three ways, depending on the particular test.

- A specified return.

  Ten specified returns are tested (as percents: 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0).

  This criterion is symmetric. $R_{\mathrm{T}t}$ is the same for both up and down movements and for every day. It does not change with the futures's volatility, which may lead to a smaller (larger) than desirable trigger in periods of high (low) volatility.

- A specified proportion of the standard deviation of daily futures returns measured over the previous 250 trading days.

  Ten proportions are tested (as percents: 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0).

  This criterion is symmetric with respect to up and down moves. However, this trigger's magnitude changes from day to day, increasing and decreasing as the future's volatility increases or decreases.

  Scaling the trigger return to the futures's volatility makes *a priori* sense.

- A specified fractile of the daily futures return distribution measured over the previous 250 trading days.

  Thirteen fractiles are tested (as percents: 70.0, 72.5, 75.0, 77.5, 80.0, 82.5, 85.0, 87.5, 90.0, 92.5, 95.0, 97.5, 100.0). For example, a trigger level corresponding to a fractile of 80% is implemented with a stop-loss limit at the 20% fractile (presumably negative) and a profit-lock limit at the 80% fractile (presumably positive).

  Since the futures's return distribution is neither constant nor symmetric, this trigger's magnitude is different for up and down moves and changes from day to day, increasing and decreasing as the future's return distribution changes.
  Scaling the trigger return to the futures's return distribution makes *a priori* sense.

The trigger return parameters were chosen arbitrarily. This minimizes *ex post* selection bias. However, it biases the exit rules' performance downward and tends to understate their statistical significance if the null hypothesis is false.

The two exit rules, applied singly and jointly, and the three ways of computing their trigger returns provide nine sets of tests each for the trend-following and gap-reversal strategies.

4.4 Base strategy intraday returns

Intraday returns are computed for the trend-following and gap-reversal base strategies for each day they are triggered and within each day for each of the sixteen intraday periods. Means are computed for each intraday period. Each of the mean returns is tested using a two-tail t-test with the null hypothesis that the mean return is zero.

As with the correlation coefficients, intraday sequences of mean returns with the same sign are suggestive of smooth time dependence but are misleading due to overlapping periods. Therefore, changes in the means are computed and their signs tested with a single tail runs test to see if the number

of runs is low enough to reject the null hypothesis of no relationship.

4.5 Exit rule performance analysis

A single test set involves one base strategy, one exit rule, and one trigger mode for the exit rule. The use of both the stop-loss and profit-lock exit rules in combination is counted as a third exit rule. Thus, there are 18 test sets ($2 \times 3 \times 3$).

When the stop-loss and profit-lock exit rules are applied in combination, the same trigger return is used for each exit rule and the position is liquidated according to whichever exit rule is triggered first.

The computations for each test set are as follows.

- Determine if the base strategy is activated for each day.
- If the base strategy is activated, compute its return.
- For each day the base strategy is activated, compute the applicable set of trigger returns $\{R_{\mathrm{T}t}\}$.
- For each day the base strategy is activated, determine the set of trigger returns that activate the exit rule.
- Compute the incremental return provided by each trigger return that activates the exit rule. This procedure provides an incremental return only for those days when the exit rule is activated by the trigger return.
- Compute the mean incremental return provided by each trigger return.
- Test the null hypothesis that the mean incremental return provided by each trigger return is zero using a one-tail paired-sample t-test and a one tail Wilcoxon matched pairs signed rank test.[5] The alternate hypothesis is that the incremental performance is positive.
- Compute the changes in the mean incremental returns across the trigger return parameters.
- Test the null hypothesis that the mean incremental returns provided by successive trigger return parameters are unrelated (i.e. that there is no functional relationship between incremental return and trigger return parameters). Do this with a one-tail runs test of the signs of the changes in mean incremental returns across trigger return parameters. Reject the null hypothesis if the number of runs is too low.

4.6 Empirical optimal exit rules

This analysis identifies the trigger return parameters that maximize mean incremental return across trigger return modes, exit rules, and base strategies (i.e. for the $3 \times 3 \times 2 = 18$ test sets).

For consistency, the data includes all the days the base strategy is activated, regardless of whether the exit rules are activated.

A one-tail t-test is used to test the null hypothesis that the true maximum mean incremental return is zero. Since the tested statistic is the result of a filtering process, the test's size is considerably larger than stated and hence should be interpreted with caution. Offsetting this bias, to an unknown degree, the tested trigger return parameters are an arbitrary subset of those available.

5 Results

5.1 Intraday return correlations

Table 1 presents the results from the correlations between one day's intraday returns and both the previous open to close and overnight returns.

The correlations between today's intraday returns and yesterday's open to close return are slightly negative from the open to 0:45 after the open, and positive for the remainder of the day except for

Table 1 Correlations and statistical significance; S&P 500 index futures, September 1987 to June 2003.

