Money or Mirage? Testing an Intraday Moving Average Trading Strategy on Exchange Traded Funds

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Abstract

Indexes cannot be traded directly, so trading strategies found profitable on indexes ultimately need to be tested on some tradable substitutes, such as exchange traded funds (ETFs). This paper tests the simple technical trading rule of moving average (MA) in a long-only portfolio against the buy-and-hold benchmark. Also, we implement a more realistic intraday version of the MA strategy that allows investors to trade immediately upon seeing MA crossover signals. We find that 1) the new intraday MA strategy outperforms the traditional version of the strategy that only trades at the close of a trading day. 2) The documented profitability of MA strategy on indexes is greatly reduced on ETFs, mainly due to more frequent and larger opening gaps on ETF prices than those on indexes. And 3) even on indexes none of these strategies can outperform the buy-and-hold benchmark in a long-only portfolio. In addition, we find that among various long-term MA lengths, the 10-day MA turns out to be overly exploited by investors as its performance is significantly lower than those of surrounding MA lengths. Overall, our findings imply that documented profitable trading strategies on non-tradable indexes may not survive a test on tradable ETFs comparing to the buy-and-hold benchmark.

JEL Classification: G11, G14, D83

Key Words: Moving average; Technical trading rules; Data-snooping bias; Exchange traded funds

1 Introduction

The technical trading rule of moving average (MA) has been found profitable in many recent studies. In its simplest form of variable holding length MA, all that the strategy requires is to buy whenever the short-term MA crosses above the long-term MA (i.e., *golden cross*), and sell when the short-term MA dives below the long-term MA (i.e., *death cross*). Therefore, it is hard to believe the MA profitability can persist in an increasingly efficient market. Since the seminal work of Block, Lakonishok, and LeBaron (1992) who find the MA strategy does generate statistically significant profit, efforts have been made to explain this anomaly in several directions. Most of the later research focuses on the possibility of *data-snooping bias* and the finding turns out to be mixed, with Sullivan, Timmermann, and White (1999) reporting that technical trading rules are robust to data-snooping bias, yet Allen and Karjalainen (1999) and Bajgrowicz and Scaillet (2012) showing the opposite. Other authors, such as Bessembinder and Chan (1998) and LeBaron (1999), reported that the break-even *transaction cost* is too large to explain the MA profitability. Recently, Han, Yang, and Zhou (2012) find that a number of widely used *risk factors* cannot explain the profitability of the MA strategy, such that in a sequel paper Han and Zhou (2012) propose the profitability of the MA strategy could be a new risk factor. Overall, the literature cannot fully explain the MA profitability by data-snooping bias, transaction cost, or risk factors.

There are several other directions that can be explored about the MA trading strategies. Firstly, we notice that almost all studies on moving average are backtested on market or sector indexes (or the equivalent entire replicating portfolios).[1] However, investors trying to deploy strategies documented in academic literature have to find a close substitute to trade with. For example, exchange traded funds (ETFs) that have very low transaction cost are perfect to apply the MA strategy. Therefore, we would like to focus our analysis on ETFs to see how the MA strategy fares in tradable securities. Secondly, due to the limitation

[1] Exceptions include LeBaron (1999) who tests on foreign exchange rates and Hsu, Hsu, and Kuan (2010) including nine ETFs in their research.

of daily return data, one simplification in the existing literature is assuming that the MA strategy only trades at the close of a trading day although an MA crossover signal can happen anytime during the day. In this study, we implement a more realistic MA strategy that allows an investor to trade immediately upon seeing an MA signal intraday. Finally, most studies on the MA strategy, especially those finding profitability, use zero or the risk-free rate as the performance benchmark under a long-short zero-balance portfolio. Given the short-sale constraints faced by many investors and the poor liquidity of the short legs, we instead test the MA strategy on long-only portfolios whose benchmark is the buy-and-hold strategy. Overall, our efforts are aimed to better reflect the real world situation when an investor actually implements the MA strategy.

Specifically, our new *intraday MA strategy* allows an investor to trade immediately when there is a golden or death cross signal. In contrast, the existing MA strategy implemented in the literature only trades at the closing price so that the trade only affects the next-day strategy return (let's denote it the *next-day MA strategy* hereafter). By not waiting to the close, the intraday strategy captures part of the profit or avoids some of the loss on days with MA crossovers because the buy(sell) signals are mostly generated on very bullish(bearish) days. One obvious trade off to this benefit is when the intraday MA crossover is later reverted before the close. In this scenario, the investor needs to rewind the previous trade at the end of the trading day suffering a loss, not to mention losing round-trip transaction costs. Another drawback is when the MA crossover occurs at the opening of a trading day due to an opening gap, the investor cannot immediately trade at the desired price which is the lagged long-term moving average. Under this situation, either trading immediately at the unfavorable opening price through a market order, or waiting for a possible price reversal via a limit order (which may not be filled) incurs a performance drag. Nonetheless, our statistics indicate an overall performance improvement of the intraday MA strategy relative to the next-day MA strategy. The performance gain from responding to MA crossover signals quickly outweighs the two possible losses from reverted intraday signals and opening gaps.

Our findings show that the documented profitability of the MA strategy on indexes is greatly reduced on ETFs, for both the intraday and the next-day versions of the strategy. When the short-term MA is 1-day[2] (i.e., the current stock price) and the long-term MA ranges from 5 to 200 days, the intraday MA strategy applied on indexes outperforms the same strategy applied on corresponding ETFs in almost all cases. While the index performance beats the passive buy-and-hold strategy especially for the S&P500 index, on ETFs only in very few cases does the intraday MA strategy outperform the buy-and-hold strategy. When we repeat the above analysis using the traditional next-day version of the MA strategy, ETFs deliver roughly the same results as indexes do. Moreover, even on indexes the next-day MA strategy cannot outperform the buy-and-hold strategy without any transaction cost. This finding shows that the documented MA profit is not robust in a long-only portfolio whose benchmark is the buy-and-hold strategy.[3] Overall, our results indicate that 1) the new intraday MA strategy performs better than the traditional next-day MA strategy, 2) MA profitability found on indexes is greatly reduced when traded on ETFs, and 3) the traditional next-day MA strategy underperforms the passive buy-and-hold strategy when implemented with a long-only portfolio.

We then investigate the intriguing question of why the intraday MA strategy effective on indexes does not work on ETFs, even though ETFs closely track the corresponding indexes. One possibility, as pointed by Bessembinder and Chan (1998), is the omission of dividends in index data. ETF data, on the other hand, does contain the daily return information that is adjusted for dividend[4]. However, we find dividend is not the main reason since even when we strip away all the dividend information from ETF prices/returns, the performance difference is still there without too much change. Instead, we find that the price discontinuity at the

[2]While we focus on the 1-day short-term MA, we also test the 5-day short-term MA for robustness. Our main conclusions are the same.

[3]The literature mostly finds the moving average rule generating "absolute returns" which implies a benchmark of zero or the risk-free rate. See, for example, Block, Lakonishok, and LeBaron (1992), Bessembinder and Chan (1998), and Sullivan, Timmermann, and White (1999).

[4]Elton, Gruber, Comer, and Li (2002) find there are about 10 bps annual performance drag from SPY because they put dividend in a non-interest-bearing account, but this is too small to explain the large performance difference we find in this study.

opening, i.e. opening gaps, plays a major role in lowering the ETF performance. Using the 10-day MA as an example, we find only 10% of the MA crosses occur at the opening gap for the S&P500 index, while this ratio jumps to 29% for the SPY during the same time period. As a result, the S&P500 index only loses an average of 1 bps (basis point) return on MA signal days versus 10 bps for the SPY. In other words, our findings show that ETFs are more efficient than indexes in reflecting information at opening, which leaves smaller room for investors to respond to and profit from MA crossover signals.

Our study addresses the empirical finding why a simple technical trading strategy can remain profitable over long time. Surprisingly, the answer turns out to be that the MA strategy never worked for a real world investor, who has to trade on liquid and tradable assets, suffers from attrition due to opening gaps, and is constantly evaluated against the passive buy-and-hold benchmark. Academic research on technical trading strategies could reach a too optimistic conclusion if details of real world trading are under-emphasized.

Our study is related to Hsu, Hsu, and Kuan (2010) who also include nine ETFs in their empirical test of the MA strategies. In a large strategy space including 9120 MA rules and 7260 filter rules, they find there are fewer strategies outperforming the risk-free benchmark when ETFs are introduced. The fundamental difference in their research is that they compare MA performances on indexes and their corresponding ETFs in *different* eras: indexes for pre-ETF and ETFs for post-ETF years. In fact, the MA performances in two different eras could be caused by many other factors. For instance, Chordia, Subrahmanyam and Tong (2013) find stock market anomalies decrease in profitability over time due to increased trading activity and market efficiency, so it is not surprising to see technical trading rules fade in recent years compared to old days. Moreover, a number of recent studies also document the effect of academic publications on the profitability of anomalies (see., e.g., Huang and Huang, 2014; Schwert, 2003). With the majority of the MA papers published in the 1990's, MA profitability can decrease simply due to more publicity. In contrast, we run a horserace between index-ETF pairs over the same time period to test the most direct feature of ETFs—

that they are tradable. In addition, we use the buy-and-hold strategy as the benchmark, instead of the risk-free rate in Hsu, Hsu, and Kuan (2010). Finally, unlike in Hsu, Hsu, and Kuan (2010), we exclude international ETFs for the testing of MA strategy. Due to trading time difference, ETFs following foreign markets have very large opening gaps. This price discontinuity makes trading at the MA crossover point very difficult. Instead, we use the three most influential indexes in the US market for our empirical study.

Several papers also test the MA strategy against the buy-and-hold benchmark. Allen and Karjalainen (1999) and Ready (2002) show MA strategy cannot outperform the buy-and-hold benchmark each on the S&P500 and the DJIA indexes, respectively. On the other hand, Han, Yang, and Zhou (2012) and Shynkevich (2012) find the MA strategy can outperform the buy-and-hold strategy on less liquid securities. Han, Yang, and Zhou (2012) use volatility and size deciles, while Shynkevich (2012) tests on technology industry and small cap sector portfolios. Therefore, it is still an open question whether or not MA strategies can outperform the buy-and-hold strategy on liquid securities such as ETFs.

The remainder of the paper proceeds with a description of our empirical methodology in Section 2. Section reports our main result by comparing the intraday MA strategy versus the next-day MA strategy, as well as performance comparison between ETFs and indexes. Section concludes.

2 Empirical Methodology

2.1 Data

We use daily data from the Center for Research in Security Prices (CRSP) for indexes and ETFs. Specifically, we compare the MA strategy performance between three major indexes: the S&P 500 index (S&P500), the Dow Jones Industrial Average (DJIA), and the NASDAQ-100 index, and their corresponding ETFs whose tickers are: SPY, DIA, and QQQ (previously QQQQ). To test our proposed intraday MA strategy, we download all daily data of ETFs before December 31, 2012, which include a total of 1462 ETFs.

The daily prices from CRSP include open, high, low, and close prices. Using the adjustment factors we back out from the dividend adjusted daily returns, we adjust the four prices to reflect dividend payments. We also manually adjust the prices of 16 ETFs that have a split, and fix 8 obvious data entry errors in prices. In this study, we assume prices are continuous within a day, but may have overnight jumps when there is an opening gap defined as nonzero difference between opening price and lagged closing price.[5] With the four daily prices as well as the intraday price continuity assumption, we are able to determine if there is at least one golden or death cross for a particular ETF or index, and possibly trade immediately around the long-term moving average where an MA crossover occurs.

Since we test MA strategies under various long-term moving average values ranging from 5 days to as long as 200 days, we require a fairly long price history on ETFs to reduce the impact from booms and busts in stock market. Therefore, our first filter requires ETFs to have more than 10 years of available data. Obviously, to avoid survivorship bias, we simply keep those ETFs launched before December 31, 2002, no matter for how long they have existed. This leaves us with 133 ETFs out of the total 1462. Our second filter is to remove any ETFs tracking international markets or sectors, because the overnight movement in foreign markets causes big opening gaps making the MA strategy impossible to trade at the long-term MA price. After removing 43 international ETFs, we have 90 ETFs left. The last filter we apply in selecting ETFs is that we focus on the large and liquid ETFs in three major series: the SPDR series, the iShare series, and the Vanguard series, as well as the QQQ that tracks the NASDAQ-100 index. This last step brings the final number of ETFs in this study to 68.[6]

[5]Therefore, any intraday price jumps preventing the MA strategy from trading at a specific price, should be categorized as transaction costs under this assumption.

[6]Among the three filters, the first two are non-forward-looking in the sense of Huang and Huang (2013) as they do not require any future knowledge. The third one does require the information in hindsight that the three major series turned out to be the largest and most successful ETFs. As a robustness check, we re-run our major results with the 22 non-major series ETFs added back and the results are qualitatively the same.

Table 1 summarizes the statistics of these 68 ETFs grouped in five types. We notice that of the five types of ETFs, index or market ETFs are the largest. Unreported result indicates that SPY, the ETF tracking the S&P500 index, averages 34 billion in size over its lifetime, growing from 69 million in February 1, 1993 to 123.7 billion in December 31, 2012. The high turnover ratios show that investors trade ETFs heavily, with ETF shares changing hands more than 12 times on average each year.

2.2 An Intraday Moving Average Trading Strategy

Following the definition in Block, Lakonishok, and LeBaron (1992), we focus on the simplest form of the MA strategy: the variable length MA. In this strategy, a position opened in response to an MA crossover will be held until an opposite MA signal is observed, so the total holding length is not fixed.[7] We implement a long-only strategy here since our benchmark is the passive buy-and-hold strategy on the same security. In other words, we focus on the relative, rather than the absolute, performance of the MA strategy. While the MA trading rule is aimed to capture big price trends, sometimes there could be too many signals when the short- and long-term MAs are entangled together. To reduce the number of trades, a band around the long-term MA can be introduced so that an MA crossover only gets confirmed when the short-term MA crosses the long-term MA far enough. For our main results, we focus on the case with no band but also test the case when a 0.5% band is introduced for robustness.

While a golden or death cross can happen anytime during a trading day, the moving average trading rule implemented in the existing literature waits until the close of a trading day to respond to a signal generated during that trading day. This possible delay causes a potential loss of performance for the MA crossover strategy. For instance, for the 68 ETFs in our study, when the short- and long-term moving averages are 1 and 10 days, respectively,

[7] Block, Lakonishok, and LeBaron (1992) also defined the fixed length MA rule in which a position is always closed after a fixed number of days, ignoring any trading signals in between. We select the variable length MA because it is less subjected to data-snooping bias as the strategy has one less exogenous variable (number of holding days) to select.

and there is no band or transaction cost, the average daily return is 1.63% when there is a golden cross, and -1.54% for days with death crosses. If we can realize partial profit or avoid partial loss on these MA signal days by responding to signals more promptly, the performance of the MA trading strategy is likely to improve.

We implement an intraday moving average trading strategy that trades immediately when an MA crossover occurs, then rewind the trade at close if the cross is later reverted before the close. As the concept of "intraday" is introduced here, it is necessary to clearly define the calculation of moving averages and the detection of MA crosses at *any time within a day*. We describe these details of the intraday MA trading strategy below focusing on the calculation of intraday moving averages, detecting confirmed and reverted intraday MA crossovers, trading strategies under different situations, and the effect of opening gaps.

- Daily and Intraday Moving Averages

  Specifically, we define the daily MA at day d for past L days as:

$$MA_{d,L} = \frac{1}{L}(P_d + P_{d-1} + ... + P_{d-L+2} + P_{d-L+1}) \tag{1}$$

  where P_d stands for the closing price of day d. Moreover, we also define the intraday MA at time t of day d as:

$$MA_{d,L}^t = \frac{1}{L}(P_d^t + P_{d-1} + ... + P_{d-L+2} + P_{d-L+1}) \tag{2}$$

  in which we replace the closing price P_d with an intraday price P_d^t at time t of that day. As we can see, intraday MA is equivalent to a daily MA assuming the current price is going to be the closing price.

- Intraday MA Crossovers

  Let's denote by m and n the short- and long-term MA lags respectively, and by B the band around the long-term MA in percentage. On day d, an intraday golden cross is detected at the *earliest* time t when:

$$1)\ MA_{d-1,m} \leq MA_{d-1,n}(1+B\%) \text{ and } 2)\ MA_{d,m}^{t} > MA_{d-1,n}(1+B\%) \tag{3}$$

An intraday death cross is detected when:

$$1)\ MA_{d-1,m} \geq MA_{d-1,n}(1-B\%) \text{ and } 2)\ MA_{d,m}^{t} < MA_{d-1,n}(1-B\%) \tag{4}$$

The first condition determines the order of the short- and long-term MA at the close of the previous trading day, while the second condition checks if that order is *ever* changed during a trading day, even if just temporarily.[8] One assumption here is that an investor calculates the short-term MA using the real-time intraday price information, but preset the long-term MA at the beginning of each trading day based on historical daily closing prices. This setting matches with the real world situation when investors constantly evaluate the current price based on a number of technical indicators at daily frequency. An alternative setting is to use the real-time intraday long-term MA ($MA_{d,n}^{t}$) instead of the lagged long-term MA ($MA_{d-1,n}$) in condition 2). This algorithm, under its special condition when t is at the daily close, is actually used in the existing literature. As explained in Ready (2002), a trader must estimate slightly before the close of each trading day whether or not there will be an MA crossover for that day. Our robustness check shows that the difference between these two algorithms is very small, since replacing one historical price with the current price has little impact when the MA lag is long.

- Detecting Intraday MA Crosses with Daily High and Low Prices

[8] There are two more technical details in identifying MA crossovers. One is the initial condition that the long-only investor started with 100% cash, so only a golden cross which is a buy signal will be responded. The other complexity is that when there is a band B, the strategy relies on the type of previous MA signal (golden or death) to determine the order of the short- and long-term MAs, as condition 1) could be satisfied in both equations 3 and 4 at the same time when B is non-zero.

For simplicity, let's set the short-term moving average to be one day, i.e., the stock price itself, and there is no band around the long-term moving average. Suppose there is an intraday golden(death) cross happening on day d, that means the stock price closed below(above) the long-term MA on day $d-1$. Referring to condition 2) in equations 3 and 4, an intraday golden cross is detected if $P_d^H > MA_{d-1,n}$ and an intraday death cross occurs when $P_d^L < MA_{d-1,n}$. Here $P_d^H(P_d^L)$ is the daily high(low) price on day d. That is, we check the daily high and low prices against the lagged long-term MA for intraday crossovers.[9]

- The Trading Strategy

When an intraday golden cross is detected, the intraday MA strategy buys immediately at the long-term MA price. If the closing price on day d (P_d) also holds above the lagged long-term MA ($MA_{d-1,n}$), this is a confirmed golden cross so that the long position is carried over to the next trading day. This scenario is very similar to the next-day MA strategy in the existing literature which buys at the close of day d, except that the investor now also enjoys part of the positive return on signal day d. However, if the closing price on day d eventually reverts back below the lagged long-term MA, the investor would have to rewind the intraday trade around the day d closing price, suffering a loss plus round-trip transaction costs. The situation of death cross is similar, in which the intraday MA strategy avoids partial loss on the MA signal day if the death cross is confirmed, or foregoes some profits after paying transaction costs in the reverted case. Overall, there are a total of four cases in this intraday trading strategy after an MA cross signal is detected: confirmed golden cross, confirmed death cross, reverted golden cross, and reverted death cross. Figure 1 illustrates the MA signals, the timing of trades, the change in portfolio positions, and the daily profit/loss under these four

[9] In the general case when short-term MA lag $m > 1$ and there is a non-zero band $B\%$, MA cross conditions are $\frac{1}{m}(P_d^H - P_{d-m}) > MA_{d-1,n}(1+B\%) - MA_{d-1,m}$ and $\frac{1}{m}(P_{d-m} - P_d^L) > MA_{d-1,m} - MA_{d-1,n}(1-B\%)$ for golden and death crosses, respectively. The left hand side of these inequalities is the maximum impact on the short-term MA caused by the daily high or low prices, and the right hand side represents the distance required for an MA crossover to occur at the beginning of a trading day.

situations.