	$\text{Ln}(\text{close}_{t-1}/\text{open}_{t-1})$		$\text{Ln}(\text{open}_{t}/\text{close}_{t-1})$	
Intraday returns (open to open +)	Correlation coefficient	Significance level (%)	Correlation coefficient	Significance level (%)
0:15	−0.094	0.1	−0.084	0.1
0:30	−0.043	0.7	−0.185	0.1
0:45	−0.007	65.9	−0.072	0.1
1:00	0.029	6.7	−0.209	0.1
1:30	0.125	0.1	−0.287	0.1
2:00	0.185	0.1	−0.307	0.1
2:30	0.208	0.1	−0.298	0.1
3:00	0.196	0.1	−0.256	0.1
3:30	0.196	0.1	−0.234	0.1
4:00	0.112	0.1	−0.162	0.1
4:30	0.093	0.1	−0.124	0.1
5:00	0.047	0.3	−0.119	0.1
5:30	0.019	23.0	−0.125	0.1
6:00	−0.002	90.0	−0.076	0.1
6:30	0.019	23.0	−0.042	0.8
Close	0.030	5.8	−0.054	0.1
Averages	0.070	13.51	−0.165	0.14
Number of days	3991			

6:00. The time pattern can be characterized as an early rise from about zero peaking at from 2:00 to 3:30 after the opening with a subsequent decline to about zero. The average and maximum correlations are 0.07 and 0.208, respectively.

Two of the initial three negative and all the positive correlations from 1:30 to 5:00 after the opening are significant at the 1% level according to the two-tail *t*-tests. The remaining six correlations are not. The average *t*-test significance level is 13.5%.

The 16 correlation coefficients transform into 15 correlation coefficient changes, eight positive and seven negative, with four sign changes and five runs. The Wilcoxon runs test requires four runs or less to be significant at the 5% level. Thus, the runs test, although not quite significant at the 5% level, somewhat validates the *t*-test results and suggests that the intraday correlation coefficient pattern reflects an underlying time dependence.

The correlations between today's intraday returns and last night's return are all negative and significant at the 1% level according to the two-tail *t*-tests. A trough is reached from 1:00 to 3:30 after the opening, with a minimum of −0.307. The average correlation is −0.165. The average significance level is 0.14%.

The 16 correlation coefficients transform into 15 correlation coefficient changes, nine positive and

six negative, with six sign changes and seven runs. The Wilcoxon runs test requires 4 runs or less to be significant at the 5% level. Thus, there is some, but not much validation of underlying time dependence.

Since the magnitudes of both sets of correlation coefficients peak early to mid-afternoon, keeping positions open until the close may not be optimal. It seems reasonable to expect that the exit rules will provide positive incremental returns.

A trend-following strategy presumes a positive correlation between today's intraday return and a previous return. Thus, the trend-following base strategy is used with yesterday's return. A gap-reversal strategy presumes a negative correlation between today's intraday return and a previous return. Therefore, the gap-reversal base strategy is used with last night's return.

5.2 Base strategy intraday returns

Table 2 provides the intraday returns of the trend-following and gap-reversal base strategies. Figure 1 contains plots of these intraday returns. Roughly, the intraday returns of both base strategies begin

Table 2 Significance tests of intraday average cumulative price movements (%); two base strategies (open to close); S&P 500 index, September 1988 to June 2003.

	Trend-following (1.1% trigger)		Gap-reversal (0.5% trigger)	
Intraday returns (open to open + "hours")	Return (%)	Significance level (%)	Return (%)	Significance level (%)
0:15	0.034	0.2	−0.020	7.2
0:30	0.013	16.6	0.042	0.5
0:45	0.017	16.8	0.058	0.2
1:00	0.021	14.0	0.081	0.1
1:30	0.036	6.4	0.094	0.1
2:00	0.058	1.1	0.090	0.1
2:30	0.060	1.6	0.075	1.1
3:00	0.066	1.2	0.057	5.1
3:30	0.076	0.6	0.052	7.4
4:00	0.053	4.8	0.041	13.2
4:30	0.039	11.7	0.058	6.4
5:00	0.017	31.8	0.057	7.9
5:30	−0.005	45.1	0.055	9.8
6:00	−0.031	23.6	0.041	19.9
6:30	−0.044	17.7	−0.001	49.6
Close	−0.025	30.1	−0.008	43.9
Averages	0.024	14.0	0.048	10.8
Number of longs	367		348	
Number of shorts	376		346	
Total number of longs and shorts	743		694	

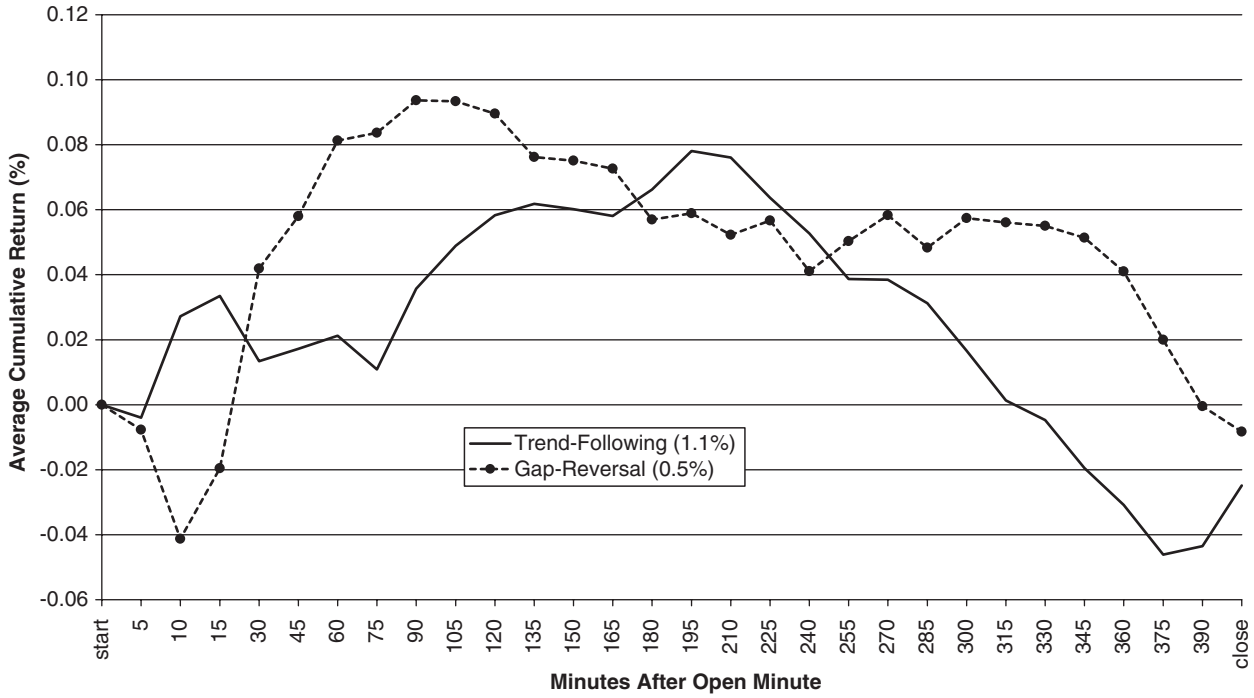

Figure 1 Intraday average cumulative price movement (%); two base strategies (open to close); S&P 500 index futures: 9/1/88–6/30/00.

at zero (of necessity), rise to a broad peak at about mid-day, and then decline to about zero.

That both base strategies' intraday returns peak well before the close suggests that the exit rules can provide incremental returns. That they have broad peaks suggests that spreading out trading may save more in transaction cost than a loss of gross return.

The trend-following base strategy's maximum intraday return is approximately 0.08%, with a broad peak from about 90 to 225 min after the opening. The gap-reversal base strategy's maximum intraday return peak is approximately 0.09%, with a broad peak from about 60 to 180 min after the opening.

The one-tail *t*-test significance levels for the trend-following base strategy average 14.0% over the intraday periods. Five of the 16 intraday returns are significant at the 1% level. The one-tail runs test of the signs of the changes in mean intraday returns is significant at the 2.5% level. All this suggests that the trend-following base strategy provides positive returns and has an underlying time dependence. The results for the gap-reversal strategy are similar. The average one-tail *t*-test significance is 10.8% and six of the 16 intraday returns are significant at the 1% level. The runs test of the signs of the changes in mean intraday returns is significant at the 5% level.

5.3 Trend-following base strategy with the percent change exit rule

Table 3a presents the results for the trend-following base strategy with the percent change based exit rule trigger.

The stop-loss exit rule provides an average incremental return of 0.17% across the 10 trigger return parameter values. All the incremental returns are

Table 3a Significance test of differences in percent and dollar profit; trend-following base strategy with percentage price change exit rule; relative to base strategy; null hypothesis: exit rule does not increase performance. S&P 500 index futures: September 1988 to June 2003.

Required change (%)	Number of trades	Average performance difference (%)	*t*-Test significance level (%)	Wilcoxon significance level (%)
Stop-loss strategy versus base strategy				
0.2	574	0.0309	27.8	18.6
0.4	459	0.0840	7.2	11.0
0.6	355	0.1012	6.6	7.1
0.8	288	0.1441	2.1	6.4
1.0	212	0.1599	3.1	14.3
1.2	160	0.2014	2.8	5.6
1.4	125	0.2111	4.5	10.5
1.6	96	0.2496	4.6	15.8
1.8	72	0.1807	13.6	18.2
2.0	54	0.3086	9.6	15.0
Averages		0.1672	8.2	12.3
Profit-lock strategy versus base strategy				
0.2	606	0.0601	12.7	5.8
0.4	487	0.0989	5.5	4.2
0.6	390	0.1231	4.2	1.9
0.8	314	0.1040	7.7	4.2
1.0	237	0.1558	4.9	1.5
1.2	196	0.1763	4.7	0.9
1.4	146	0.2300	4.3	1.2
1.6	112	0.1954	11.7	6.3
1.8	84	0.1177	25.4	15.7
2.0	69	0.1440	24.5	18.7
Averages		0.1405	10.6	6.0
Stop-loss/profit-lock strategies versus base strategy				
0.2	711	0.0377	21.8	12.6
0.4	685	0.0641	9.4	3.5
0.6	616	0.1027	2.2	0.4
0.8	547	0.1043	2.3	1.9
1.0	418	0.1099	4.2	2.4
1.2	341	0.1590	1.6	0.5
1.4	262	0.1764	2.5	1.2
1.6	202	0.1796	4.7	3.3
1.8	153	0.1391	13.0	9.3
2.0	121	0.2045	9.7	10.0
Averages		0.1277	7.1	4.5