- Loss from Opening Gaps

  When implementing the intraday MA trading strategy, there is a special situation when the opening price on day d gaps up(down) directly above(below) the lagged long-term MA. If that happens, in all of the four cases in figure 1 the strategy has to buy(sell) immediately using market order at the unfavorable opening price instead of the long-term moving average. An alternative treatment to opening gap is to use a limit order at the lagged long-term MA, then there is a chance the limit order can never be filled, which can be detected if the daily low(high) price is higher(lower) than the lagged long-term MA for golden(death) crosses. If that happens, the intraday MA strategy has to trade at the close of day d, likely at an even worse price than the opening price. Figure 2 compares the two strategies dealing with MA crosses at opening gaps: market order v.s. limit order, for both golden cross and death cross. In each case, there are three possible price paths: confirmed and missing MA, confirmed but reaching MA, and reverted (which always crosses MA). Obviously, only the first case: confirmed and missing MA is in favor of the market order strategy. However, our statistics show that the two strategies on opening gaps roughly perform the same, since the open-to-close price movement is generally larger than the MA-to-open difference, and the confirmed and missing MA case happens slightly more often. That is, the price path in favor of the market order occurs more frequently and with better return than the other two paths which benefit the limit order.

  Table 2 summarizes the frequencies of the three possible paths when there is an MA signal at opening gap, as well as the average intraday returns from open to close, versus from the lagged long-term MA to open. In the last column, we also calculate a performance score for each case by multiplying the total number of samples for that case to the corresponding return that captures the performance gain under that case. Specifically, the open-to-close return is the gain for the two confirmed-and-miss-MA cases and the MA-to-open return is the gain for the other four cases. As we can see, whether using limit or market order here is a trade off between taking the performance gain from the confirmed-and-miss-MA case or that of the other four cases. We use the overall score in the last line to summarize this tradeoff, with positive(negative) values indicating the advantage of the market(limit) order strategy. The long-term MA length in Table 2 is set to be 10 days but we run 21 different MA lengths ranging from 5 days to 200 days in unreported tables. We find the market order strategy at opening gap is better for MA lengths shorter than 50, while the limit order strategy prevails for longer MA lengths. Overall, the two strategies on opening gaps do not generate too much difference, and we use the market order strategy for the remaining analysis in this study. In a related paper, Berkman, Koch, Tuttle, and Zhang (2012) find that buying at opening when there is a gap up is not optimal since prices are likely to reverse during the trading day. Our finding indicates that for the small portion of overnight movements not later reverted, they are the big ones which are more likely to trigger MA crossovers. Therefore, while many overnight movements end up reverted, the few big ones affecting the MA strategy mostly continue its trend during the day, especially when the long-term MA is shorter than 50 days.

As we can see, the intraday moving average strategy tries to reap extra profits by trading quickly after an MA signal is observed, but suffers from reverted intraday signals and losses from opening gaps. Table 3 presents the detailed summary statistics on days with MA signals for 68 ETFs in our sample. Panel A calculates the average signal day returns, intraday MA strategy returns, and losses from opening gap for eight cases. The last column is the performance gain/loss relative to the next-day version of the MA strategy if trading at the close of the signal day. Panel B condense the information in Panel A into only four cases focusing on the comparison between confirmed and reverted MA crossovers. From Panel B, we can see if an MA signal is eventually confirmed, the intraday MA strategy captures about 40% of the entire signal day return, or 0.66%. If an MA signal is later reverted, the intraday

MA strategy incurs a daily loss of about 0.83%, plus round-trip transaction costs. With reverted crosses happening 67% as often as confirmed crosses, the overall improvement on MA signal days is $0.66\% - 0.83\% * 0.67 = 0.10\%$ without considering transaction cost. This overall improvement has already considered the loss from opening gaps listed in the second to last column. Therefore, according to these statistics, the proposed intraday MA strategy should be able to outperform the next-day MA strategy when the one-way transaction cost for ETFs is no more than 5 bps which is used in Hsu, Hsu, and Kuan (2010).

3 Empirical Results

In this section, we first validate our intraday MA strategy by comparing its performance relative to the next-day MA strategy, with and without transaction cost. Section 3.2 shifts to the performance comparison between indexes and their corresponding ETFs. We then discuss our results focusing on what factors affect the profitability of the MA strategy. Liquidity is clearly one factor, which can more or less explain why literature finds mixed conclusion about the profitability of the MA strategy. We also find MA profitability is sensitive to trader exploitation. ETFs have larger opening gaps than corresponding indexes, making them less profitable for the MA strategy. Finally, we discover that among various MA lengths, the 10-day lag seems to be widely used by investors as its performance is notably worse than nearby MA lengths. Unless noted otherwise, the short-term MA is one day (the stock price), and there is no transaction cost or band around the long-term MA.

3.1 Performances of the Intraday and Next-day MA Strategies

Table 4 compares the intraday MA strategy to the next-day MA strategy across long-term MA lengths ranging from 5 days to 200 days. We present three performance measures: strategy return, Sharpe ratio, and CAPM alpha, all annualized by multiplying daily returns and alphas by 252, and daily Sharpe ratio by $\sqrt{252}$ following Sullivan, Timmermann, and

White (1999) and Bajgrowicz and Scaillet (2012).[10] The last two rows of Table 4 also list the three performance measures of the buy-and-hold strategy on ETF itself and the value-weighted market return. All results are first computed on individual ETFs before averaged across the 68 ETFs in our sample, which is equivalent to the performance of a portfolio invested on these ETFs equal-weighted. Table 5 repeats the same analysis with a 5-bps one-way transaction cost imposed.

As we can see, without transaction cost, the intraday MA strategy is superior to the next-day MA strategy in almost all cases, especially when the long-term MA is no more than 50 days. When there is a 5-bps one-way transaction cost, the intraday MA strategy wins when the long-term MA is shorter than 50 days while the next-day MA strategy dominates in longer MA lengths. Performance of the intraday MA strategy gets eroded more because there is an additional round-trip transaction cost when there is a reverted MA crossover. The finding that the intraday MA strategy works better with short long-term MA is quite intuitive. Based on statistics shown in Table 3, intraday MA strategy does slightly better than the next-day MA strategy on MA signal days. Therefore, more frequent MA crossovers under shorter long-term MA lengths help the intraday strategy. In addition, we find in untabulated result that when the long-term MA length is short, the intraday MA crosses are more "decisive" in the sense that the ratio of confirmed versus reverted MA crosses is higher. This also makes sense as in the investment community, longer MAs represent stronger support/resistance. Intraday attempts to cross longer MA is therefore less likely to hold through the day.

When we compare the MA performances to the buy-and-hold benchmark based on annualized return, even the improved intraday MA strategy cannot beat the passive buy-and-hold benchmark strategy without any transaction cost. The only exception: the 5-day long-term MA for intraday MA strategy averaging an annual return of 10.12%, still does not survive a 5-bps transaction cost. Based on Sharpe ratio or one-factor alpha, performances of MA

[10] We also test using natural logarithm to calculate daily return as in Ready (2002). The results are almost identical since daily returns are so small that compounding causes very little impact in the calculation.

strategies improve. In some cases, they outperform the buy-and-hold strategy. Overall, Tables 4 and 5 show improvements of the intraday MA strategy relative to the traditional next-day MA strategy, but both strategies fail to outperform the buy-and-hold strategy after transaction cost on ETF data. The MA strategies are not superior to a simple buy-and-hold strategy at least on ETFs.

3.2 Performance Comparison between ETFs and Indexes

Table 6 compares the performance in terms of annualized return of intraday MA strategy on indexes versus on ETFs. We can see that the intraday MA strategy performs much better on the non-tradable S&P500 and DJIA indexes than on tradable ETFs of SPY and DIA. Among different MA lengths, the performance difference is larger when the long-term MA is not too long. However, there is not much difference between the NASDAQ-100 index and its tracking ETF of QQQ. We also attach the buy-and-hold benchmark returns and the return correlations between ETFs and indexes at the bottom of Table 6. Relative to the buy-and-hold return of the same security, only some intraday MA strategies on the S&P and DJIA indexes outperform.

Table 7 repeats the comparison using the next-day MA strategy which is used in the existing literature. In this case, we do not see worse MA performance on ETFs relative to indexes. In fact, MA strategies perform slightly better on ETFs. In addition, because on both ETFs and indexes the next-day MA strategy underperforms the buy-and-hold benchmark, we do not find the documented MA profit in a long-only portfolio whose performance benchmark is the buy-and-hold strategy. A close look at the literature reveals that papers testing the MA trading rule on indexes mostly use zero or the risk-free rate as the performance benchmark such as in Block, Lakonishok, and LeBaron (1992), Bessembinder and Chan (1998), and Sullivan, Timmermann, and White (1999). Allen and Karjalainen (1999) and Ready (2002) use the buy-and-hold return as benchmark, but find the MA profitability is unconvincing. Han, Yang, and Zhou (2012) and Shynkevich (2012) find the MA trading rule can beat the buy-and-hold benchmark, but they test the strategy on risk or industry portfolios rather than on broad indexes. To summarize, Table 7 finds while the next-day MA strategies do generate positive returns as documented in the literature, they underperform the passive buy-and-hold benchmark.

3.3 Discussion

3.3.1 Liquidity and MA Performance

Our findings in Section 3.1 contrast to Han, Yang, and Zhou (2012) and Shynkevich (2012) who find the MA strategy, tested on stock portfolios, outperforming the buy-and-hold benchmark by large margin. On the other hand, Allen and Karjalainen (1999) and Ready (2002) do not find profitability when testing the MA strategy on the S&P500 and the DJIA indexes. Therefore, liquidity may play an important roll in the profitability of the MA technical trading strategy. In this section we investigate cross-sectionally the relationship between ETF liquidity and the performance of the MA strategy. Our prior is that even though ETFs in general have superior liquidity, we should still see MA profitability stronger in relatively illiquid ETFs.

As to liquidity measures, we choose to use the trading volume, the bid-ask spread, and the Amihud (2002) measures. However, we notice that the Amihud (2002) illiquidity measure is essentially a volume denominated volatility that increases either as volatility increases or when trading volume decreases. By definition, the MA trading strategy works better when volatility is high because that way there are more MA crossovers. So we are concerned that the Amihud (2002) measure may reflect a mixed effect to MA performance from volatility and trading volume. Nonetheless, the Amihud measure generates roughly the same results as the other two measures do.