positive, ranging from 0.03% to 0.31%. The average one-tail *t*-test significance is 8.2%. Five of the 10 *t*-tests are significant at the 5% level. The average one-tail Wilcoxon test significance is 12.3%, with none of the 10 tests significant at the 5% level. The runs test of the signs of the changes in incremental returns across the trigger return parameters requires two runs or less to be significant at the 5% level. There are three runs, so the null hypothesis that there is no smooth functional relationship between the exit rule's performance and its trigger return level is rejected at the 5% level. Nevertheless, the composite picture presented by all the tests suggests that the exit rule does provide positive performance and that the performance is smoothly related to the trigger return parameter level.

The profit-lock exit rule improves performance by an average of 0.14%, with a range from 0.06% to 0.23%. All the incremental returns are positive. One-tail *t*- and Wilcoxon tests average significant at the 10.6% and 6.0% levels, respectively. Four of the *t*- and six of the Wilcoxon tests are significant at the 5% level. There are five runs in the signs of the performance changes compared to the two or less required to reject the null hypothesis of no smooth relationship between exit rule performance and trigger return parameter level. Nevertheless, the composite picture suggests positive performance and a relationship between performance and trigger parameter level.

Using the stop-loss and profit-lock exit rules in combination results in more significant *t*- and Wilcoxon tests than for either exit rule used alone. The runs test results are the same as for the stop-loss exit rule alone.

The pattern of incremental performance over the trigger return parameter level is relatively smooth for all three test sets.

It is probably fair to characterize this set of tests as promising.

5.4 Trend-following base strategy with the standard deviation based exit rule

Table 3b presents the results for the trend-following base strategy with the standard deviation based exit rule.

Average incremental returns provided by the stop-loss, profit-lock, and Both exit rules are 0.15%, 0.09%, and 0.10%, respectively. Note that combining the two rules does not improve on the average performance of the better of the two. Maximum performances are 0.35%, 0.20%, and 0.16% for these exit rules, respectively. The average significance levels are 14.1%, 20.6%, and 13.9% for the one-tail *t*-test and 23.2%, 12.4%, and 10.7% for the Wilcoxon test. While these significance levels are not notable, the results for several trigger return parameter levels are highly significant. None of the runs tests on the changes in incremental returns is close to significant at the 5% level.

These results, while suggestive, are not as strong as those for the percent change based trigger return.

5.5 Trend-following base strategy with the fractile based exit rule

Results for this strategy are in Table 3c.

This strategy is characterized by little evidence of a smooth functional relationship between performance and trigger return parameter level, reasonable performance, and impressive significance levels in the *t*- and Wilcoxon tests.

Average performances for the stop-loss, profit-lock, and Both exit rules are 0.26%, 0.11%, and 0.16%, respectively, with maxima of 1.36%, 0.20%, and 0.67%. However, the stop-loss maximum of 1.36%, which also drives the Both maximum, appears to be an outlier.

Table 3b Significance test of differences in percent profit; trend-following base strategy with number of standard deviations change exit rule; relative to base strategy; null hypothesis: exit rule does not increase performance. S&P 500 index futures: September 1988 to June 2003.

Required standard deviations (%)	Number of trades	Average performance difference (%)	*t*-Test significance level (%)	Wilcoxon significance level (%)
Stop-loss strategy versus base strategy				
0.2	579	0.0022	48.3	43.5
0.4	452	0.0575	15.8	18.7
0.6	336	0.1310	2.5	1.7
0.8	256	0.1354	2.1	5.5
1.0	199	0.1289	6.9	24.2
1.2	141	0.1774	5.1	27.4
1.4	98	0.1717	12.4	32.7
1.6	78	0.0792	30.7	40.1
1.8	55	0.3012	8.9	13.8
2.0	43	0.3492	8.7	24.2
Averages		0.1534	14.1	23.2
Profit-lock strategy versus base strategy				
0.2	599	0.0597	13.1	9.1
0.4	485	0.1025	4.7	2.8
0.6	376	0.0996	6.8	2.1
0.8	288	0.0799	15.1	4.7
1.0	226	0.1122	11.0	2.0
1.2	167	0.1812	6.2	1.0
1.4	126	0.1967	9.0	2.3
1.6	88	0.0176	45.7	26.4
1.8	67	0.0464	41.0	36.1
2.0	53	−0.0181	53.0	37.0
Averages		0.0878	20.6	12.4
Stop-loss/profit-lock strategies versus base strategy				
0.2	714	0.0307	26.3	17.2
0.4	689	0.0566	11.8	4.0
0.6	613	0.1089	1.4	0.3
0.8	502	0.0791	6.6	2.1
1.0	404	0.0958	6.5	2.9
1.2	298	0.1591	2.1	0.8
1.4	220	0.1394	8.2	3.8
1.6	164	0.0366	37.5	27.9
1.8	120	0.1497	16.3	19.1
2.0	95	0.1319	22.7	28.9
Averages		0.0988	13.9	10.7

Table 3c Significance test of differences in percent profit; trend-following base strategy with fractile change exit rule; relative to base strategy; null hypothesis: exit rule does not increase performance. S&P 500 index futures: September 1988 to June 2003.

Required fractile	Number of trades	Average performance difference (%)	*t*-Test significance level (%)	Wilcoxon significance level (%)
Stop-loss strategy versus base strategy				
70.0	435	0.0862	6.8	5.5
72.5	405	0.0995	4.2	6.2
75.0	365	0.1205	2.4	4.8
77.5	328	0.1466	1.1	2.9
80.0	301	0.1423	1.7	5.6
82.5	264	0.1678	0.9	6.8
85.0	229	0.1628	1.9	9.2
87.5	192	0.1527	4.6	17.6
90.0	165	0.1418	8.2	29.4
92.5	123	0.2111	4.9	8.4
95.0	92	0.2072	9.5	22.5
97.5	50	0.3335	10.2	12.4
100.0	9	1.3643	5.2	10.7
Averages		0.2566	4.7	10.9
Profit-lock strategy versus base strategy				
70.0	457	0.1088	3.5	1.9
72.5	427	0.1256	2.3	0.8
75.0	399	0.1185	3.4	1.1
77.5	352	0.0927	9.3	4.7
80.0	319	0.1040	8.1	3.5
82.5	273	0.0919	12.9	3.9
85.0	246	0.0723	20.2	8.2
87.5	215	0.1216	10.2	2.1
90.0	183	0.1327	11.0	2.3
92.5	143	0.1995	6.4	0.7
95.0	104	0.1633	13.5	3.1
97.5	59	0.1007	32.9	21.6
100.0	10	0.0499	46.9	32.3
Averages		0.1140	13.9	6.6
Stop-loss/profit-lock strategies versus base strategy				
70.0	684	0.0822	4.1	1.0
72.5	669	0.0844	3.7	0.7
75.0	641	0.0920	2.7	0.7
77.5	598	0.0955	2.9	1.9

Table 3c (*continued*)

Required fractile	Number of trades	Average performance difference (%)	*t*-Test significance level (%)	Wilcoxon significance level (%)
80.0	551	0.1054	2.3	1.9
82.5	494	0.1038	3.0	2.4
85.0	445	0.0850	7.5	5.0
87.5	384	0.1146	4.3	1.8
90.0	331	0.1093	6.9	3.5
92.5	255	0.1721	2.8	0.4
95.0	191	0.1537	7.4	3.9
97.5	107	0.1503	18.1	12.4
100.0	19	0.6725	10.3	27.3
Averages		0.1554	5.8	4.8

Table 4a Significance test of differences in percent profit; gap-reversal base strategy with percentage price change exit rule; relative to base strategy; null hypothesis: exit rule does not increase performance. S&P 500 index futures: September 1988 to June 2003.

Required change (%)	Number of trades	Average performance difference (%)	*t*-Test significance level (%)	Wilcoxon significance level (%)
Stop-loss strategy versus base strategy				
0.2	536	0.0799	7.9	1.1
0.4	434	0.1234	2.3	0.1
0.6	375	0.0808	11.5	0.3
0.8	302	0.0755	12.5	1.1
1.0	241	0.0501	26.2	4.5
1.2	208	0.0074	46.6	15.0
1.4	150	0.0062	47.7	18.2
1.6	123	−0.0531	66.9	63.0
1.8	87	0.0092	47.1	50.0
2.0	68	0.0001	50.0	48.5
Averages		0.0380	31.9	20.2
Profit-lock strategy versus base strategy				
0.2	537	−0.0401	75.1	60.5
0.4	454	−0.0341	70.0	54.1
0.6	381	−0.0414	71.6	53.3

Table 4a (*continued*)

Required change (%)	Number of trades	Average performance difference (%)	*t*-Test significance level (%)	Wilcoxon significance level (%)
0.8	323	−0.0313	66.0	51.3
1.0	250	−0.0670	77.4	62.3
1.2	206	−0.0468	67.9	52.9
1.4	166	−0.0143	54.8	55.9
1.6	128	−0.0724	69.7	63.8
1.8	104	−0.0077	52.1	59.9
2.0	83	−0.0856	67.4	55.8
Averages		−0.0441	67.2	57.0
Stop-loss/profit-lock strategies versus base strategy				
0.2	666	−0.0020	51.5	73.4
0.4	647	0.0156	38.4	9.7
0.6	621	0.0261	31.4	3.1
0.8	555	0.0004	49.7	16.3
1.0	460	−0.0172	61.4	77.6
1.2	395	−0.0190	61.4	74.0
1.4	304	−0.0041	52.1	75.0
1.6	244	−0.0567	73.8	63.5
1.8	188	−0.0153	56.2	50.4
2.0	149	−0.0624	69.3	50.4
Averages		−0.0135	54.5	49.3

Average significances for the *t*- and Wilcoxon tests are 4.7% and 10.9% for the stop-loss rule, 13.9% and 6.6% for the profit-lock rule, and 5.8% and 4.8% for Both. Many of the individual tests are highly significant.