We repeat in Table 8 the main back-testing about MA profitability on liquidity terciles: those with high, medium, and low liquidity measured by average daily volume. We also run robustness checks using the bid-ask spread or the Amihud illiquidity measure and the results are very similar. Table 8 shows that the newly proposed intraday MA strategy outperforms the next-day strategy for all three liquidity groups. However, both MA strategies perform better on relatively illiquid ETFs. Unreported here, a simple univariate regression shows that cross-sectionally MA performance increases with illiquidity significantly at the 1% level. Still, in none of the liquidity groups can MA strategies barely beat the buy-and-hold benchmark. Our finding indicates that the market is pretty efficient in pricing ETF liquidity into the profitability of MA strategies. Those popular, widely traded ETFs fare worse than illiquid ones, although the latter also fail to beat the buy-and-hold strategy.

3.3.2 Why the Intraday MA Strategies Perform Worse on ETFs?

Looking back at Table 6 on both ETFs and indexes, we can see that despite the performance difference between ETFs and indexes, ETFs do track their corresponding indexes closely as their daily return correlations are all high in the 90% range. Then why does the exactly same intraday MA strategy dramatically underperform when applied on ETFs?

One possibility is the dividend omission in these indexes. Bessembinder and Chan (1998) find that omitting dividends has very little impact to the MA performance. In fact, not counting dividends reduces index returns as the buy-and-hold return for index is always lower than corresponding ETFs in Table 6. This makes the stronger MA performance on indexes even more puzzling. To verify that dividend omission indeed does not cause the return difference, we rerun our results after stripping away all dividends from ETF return/prices as well. Unreported tables show that the performance difference between ETFs and indexes is still there. Given all these evidence, the different treatments to dividend payments by ETF and index data cannot explain the MA performance difference.

In Table 6, among the three major market indexes, MA strategies do not work well on the NASDAQ-100 index. While greatly outperforming the buy-and-hold benchmark on the S&P500 and DJIA indexes, the intraday MA strategy shows underperformance on the NASDAQ-100 index in many cases. Also, in contrast to the S&P500 and DJIA indexes, we do not see much difference in MA performances for the QQQ and the NASDAQ-100 index. In fact, we notice that the literature about the MA trading strategy is heavily focused on the S&P500 and DJIA indexes. Therefore, it is reasonable to hypothesize that it is trader exploitation that drives down the performance on ETFs for the two outperforming indexes. Specifically, when many investors are following the same MA strategy, they buy (sell) roughly at the same time when they see a golden (death) cross MA signal. During normal trading hours, this type of simultaneous trading can be well absorbed by the superb liquidity of index ETFs. However, as liquidity drops sharply during after hours, we should expect a larger opening gap on ETFs when investors rush to trade at the opening price, if an MA crossover occurs at the opening.

Table 9 provides a detailed summary of opening gaps on MA signal days for both the ETFs and indexes. The first few columns in Panel A focus on the ratio of reverted intraday crosses (*Rvt/Cfm*), which is larger for ETFs than for indexes. This means for all three indexes the intraday MA strategy generates more reverted intraday crosses on ETFs than on indexes. The last three columns summarize the performance drag from opening gap, including the number of days when the MA crossover occurs at an opening gap, its percentage among all signal days, and the average loss from opening gaps spreaded to each signal day. As we can see, the S&P500 and DJIA indexes have a much lower probability of being affected by opening gaps than their corresponding ETFs. The average daily performance losses on signal days due to opening gap are only 1 and 3 bps for the S&P500 and the DJIA indexes, respectively, while on ETFs the losses are more than 10 bps. However, this is not the case for the NASDAQ-100 index, which has opening gaps of similar size and frequency as those for QQQ.

Panel B is an example of opening gap on the Friday of September 19, 2008, when the market was gyrating after the fall of Lehman Brothers. We can see on 09/19/2008 the S&P500 index did not gap up too much, but the corresponding ETF (SPY) gapped up more than 6%, well above the 10-day MA at which an investor would want to buy. The intraday

MA strategy using market order to buy immediately at opening could have reaped 2.57% in profit on S&P500 index, but instead suffered a loss of 2.04% that day on the SPY.[11] Figure 3 is the intraday price chart for SPY and the S&P500 index on that day. The two time series move very closely throughout the day, except that they open at dramatically different levels before converging together after about 10 minutes. These evidences support that investor exploitation as reflected by larger opening gaps reduces MA performance on ETFs.

3.3.3 The 10-Day Moving Average

One interesting feature in Tables 4 and 5 is that the 10-day long-term MA performs worse than nearby MA lengths. Since the 10-day moving average is an important trend indicator for stocks in short-term, it is possible that trader exploitation drives away the profit for the 10-day MA strategy. Figure 4 takes a close look at the performances of MA strategies across different long-term MA lengths. The upper-left and upper-right figures illustrate the performances of MA lengths ranging from 5 to 250 days, and from 5 to 50 days, respectively. As we can see, there is a clear performance dent around the 10-day MA length when the investor uses the intraday MA strategy, but not for the next-day MA strategy. To quantitatively measure the significance of the performance dent caused by the 10-day MA, we first fit all these annual returns into a quadratic regression, then estimate the significance of the return of 10-day MA based on the standard deviation of the error term. The p-Value of the 10-day MA, denoted by P_{10} on the graph, are less than 1%.

Naturally, we would like to find out if this is really due to trader exploitation or simply a statistical fluke. One way is to test on some other liquid stocks and market indexes. If it is due to trader exploitation, we should see this pattern stronger on tradable stocks then on non-tradable indexes. The bottom-left figure compares the 5- to 50-day MA lengths on the 30 DJIA component stocks as of December 31, 2012, also during the same time period

[11] Note that in this example a limit order at the 10-day MA level would avoid the loss from opening gap for SPY. However, on average limit order fares slightly worse than market order for short long-term MAs as compared in Table 2.

from February 1993 to December 2012. We can also see MA strategy performance decreases before the 10-day MA length then picks up after it. The performance dent caused by the 10-day MA is also significant at the 1% level.

Finally, since academic publications affect the trading behavior of investors as found in Huang and Huang (2013) and Scwert (2003), we would like to see if the 10-day MA behaves differently before the publication of Block, Lakonishok, and LeBaron (1992) that pioneers a plethora of academic studies on the MA technical trading rule. Since there is no earlier history for ETFs before 1993, we use the DJIA component stocks for the test. The bottom-right figure looks at those DJIA component stocks as of December 31, 1992, during the 10-year time period from January 1983 to December 1992. As we can see, in the ten years prior to 1992, the 10-day MA length does not under-perform surrounding MA lengths. These evidence implies as the popularity of the MA crossover trading strategy grows with the recent academic publications, the 10-day MA length received more trader exploitation than other MA lengths.

Figure 5 further looks at this performance dent around the 10-day MA across different ETF types. Based on the reported significance, we see more trader exploitation of the 10-day MA strategy on index, style, and real estate ETFs, rather than on sector and fixed income ETFs. In unreported tables, we also run a "resonance test" for all different MA training lengths to see if on days with a 10-day MA crossover, there are exceptionally high probability for MA crossovers of other MA lengths to occur. We do not find anything special about the 10-day MA length. That is, the 10-day MA itself is nothing special technically. It is investor's trading activity that drives down the performance of the 10-day MA strategy.

4 Conclusion

In this paper we test the moving average trading strategy on ETFs, in comparison to non-tradable indexes. We also improve the existing MA trading strategy to an intraday MA strategy that allows the trader to trade immediately when an MA crossover occurs. Our results indicate that the MA profitability is reduced on ETFs due to trader exploitation as ETFs have larger opening gaps than indexes on days with MA crossover signals. However, while MA strategies generate positive returns, they mostly underperform the buy-and-hold strategy on the same asset. This implies that a long-only portfolio without any leverage cannot earn excess return using the MA technical trading rule relative to just holding the ETF. We also find the new intraday MA strategy performs slightly better than the traditional version of the MA strategy that only trades at daily close. Among different lengths of the long-term moving average, the widely used 10-day moving average earns a much lower return relative to nearby MA lengths. Again, this phenomenon is caused by the increased investor awareness of the MA trading rule because we could also find this performance dent on liquid DJIA component stocks, but not before the publication of major papers on the MA strategy.

Our study focuses on the direction of testing academic findings under more realistic settings. In addition to those commonly considered factors such as transaction costs, we further explore the selection of trading targets, the timing in response to technical signals, the treatment of price discontinuities in actual trading, and the use of performance benchmarks. Our findings imply that the details in implementing trading strategy can dramatically affect its performance. Our proposed intraday MA strategy clearly defines possible actions under different situations in real world trading such as when price gaps across the desired trading price or when the MA signal is reversed shortly within a day.

Our findings also contribute to the broader literature on technical analysis because many trading systems are based on technical trading signals as in, for example, Fama and Blume (1966), Jensen and Benington (1970), Brown, Goetzmann, and Kumar (1998), and Lo, Mamaysky, and Wang (2000). In backtesting technical trading strategies, we should not limit to the daily close data as most of these trading signals are generated intraday. An investor is very likely to respond to a signal immediately instead of waiting to the close. Our results also show that the opening gap cannot be ignored in evaluating technical trading strategies, because technical trading signals are more likely to be generated in days with large price swing—and therefore with large opening gaps that prevents trading at a desired price level. More future research is needed in the reevaluation of other technical trading rules under this direction, because the results will help us to understand which technical rules are associated with known or unknown risk factors so that they cannot be arbitraged away, while others strategies are just caused by mispricing and go away quickly as they become widely known.

Table 1: Summary Statistics of 68 ETFs in Five Types

This table presents the summary statistics of the 68 ETFs categorized into five different types. For each type, we list their average annualized *Return*, *Sharpe* ratio, and one-factor *Alpha*. We also report ETF *Size* and annual *Turnover* ratio by first averaging over its lifetime then averaging across ETFs within the same group.

ETF Type	N	Return (%)	Sharpe	Alpha (%)	Size (million $)	Turnover
Index/Market	9	6.4898	0.2251	0.20	9,601	27.16
Style	24	8.0345	0.2866	2.10	2,010	5.42
Sector	29	4.6156	0.1716	0.53	801	13.39
Bond	4	6.2464	0.7293	6.17	3,879	15.13
Real Estate	2	15.5490	0.4283	9.55	1,272	26.45
All ETFs	68	6.4878	0.2596	1.64	2,588	12.88

Table 2: Summary Statistics of MA Signals at Opening Gap

This table summarizes the frequencies (*N of Samples*) of the three possible paths when there is an MA signal at opening gap, as well as the average signal day return (*Signal Day Ret*), size of the opening gap (*Gap*), intraday returns from open to close (*Open-Close Ret*) versus from the lagged long-term MA to open (*MA-Open Ret*). We also calculate a performance score (*Score*) for each case by multiplying the number of samples and the open-to-close return for the confirmed/missing MA cases, and multiplying the number of samples and the MA-to-open return for the other four cases, both in absolute values of basis point. The overall score (*Overall Score*) in last line is the percentage difference with positive(negative) values indicating the advantage of the market(limit) order strategy over the other. The short and long-term moving averages used in this table are 1 and 10 days, respectively, and there is no band or transaction cost.