5.6 Gap-reversal base strategy with the percent change, standard deviation, and fractile based exit rules

The results for the percent change, standard deviation, and fractile based exit rule trigger returns are shown in Tables 4a, 4b, and 4c, respectively. The format is the same as for Tables 3 and hence can be interpreted in the same way.

Judging from Tables 4, none of these strategies provides notable and reliably statistically significant results. It is tempting to conclude that the adage "cut your losses and let your profits run" has an element of truth.

5.7 Empirical optimal incremental returns

Tables 5 and 6 contain the empirical optimum performances provided by the trend-following and gap-reversal base strategies with exit rules. These empirical optima reflect a filtering process, i.e. many combinations were tried and the best noted. Unadjusted statistical significance tests have larger Type I

Table 4b Significance test of differences in percent profit; gap-reversal base strategy with number of standard deviations change exit rule; relative to base strategy; null hypothesis: exit rule does not increase performance. S&P 500 index futures: September 1998 to June 2003.

Required standard deviations (%)	Number of trades	Average performance difference (%)	*t*-Test significance level (%)	Wilcoxon significance level (%)
Stop-loss strategy versus base strategy				
0.2	520	0.1095	2.5	0.4
0.4	438	0.0667	13.7	1.4
0.6	340	0.1004	5.7	0.9
0.8	276	0.0638	18.8	2.3
1.0	216	0.0536	25.8	3.9
1.2	168	−0.0288	61.5	51.2
1.4	116	−0.0659	69.2	52.1
1.6	87	0.0319	40.0	67.5
1.8	68	−0.0089	52.4	57.3
2.0	55	−0.0031	50.8	65.0
Averages		0.0319	34.0	30.2
Profit-lock strategy versus base strategy				
0.2	540	−0.0356	72.4	53.7
0.4	452	−0.0533	79.5	62.9
0.6	363	−0.0414	71.3	59.2
0.8	282	−0.0695	81.5	81.2
1.0	222	−0.0782	79.4	73.0
1.2	172	−0.1131	84.5	80.4
1.4	136	−0.1224	82.6	79.4
1.6	110	−0.0643	67.6	73.9
1.8	84	−0.2053	87.3	83.3
2.0	66	−0.2315	86.2	72.3
Averages		−0.1015	79.2	71.9
Stop-loss/profit-lock strategies versus base strategy				
0.2	669	−0.0061	54.5	74.2
0.4	666	−0.0014	51.1	84.3
0.6	599	0.0141	39.4	11.7
0.8	514	−0.0088	56.5	73.6
1.0	416	−0.0097	56.1	80.2
1.2	330	−0.0635	81.1	66.3
1.4	248	−0.0995	87.1	76.3
1.6	195	−0.0340	63.7	61.9
1.8	150	−0.1312	86.2	78.8
2.0	120	−0.1415	85.2	82.8
Averages		−0.0482	66.1	69.0

Table 4c Significance test of differences in percent profit; gap-reversal base strategy with fractile change exit rule; relative to base strategy; null hypothesis: exit rule does not increase performance. S&P 500 index futures: September 1998 to June 2003.

Required fractile (%)	Number of trades	Average performance difference (%)	*t*-Test significance level (%)	Wilcoxon significance level (%)
Stop-loss strategy versus base strategy				
70.0	409	0.1305	1.2	0.1
72.5	384	0.1071	3.8	0.4
75.0	348	0.0978	6.3	0.8
77.5	342	0.0847	9.2	0.9
80.0	311	0.0733	13.7	1.3
82.5	273	0.0901	10.5	0.9
85.0	246	0.0945	10.6	1.3
87.5	216	0.0222	39.5	15.4
90.0	179	0.0332	36.5	8.8
92.5	134	0.0217	42.5	19.0
95.0	101	0.0694	26.1	31.1
97.5	61	−0.0422	60.4	65.0
100.0	6	0.6643	16.3	23.2
Averages		0.1113	21.3	12.9
Profit-lock strategy versus base strategy				
70.0	427	−0.0440	74.8	53.5
72.5	403	−0.0574	80.3	61.7
75.0	376	−0.0561	78.9	66.2
77.5	343	−0.0928	89.7	82.0
80.0	308	−0.0800	84.5	73.3
82.5	278	−0.1399	95.9	92.7
85.0	254	−0.1080	89.8	84.6
87.5	225	−0.1005	86.0	83.4
90.0	197	−0.1004	84.1	79.9
92.5	158	−0.0889	77.1	73.5
95.0	125	−0.1536	87.0	85.6
97.5	75	−0.1363	74.0	66.7
100.0	13	−1.0447	96.5	93.4
Averages		−0.1694	84.5	76.7
Stop-loss/profit-lock strategies versus base strategy				
70.0	657	0.0216	33.4	7.5
72.5	640	0.0135	39.7	13.1
75.0	607	0.0079	44.0	14.1
77.5	590	−0.0098	57.4	79.4