Case Description	N of Samples	Signal Day Ret	Gap	Open-Close Ret	MA-Open Ret	Score
Golden/Confirmed/Miss MA	3,894	1.80%	1.17%	0.67%	0.76%	259716
Golden/Confirmed/Reach MA	3,206	1.13%	0.81%	0.32%	0.40%	128048
Golden/Reverted	3,501	-0.46%	0.85%	-1.31%	0.39%	137050
Death/Confirmed/Miss MA	3,490	-1.78%	-1.13%	-0.69%	-0.76%	242101
Death/Confirmed/Reach MA	2,452	-1.19%	-0.77%	-0.43%	-0.34%	84322
Death/Reverted	3,467	0.50%	-0.78%	1.28%	-0.37%	129596
Overall Score						4.54%

Table 3: Summary of Eight Cases on Signal Days

This table presents the summary statistics on days with an MA cross signal for the 68 ETFs in our sample. The short and long-term moving averages are 1 and 10 days, respectively, and there is no band or transaction cost. In Panel A, signal days are grouped into eight cases determined by the direction of the cross (Golden/Death), the type of the intraday cross (Confirmed/Reverted), and whether or not the cross occurs at the opening gap. For each case, we report the number of samples, followed by the averages of the total signal day return (Signal Day Ret), the return captured by the intraday MA strategy (MA Ret), the performance loss caused by opening gaps (Gap Loss), and the overall performance gain or loss on the MA signal day compared to the next-day MA strategy. Performance gain/loss in the last column is just the MA strategy return (MA Ret) if the signal is a golden cross, or the MA strategy return (MA Ret) minus the signal day return (Signal Day Ret) if it is a death cross. The last line is the average of these statistics weighted by the number of samples. Panel B repeats the panel A statistics focusing on four cases only.

Panel A: Statistics of Eight Cases

Case Description	N of Samples	Signal Day Ret	MA Ret	Gap Loss	Performance Gain/Loss
Golden, Confirmed, No Gap	10,894	1.71%	0.70%	0.00%	0.70%
Golden, Confirmed, With Gap	7,100	1.50%	0.59%	0.51%	0.59%
Golden, Reverted, No Gap	7,088	0.20%	-0.72%	0.00%	-0.72%
Golden, Reverted, With Gap	3,501	-0.46%	-1.25%	0.35%	-1.25%
Death, Confirmed, No Gap	12,055	-1.55%	-0.89%	0.00%	0.66%
Death, Confirmed, With Gap	5,942	-1.54%	-0.88%	0.49%	0.65%
Death, Reverted, No Gap	10,197	-0.16%	-0.76%	0.00%	-0.60%
Death, Reverted, With Gap	3,467	0.50%	-0.73%	0.33%	-1.23%
Weighted Avg	N/A	0.02%	-0.40%	0.1483%	0.0624%

Panel B: Confirmed v.s. Reverted

Case Description	N of Samples	Signal Day Ret	MA Ret	Gap Loss	Performance Gain/Loss
Golden, Confirmed	17,994	1.63%	0.66%	0.20%	0.66%
Golden, Reverted	10,589	-0.02%	-0.89%	0.11%	-0.89%
Death, Confirmed	17,997	-1.54%	-0.89%	0.16%	0.66%
Death, Reverted	13,664	0.01%	-0.75%	0.08%	-0.76%

Table 4: Intraday MA v.s. Next-day MA

This table compares the intraday MA strategy with the next-day MA strategy across different long-term MA lengths. The short-term moving average is 1 day (the ETF price) and there is no band or transaction cost. We present three performance measures: *Return*, *Sharpe Ratio*, and one-factor *Alpha*, annualized by multiplying 252 on daily returns and alphas, and multiplying $\sqrt{252}$ on daily Sharpe ratios. Difference (*Diff*) is the performance of the intraday MA strategy minus that of the next-day MA strategy. For all these measures, we first calculate the time-series average for each ETF, then average across 68 ETFs. Significance is based on standard t-test against zero. The last two rows also list the three performance measures of the buy-and-hold strategy on ETF itself and the value-weighted market return. The ETF buy-and-hold performance is annulized, averaged over time for each ETF, then averaged across ETFs. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Long MA	Return (%)			Sharpe Ratio			Alpha (%)		
(Days)	Intraday	Nextday	Diff	Intraday	Nextday	Diff	Intraday	Nextday	Diff
5	10.12	-0.39	10.51***	0.5303	-0.1198	0.6501***	7.33	-3.16	10.48***
10	5.42	0.92	4.50***	0.2503	-0.0243	0.2746***	2.71	-1.81	4.51***
20	6.09	3.39	2.69***	0.3204	0.1484	0.1720***	3.47	0.76	2.71***
30	5.99	3.99	2.00***	0.3331	0.2062	0.1269***	3.48	1.47	2.00***
40	5.20	3.54	1.65***	0.2879	0.1713	0.1166***	2.72	1.05	1.67***
50	5.67	4.22	1.44***	0.3206	0.2257	0.0949***	3.19	1.73	1.46***
60	5.47	4.87	0.60**	0.3132	0.2693	0.0439**	3.00	2.39	0.61**
70	5.30	4.61	0.69***	0.3022	0.2589	0.0433**	2.85	2.15	0.70***
80	5.57	5.32	0.25	0.3251	0.3143	0.0108	3.12	2.86	0.26
90	5.53	5.01	0.51***	0.3195	0.2895	0.0300***	3.09	2.56	0.52***
100	5.35	4.88	0.46***	0.3086	0.2789	0.0298**	2.93	2.45	0.47***
110	4.86	4.41	0.45**	0.2726	0.2469	0.0257*	2.44	1.98	0.46**
120	4.82	4.11	0.71***	0.2713	0.2225	0.0487***	2.39	1.67	0.72***
130	4.43	3.81	0.62***	0.2438	0.1994	0.0443***	2.01	1.38	0.63***
140	4.21	3.88	0.34**	0.2320	0.2082	0.0238**	1.80	1.45	0.34**
150	4.68	4.23	0.45***	0.2621	0.2330	0.0291***	2.27	1.81	0.46***
160	4.32	4.27	0.05	0.2390	0.2393	-0.0003	1.90	1.85	0.05
170	4.11	4.30	-0.19*	0.2228	0.2412	-0.0183*	1.68	1.87	-0.19*
180	4.14	4.31	-0.17	0.2256	0.2443	-0.0187**	1.71	1.88	-0.17
190	4.55	4.63	-0.08	0.2591	0.2695	-0.0104	2.12	2.20	-0.08
200	4.48	4.75	-0.26*	0.2543	0.2768	-0.0225*	2.07	2.32	-0.26*
Benchmark Performance	Return (%)			Sharpe Ratio			Alpha (%)		
Buy and Hold:	6.49			0.2596			1.64		
Market Return:	5.59			0.2024			0		

Table 5: Intraday MA v.s. Next-day MA, 5 bps Transaction Cost

This table compares the intraday MA strategy with the next-day MA strategy across different long-term MA lengths, with 5 bps one way transaction cost imposed. The short-term moving average is 1 day (the ETF price) and there is no band or transaction cost. We present three performance measures: *Return*, *Sharpe Ratio*, and one-factor *Alpha*, annualized by multiplying 252 on daily returns and alphas, and multiplying $\sqrt{252}$ on daily Sharpe ratios. Difference (*Diff*) is the performance of the intraday MA strategy minus that of the next-day MA strategy. For all these measures, we first calculate the time-series average for each ETF, then average across all ETFs. Significance is based on standard t-test against zero. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Long MA	Return (%)			Sharpe Ratio			Alpha (%)		
(Days)	Intraday	Nextday	Diff	Intraday	Nextday	Diff	Intraday	Nextday	Diff
5	5.66	-3.74	9.40***	0.1188	-0.3834	0.5022***	2.86	-6.51	9.37***
10	0.96	-1.33	2.29***	-0.1162	-0.2017	0.0854	-1.73	-4.06	2.33***
20	3.60	1.91	1.69***	0.1028	0.0292	0.0736*	1.01	-0.73	1.74***
30	3.67	2.82	0.85**	0.1341	0.1104	0.0237	1.16	0.30	0.86**
40	3.18	2.54	0.64*	0.1086	0.0880	0.0206	0.70	0.05	0.65*
50	3.69	3.34	0.35	0.1498	0.1523	-0.0025	1.22	0.85	0.36
60	3.57	4.10	-0.54	0.1479	0.2053	-0.0574**	1.11	1.62	-0.52
70	3.43	3.90	-0.46	0.1400	0.1989	-0.0589**	0.99	1.43	-0.44
80	3.86	4.68	-0.82***	0.1741	0.2600	-0.0860***	1.43	2.23	-0.80***
90	3.91	4.40	-0.49*	0.1752	0.2370	-0.0617***	1.48	1.95	-0.47*
100	3.75	4.30	-0.55**	0.1685	0.2282	-0.0597***	1.33	1.87	-0.54**
110	3.45	3.83	-0.38	0.1470	0.1972	-0.0502**	1.03	1.40	-0.38
120	3.54	3.54	-0.01	0.1579	0.1746	-0.0166	1.12	1.11	0.01
130	3.25	3.26	-0.01	0.1380	0.1528	-0.0148	0.84	0.83	0.01
140	3.06	3.35	-0.28	0.1270	0.1630	-0.0359**	0.65	0.92	-0.27
150	3.46	3.72	-0.26	0.1550	0.1897	-0.0348**	1.05	1.30	-0.25
160	3.17	3.79	-0.63***	0.1374	0.1986	-0.0613***	0.76	1.37	-0.61***
170	3.06	3.84	-0.78***	0.1301	0.2029	-0.0728***	0.64	1.41	-0.77***
180	3.30	3.87	-0.57***	0.1519	0.2083	-0.0564***	0.89	1.45	-0.56***
190	3.73	4.22	-0.49***	0.1877	0.2354	-0.0478***	1.31	1.79	-0.48***
200	3.72	4.35	-0.63***	0.1864	0.2435	-0.0571***	1.31	1.93	-0.62***

Table 6: ETF v.s. Index Performance Comparison using the Intraday MA Strategy

In this table we test the intraday MA strategy on three major market indexes S&P500, Dow Jones Industrial Average (DJIA), and Nasdaq-100, in comparison with their tracking ETFs: SPY, DIA, and QQQ (formerly QQQQ). The short-term moving average is 1 day (the ETF price) and the long-term MA ranges from 5 to 200 days as listed in the first column. There is no band or transaction cost. All results are annualized MA strategy returns. The difference (*Diff*) of each pair is calculated by subtracting the index performance from the ETF performance. At the bottom of this table, we also report the return correlations (*Rt Corr*) of each ETF-index pair, the buy-and-hold annualized return of each security (*Buy-and-Hold*), as well as the value-weighted market return over the same period (*Market*).

Long MA (Days)	SPY (%)	S&P500 (%) From 02/01/1993	Diff	DIA (%)	DJIA (%) From 01/20/1998	Diff	QQQ (%)	NASDAQ-100 (%) From 03/11/1999	Diff
5	5.74	20.04	-14.29	6.91	13.61	-6.71	3.28	3.22	0.06
10	3.67	13.55	-9.88	6.58	9.89	-3.31	1.98	0.94	1.04
20	5.57	12.84	-7.27	6.88	8.11	-1.23	8.31	6.16	2.15
30	5.28	10.15	-4.87	5.00	7.15	-2.15	5.66	6.90	-1.25
40	4.89	9.98	-5.09	4.15	5.91	-1.76	9.03	6.85	2.18
50	6.24	8.86	-2.61	3.12	4.69	-1.57	6.99	6.35	0.64
60	5.40	8.69	-3.29	2.51	5.77	-3.26	6.02	7.17	-1.15
70	5.51	8.54	-3.03	2.20	4.72	-2.52	7.42	6.47	0.95
80	5.82	9.10	-3.28	1.07	4.52	-3.45	7.54	8.00	-0.45
90	4.87	8.68	-3.80	2.22	4.76	-2.55	6.67	7.77	-1.10
100	5.39	7.62	-2.23	0.55	3.14	-2.59	5.74	7.94	-2.20
110	6.23	8.25	-2.03	-0.29	3.50	-3.79	2.56	3.05	-0.50
120	6.29	8.88	-2.59	1.38	3.71	-2.33	4.02	4.61	-0.59
130	6.06	8.78	-2.72	0.29	3.90	-3.62	3.31	5.39	-2.07
140	5.87	8.16	-2.29	1.00	3.71	-2.72	4.61	4.51	0.10
150	6.36	8.90	-2.54	1.52	2.86	-1.34	4.88	5.57	-0.69
160	5.68	8.43	-2.75	2.14	3.71	-1.56	3.62	4.37	-0.75
170	5.75	7.52	-1.77	0.49	3.09	-2.60	3.22	3.20	0.02
180	5.59	7.70	-2.11	1.05	3.11	-2.06	3.73	3.97	-0.23
190	5.94	7.65	-1.71	1.10	3.16	-2.07	2.94	4.53	-1.59
200	6.46	7.32	-0.86	1.38	3.57	-2.19	1.55	4.12	-2.57
Rt Corr	97.73%			98.04%			91.93%		
Buy and Hold	9.57	7.78	1.79	7.57	5.37	2.20	6.86	6.42	0.44
Market	9.89	9.89		7.25	7.25		5.88	5.88	

Table 7: ETF v.s. Index Performance Comparison using the Next-day MA Strategy

In this table we test the next-day MA strategy on three major market indexes S&P500, Dow Jones Industrial Average (DJIA), and Nasdaq-100, in comparison with their tracking ETFs: SPY, DIA, and QQQ (formerly QQQQ). The short-term moving average is 1 day (the ETF price) and the long-term MA ranges from 5 to 200 days as listed in the first column. There is no band or transaction cost. All results are annualized MA strategy returns. The difference (*Diff*) of each pair is calculated by subtracting the index performance from the ETF performance. At the bottom of this table, we also report the return correlations (*Rt Corr*) of each ETF-index pair, the buy-and-hold annualized return of each security (*Buy-and-Hold*), as well as the value-weighted market return over the same period (*Market*).

Long MA	SPY (%)	S&P500 (%)	Diff	DIA (%)	DJIA (%)	Diff	QQQ (%)	NASDAQ-100 (%)	Diff
(Days)	From 02/01/1993			From 01/20/1998			From 03/11/1999		
5	0.82	1.07	-0.25	0.37	-1.16	1.53	-6.64	-11.31	4.67
10	0.52	0.42	0.09	1.23	-2.11	3.34	-2.84	-5.24	2.40
20	3.20	3.04	0.16	3.80	2.58	1.22	3.71	2.88	0.83
30	4.80	3.96	0.84	2.44	0.32	2.12	4.78	5.08	-0.30
40	2.97	2.56	0.41	1.14	1.98	-0.84	6.92	4.71	2.21
50	4.37	4.23	0.13	2.88	2.34	0.54	9.05	6.37	2.68
60	5.25	5.30	-0.05	1.73	1.82	-0.09	8.75	7.22	1.53
70	5.34	5.03	0.30	2.72	1.60	1.12	6.38	5.55	0.83
80	6.65	5.57	1.08	2.11	1.11	1.01	8.45	6.83	1.62
90	5.57	4.49	1.08	2.66	0.68	1.98	8.19	7.82	0.37
100	5.66	5.03	0.63	3.19	0.15	3.04	5.69	5.56	0.13
110	4.89	4.37	0.52	2.54	-0.02	2.56	4.61	4.32	0.29
120	4.68	3.73	0.96	1.72	-0.08	1.79	5.23	4.24	0.99
130	4.71	3.78	0.93	0.94	0.21	0.73	4.36	3.64	0.72
140	5.27	4.54	0.74	2.36	0.50	1.86	2.23	3.07	-0.84
150	6.26	5.01	1.25	1.79	0.50	1.29	2.58	1.06	1.52
160	6.26	5.45	0.81	2.60	-0.09	2.68	2.75	0.47	2.28
170	7.06	5.50	1.56	2.04	0.90	1.14	3.44	0.99	2.45
180	6.94	5.83	1.11	1.39	1.82	-0.43	3.30	1.41	1.89
190	6.70	6.98	-0.28	1.08	1.45	-0.37	2.59	1.54	1.06
200	7.58	6.22	1.36	0.32	1.92	-1.61	1.96	1.69	0.27
Rt Corr	97.73%			98.04%			91.93%		
Buy and Hold	9.57	7.78	1.79	7.57	5.37	2.20	6.86	6.42	0.44
Market	9.89	9.89		7.25	7.25		5.88	5.88	

Table 8: Liquidity and MA Strategy Return

This table reports the annualized MA strategy returns on ETFs in three liquidity groups: High, Medium, and Low, based on the liquidity measure of average daily trading volume. Within each group, we compare the intraday MA strategy with the next-day MA strategy across different long-term MA lengths. The short-term moving average is 1 day (the ETF price) and there is no band or transaction cost. Difference (*Diff*) is the performance of the intraday MA strategy minus that of the next-day MA strategy. For all annual returns, we first calculate the time-series average for each ETF, then average across all ETFs within that liquidity group. Significance is based on standard t-test against zero. The last two rows also list the annual returns of the buy-and-hold strategy on ETF itself and the value-weighted market return. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Long MA	High Liq (%)			Medium Liq (%)			Low Liq (%) †		
(Days)	Intraday	Nextday	Diff	Intraday	Nextday	Diff	Intraday	Nextday	Diff
5	7.61	-1.43	9.03***	10.61	0.18	10.44***	11.49	-0.37	11.85***
10	3.79	-0.34	4.13***	5.30	1.10	4.20***	7.02	1.97	5.05***
20	5.32	2.39	2.93***	6.94	3.79	3.15***	6.83	4.33	2.51***
30	5.05	3.20	1.85***	7.04	4.46	2.58***	7.07	5.13	1.93***
40	4.47	3.11	1.36***	6.04	3.76	2.28***	6.44	4.71	1.72***
50	4.84	3.53	1.31**	6.21	4.66	1.56***	7.00	5.51	1.49***
60	4.74	4.12	0.62*	5.87	5.10	0.76	6.63	5.56	1.08***
70	4.55	4.08	0.47	5.67	4.60	1.07***	6.52	5.64	0.89**
80	4.70	4.62	0.08	5.73	5.41	0.32	6.98	6.55	0.43*
90	4.35	4.11	0.24	6.02	5.30	0.73**	6.59	6.22	0.36*
100	4.53	4.11	0.42	5.49	5.24	0.25	6.24	5.79	0.45**
110	4.01	4.05	-0.04	5.61	4.80	0.81**	5.50	5.14	0.36
120	4.37	3.66	0.71**	5.17	4.73	0.44*	5.43	4.69	0.75***
130	3.75	3.33	0.42	5.07	4.60	0.47*	5.07	4.27	0.80***
140	3.73	3.47	0.26	4.96	4.64	0.32	5.19	4.57	0.62**
150	4.35	3.85	0.50**	5.39	5.15	0.24	5.03	4.59	0.43**
160	3.91	3.94	-0.03	5.41	5.31	0.10	4.75	4.73	0.03
170	3.81	4.10	-0.29*	5.09	5.26	-0.17	4.61	4.60	0.02
180	3.56	4.03	-0.47***	5.01	5.19	-0.18	4.86	4.71	0.15
190	3.90	4.14	-0.24	5.19	5.50	-0.31	5.05	4.87	0.19
200	3.87	4.25	-0.38*	5.02	5.48	-0.46*	5.04	5.07	-0.03

Benchmark Performance	Return (%)	Return (%)	Return (%)
Buy and Hold:	7.93	7.57	6.43
Market Return:	6.53	6.37	5.52

†Two ETFs, IYV and IYD, are removed because their short existence significantly biases benchmark returns.