Table 4c (*continued*)

Required fractile (%)	Number of trades	Average performance difference (%)	*t*-Test significance level (%)	Wilcoxon significance level (%)
80.0	556	−0.0101	57.4	80.0
82.5	508	−0.0198	63.9	72.4
85.0	473	−0.0045	53.1	75.6
87.5	420	−0.0368	72.2	51.6
90.0	362	−0.0265	65.0	67.5
92.5	283	−0.0297	64.3	57.8
95.0	222	−0.0787	81.7	69.4
97.5	134	−0.1407	86.0	74.4
100.0	19	−0.5050	85.5	76.6
Averages		−0.0630	61.8	56.9

Table 5 Optimal stop-loss/profit-lock exit rules and levels; trend-following base strategy (743 trades); relative to base strategy; null hypothesis: exit rule does not increase performance. S&P 500 index futures: September 1988 to June 2003.

	Stop-loss only		Profit-lock only		Stop-loss/profit-lock	
	Average performance difference (%)	*t*-Test significance level (%)	Average performance difference (%)	*t*-Test significance level (%)	Average performance difference (%)	*t*-Test significance level(%)
Panel A: percentage price change exit rule						
Required change (%)						
0.2	0.0239	27.8	0.0490	12.7	0.0360	21.8
0.4	0.0519	7.2	**0.0648**	5.5	0.0591	9.4
0.6	0.0484	6.6	0.0646	4.2	**0.0851**	2.2
0.8	**0.0559**	2.2	0.0439	7.7	0.0768	2.3
1.0	0.0456	3.1	0.0497	4.9	0.0618	4.3
1.2	0.0434	2.9	0.0465	4.8	0.0730	1.6
1.4	0.0355	4.6	0.0452	4.4	0.0622	2.5
1.6	0.0322	4.7	0.0295	11.8	0.0488	4.8
1.8	0.0175	13.6	0.0133	25.3	0.0286	13.0
2.0	0.0224	9.7	0.0134	24.4	0.0333	9.8
Panel B: number of standard deviations decline exit rule						
Required standard deviations (%)						
0.2	0.0017	48.3	0.0482	13.1	0.0295	26.3
0.4	0.0350	15.8	**0.0669**	4.7	0.0525	11.8
0.6	**0.0593**	2.5	0.0504	6.8	**0.0899**	1.4
0.8	0.0466	2.2	0.0310	15.1	0.0534	6.6
1.0	0.0345	6.9	0.0341	11.0	0.0521	6.5
1.2	0.0337	5.2	0.0407	6.3	0.0638	2.2
1.4	0.0226	12.4	0.0334	9.1	0.0413	8.2
1.6	0.0083	30.6	0.0021	45.7	0.0081	37.5
1.8	0.0223	9.1	0.0042	41.0	0.0242	16.3
2.0	0.0202	8.9	−0.0013	53.1	0.0169	22.6

Table 5 (*continued*)

	Stop-loss only		Profit-lock only		Stop-loss/profit-lock	
	Average performance difference (%)	*t*-Test significance level (%)	Average performance difference (%)	*t*-Test significance level (%)	Average performance difference (%)	*t*-Test significance level (%)
Panel C: fractile decline exit rule						
Required fractile (%)						
70.0	0.0505	6.8	0.0669	3.5	0.0757	4.1
72.5	0.0543	4.2	**0.0722**	2.3	0.0760	3.7
75.0	0.0592	2.4	0.0636	3.4	**0.0794**	2.7
77.5	**0.0647**	1.1	0.0439	9.3	0.0769	2.9
80.0	0.0577	1.7	0.0447	8.1	0.0781	2.3
82.5	0.0596	0.9	0.0338	12.9	0.0690	3.0
85.0	0.0502	1.9	0.0239	20.2	0.0509	7.5
87.5	0.0395	4.6	0.0352	10.2	0.0592	4.3
90.0	0.0315	8.2	0.0327	11.0	0.0487	6.9
92.5	0.0349	5.0	0.0384	6.5	0.0591	2.8
95.0	0.0257	9.6	0.0229	13.5	0.0395	7.4
97.5	0.0224	10.3	0.0080	32.8	0.0216	18.1
100.0	0.0165	6.7	0.0007	46.8	0.0172	10.7

Table 6 Optimal stop-loss/profit-lock exit rules and levels; gap-reversal base strategy (694 trades); relative to base strategy; null hypothesis: exit rule does not increase performance. S&P 500 index futures: September 1988 to June 2003.