Table 9: Opening Gaps for ETFs and Indexes

This table focuses on the performance loss caused by opening gaps for the intraday MA strategy on signals days when trading on indexes and their corresponding ETFs. The short-term moving average is 1 day (the ETF price) and the long-term MA length is 10 days. There is no band or transaction cost. In Panel A, for each index/ETF, we report the total number of MA signal days with *Confirmed* and *Reverted* MA signals. Their ratio *Rvt / Cfm* is calculated as the number of reverted MA signal days divided by the number of confirmed MA signal days. The *Total* number of MA signal days is then used to divide signal days caused by opening gaps (*Days by Gap*) to get the percentage (*Percent*) of signal days caused by opening gaps. The last column, average gap loss (*Avg Gap Loss*), is calculated by dividing the total loss from opening gaps by the total number of signal days, with confirmed or reverted MA signals. Panel B uses September 19, 2008 as an example to show how opening gaps affect the performance of the intraday MA strategy differently on S&P500 index and on SPY. Notice that the SPY prices have been adjusted for dividends up to 12/31/2012.

Panel A: Loss from Opening Gap On Signal Days

	Number of Signal Days				Loss from Opening Gap		
Security	Confirmed	Reverted	Rvt / Cfm	Total	Days by Gap	Percent	Avg Gap Loss
SP500:	860	543	0.6314	1403	142	0.1012	0.0104%
SPY:	857	638	0.7445	1495	432	0.2890	0.1006%
DJIA:	605	407	0.6727	1012	139	0.1374	0.0344%
DIA:	625	448	0.7168	1073	317	0.2954	0.1048%
NASDAQ-100:	605	418	0.6909	1023	303	0.2962	0.2000%
QQQ:	597	453	0.7588	1050	286	0.2724	0.1377%

Panel B: Example: Opening Gap on September 19, 2008

Security	Previous Close	10-Day MA	OPEN	HIGH	LOW	Close	MA Ret
SP500	1206.51	1224.94	1213.11	1265.12	1213.11	1255.08	2.57%
SPY	108.78	111.36	115.42	116.61	106.15	113.07	-2.04%

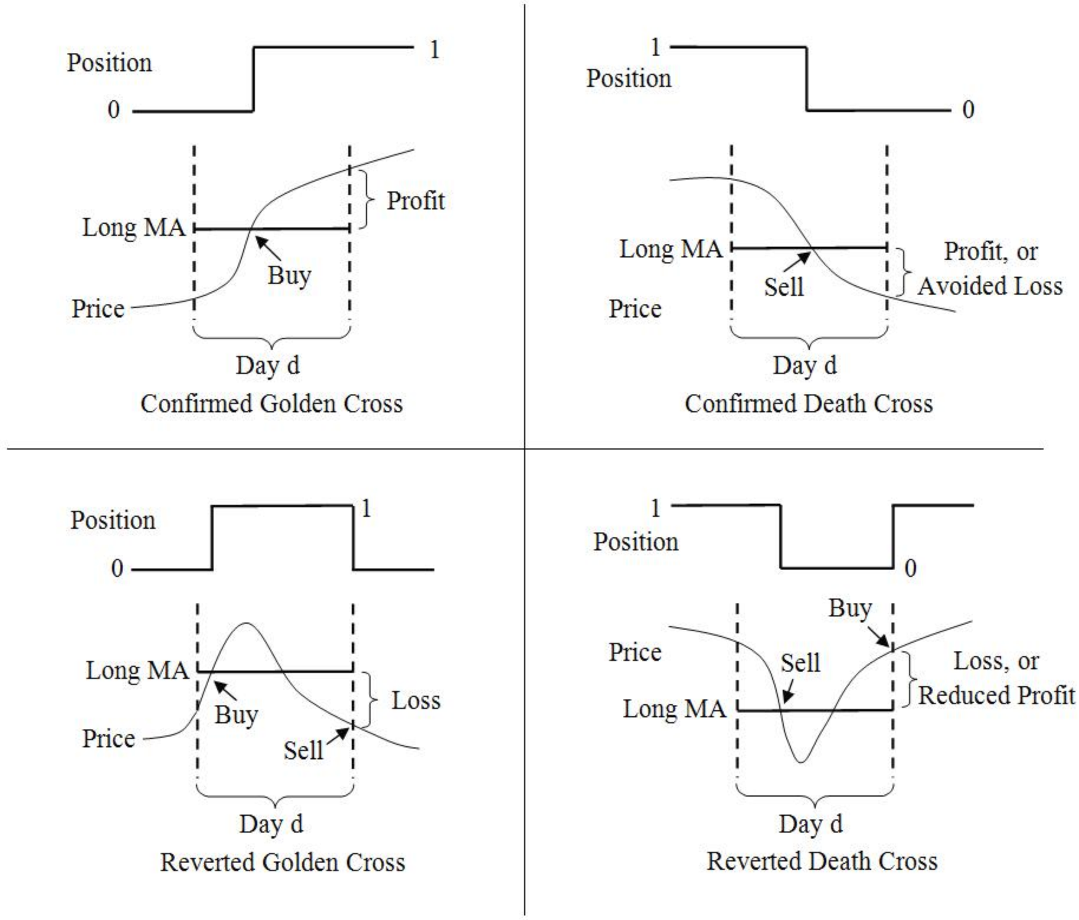

Figure 1: This figure illustrates the intraday moving average trading strategy in four basic cases: confirmed golden cross, confirmed death cross, reverted golden cross, and reverted death cross. In each case, we identify the buy/sell trading signals and the corresponding change in portfolio position, with 1 indicating a full position invested in the stock and 0 for a full position in the risk-free asset. Also, to the right side of each figure we mark the intraday profit/loss relative to a strategy that only respond to signals the next trading day.

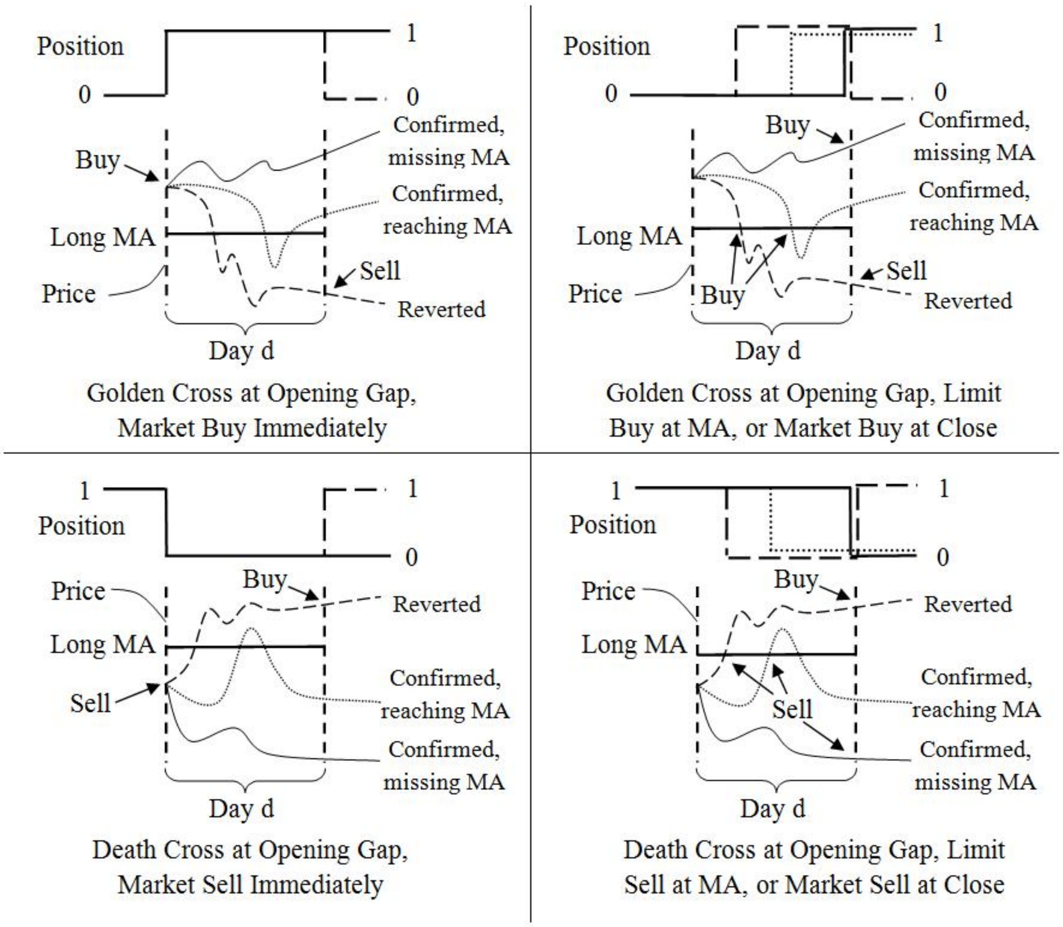

Figure 2: This figure illustrates the intraday moving average trading strategy when a trading signal is generated by an opening gap. Whenever there is a cross at opening, there are three possible scenarios: the solid line is the case when the price confirms the cross at close and never reverts back to the long-term MA; the dotted line is the case when the price confirms the cross at close but temporarily reverts back to the long-term MA within the trading day; and finally the dashed line is the case when the price reverts back to the long-term MA and stays on the other side at closing. The two upper figures are for golden crosses while the bottom two figures are for death crosses, both caused by an opening gap. In the two cases on the left, the strategy buys(sells) immediately at opening, which is a less favorable price than the long-term average. In the two cases on the right, the strategy puts a limit order to buy(sell) at the more favorable price of long-term moving average, but risks the possibility that the limit order will never be filled if the price does not come back to the long-term MA in that day (the solid line scenario). If this is the case, the strategy has to buy(sell) at the closing price.