	Stop-loss only		Profit-lock only		Stop-loss/profit-lock	
	Average performance difference (%)	*t*-Test significance level (%)	Average performance difference (%)	*t*-Test significance level (%)	Average performance difference (%)	*t*-Test significance level (%)
Panel A: percentage price change exit rule						
Required change (%)						
0.2	0.0617	8.5	−0.0310	74.5	−0.0019	51.5
0.4	**0.0772**	2.6	−0.0223	69.5	0.0146	38.7
0.6	0.0437	12.2	−0.0227	71.1	**0.0233**	31.8
0.8	0.0329	13.2	−0.0146	65.6	0.0004	49.7
1.0	0.0174	26.8	−0.0241	76.8	−0.0114	61.1
1.2	0.0022	46.7	−0.0139	67.4	−0.0108	61.1
1.4	0.0013	47.8	−0.0034	54.7	−0.0018	52.0
1.6	−0.0094	66.5	−0.0134	69.3	−0.0199	73.2
1.8	0.0012	47.2	−0.0012	52.1	−0.0041	56.0
2.0	0.0000	50.0	−0.0102	67.0	−0.0134	68.9
Panel B: number of standard deviations decline exit rule						
Required standard deviations (%)						
0.2	**0.0820**	2.8	−0.0277	71.9	−0.0059	54.4
0.4	0.0421	14.4	−0.0347	78.9	−0.0013	51.0
0.6	0.0492	6.3	−0.0217	70.8	**0.0122**	39.7
0.8	0.0254	19.4	−0.0282	80.9	−0.0065	56.3
1.0	0.0167	26.3	−0.0250	78.7	−0.0058	55.9
1.2	−0.0070	61.2	−0.0280	83.8	−0.0302	80.4

Table 6 (*continued*)

	Stop-loss only		Profit-lock only		Stop-loss/profit-lock	
	Average performance difference (%)	*t*-Test significance level (%)	Average performance difference (%)	*t*-Test significance level (%)	Average performance difference (%)	*t*-Test significance level (%)
1.4	−0.0110	68.7	−0.0240	81.9	−0.0356	86.4
1.6	0.0040	40.2	−0.0102	67.2	−0.0095	63.4
1.8	−0.0009	52.3	−0.0249	86.6	−0.0284	85.5
2.0	−0.0002	50.8	−0.0220	85.5	−0.0245	84.5
Panel C: fractile decline exit rule						
Required fractile (%)						
70.0	**0.0769**	1.4	−0.0271	74.2	**0.0205**	33.8
72.5	0.0593	4.2	−0.0333	79.6	0.0124	40.0
75.0	0.0490	6.9	−0.0304	78.2	0.0069	44.2
77.5	0.0417	9.9	−0.0458	89.1	−0.0084	57.2
80.0	0.0328	14.3	−0.0355	83.8	−0.0081	57.2
82.5	0.0354	11.2	−0.0560	95.5	−0.0145	63.5
85.0	0.0335	11.2	−0.0395	89.1	−0.0031	53.1
87.5	0.0069	39.7	−0.0326	85.3	−0.0223	71.7
90.0	0.0086	36.8	−0.0285	83.4	−0.0138	64.6
92.5	0.0042	42.7	−0.0202	76.5	−0.0121	63.9
95.0	0.0101	26.6	−0.0277	86.3	−0.0252	81.0
97.5	−0.0037	60.1	−0.0147	73.5	−0.0272	85.3
100.0	0.0057	16.9	−0.0196	94.8	−0.0138	84.8

error than on their face. Thus, the significance levels shown for the optimum combinations of trigger return parameters should be treated with caution.

As before, the trend-following base strategy with exit rules shows considerable promise and the gap-reversal base strategy with exit rules does not.

6 Conclusion

Intraday stop-loss exit rules appear to add return to a trend-following base strategy of buying index futures at the opening and closing out the position at the close. There is no strong evidence that the same is true of profit-lock exit rules or that either work with a gap-reversal strategy.

For the data used in this paper, the intraday exit rules increase the returns of the trend-following base strategy. Many of these incremental returns are highly statistically significant. Others are not. The average statistical significances (one tail *t*-test) of the intraday return increments range from 4.7% to 20.6%. In addition, the patterns of the incremental returns are inconsistent with randomness. This is inconsistent with the null hypothesis that the exit rules provide no benefit. The intraday exit rules probably do add return to the trend-following strategy.

The results for the gap-reversal base strategy are less clear. The stop-loss exit rule provides positive incremental performance on average in all three of its forms. Average statistical significances only range from 21.3% to 34.0%. However, a number of individual rules have statistically significant performance. The profit-lock exit rule only provides negative incremental performance. The performance pattern is consistent with randomness. When both rules are used together, the poor performance of the profit-lock exit rule dominates.

Notes

[1] See, for example, Yu *et al.* (2003).

[2] Hence the adage "cut your losses and let your profits run."

[3] Roughly, half of the paths are cut at the first move, since there is a 50–50 chance of a move down. Measuring from after the first move, about half of the paths end up. These up paths are cut at move one. Of the paths that have a first move up, about half end up and half end down. But many of the up paths turn down at some point and are cut.

[4] It does not make sense for an expected return maximizer to use a base strategy with short positions in index futures unless their efficacy provides an offset to the reduction of exposure. However, investors interested in stop-loss or profit-lock exit rules, probably, are not expected return maximizers.

[5] The Wilcoxon test's efficiency is about 95% relative to the *t*-test when the latter is appropriate.

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