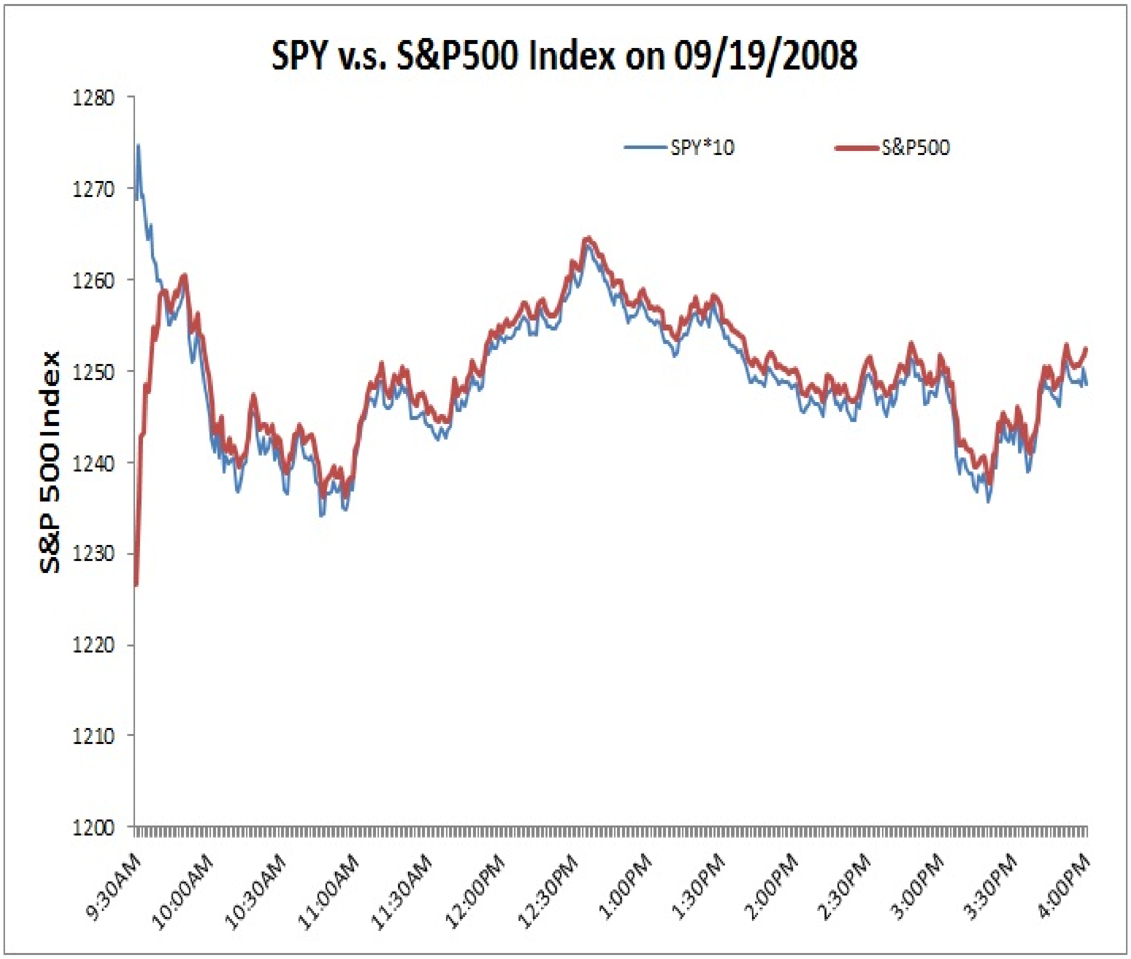

Figure 3: Intraday price chart for SPY multiply by 10 (SPY * 10) and the S&P500 index on September 19, 2008.

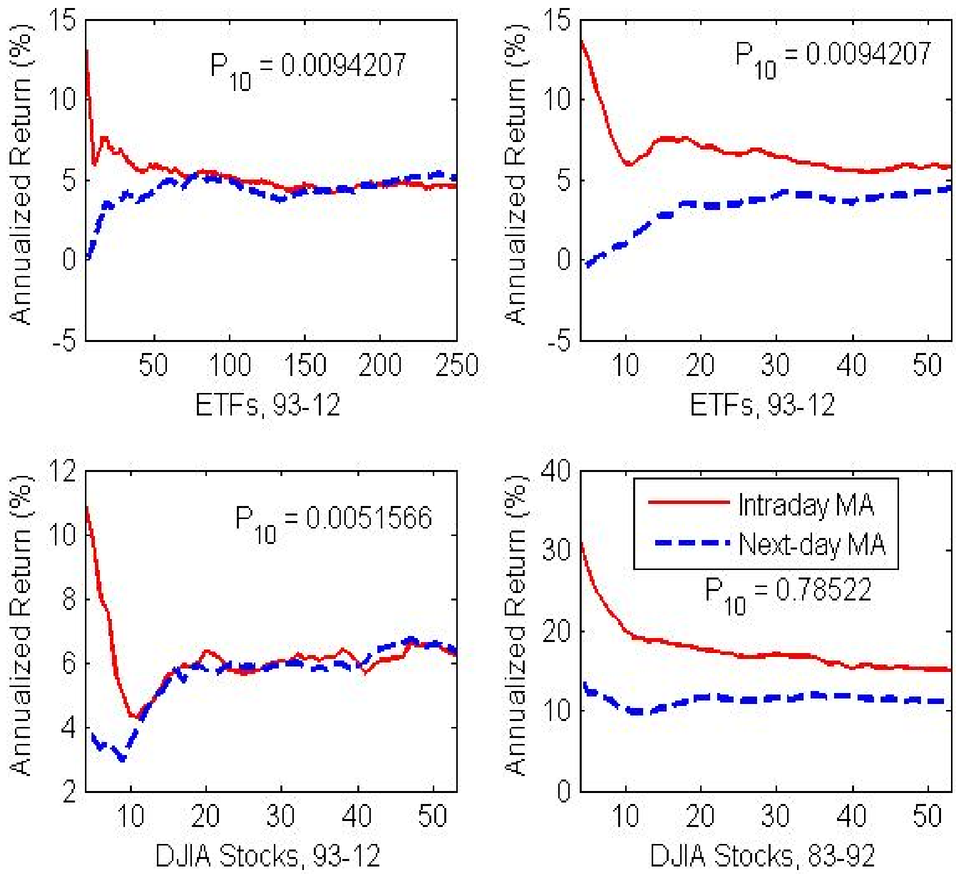

Figure 4: These figures compare the MA performance across different long-term MA lengths for both the intraday and next-day MA strategies. The short-term MA is set at 1 day (the ETF/stock price), and there is no band or transaction cost. The upper-left and upper-right figures illustrate the performances of MA lengths ranging from 5 to 250 days, and from 5 to 50 days, respectively. These two figures use our main data set of 68 ETFs from February 1, 1993 to December 31, 2012. The bottom-left figure compares the 5 to 50-day MA lengths on the 30 DJIA component stocks as of December 31, 2012, also during the same time period from February 1993 to December 2012. The bottom-right figure instead looks at those DJIA component stocks as of December 31, 1992, during the time period from January 1983 to December 1992. All returns are annual returns averaged within each ETF, then across 68 ETFs. We calculate the statistical significance of the underperformance of 10-day MA length (P_{10}) using quadratic regression. p-Values for the intraday MA strategy are printed along each figure.

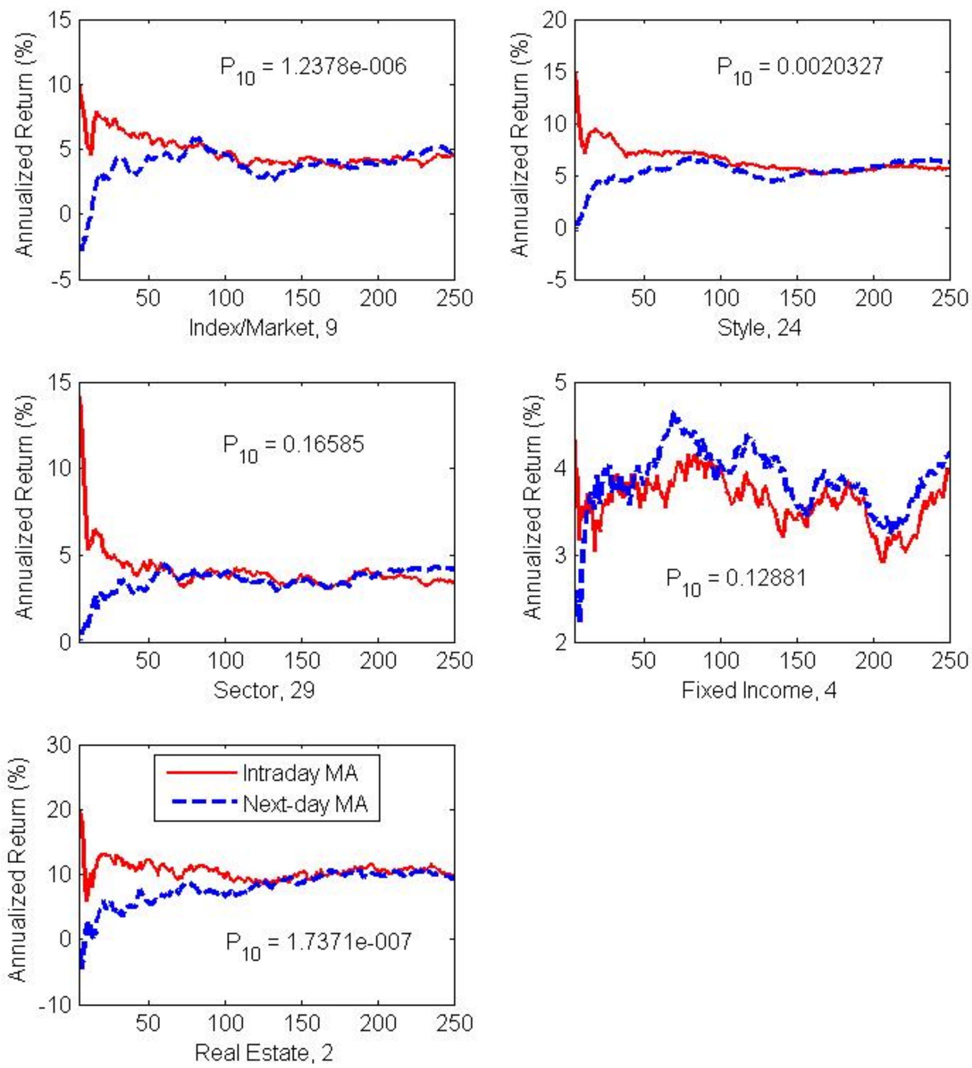

Figure 5: These figures compare the performance dent around the 10-day MA length across different ETF types. The short-term MA is set at 1 day (the ETF/stock price), and there is no band or transaction cost. Each figure presents the average result for one of the ETF types: Index/market, Style, Sector, Fixed Income, and Real Estate ETFs. The number of ETFs of each type is also given after the type description. All returns are annual returns averaged within each ETF, then across ETFs of that type. We calculate the statistical significance of the underperformance of 10-day MA length (P_{10}) using quadratic regression. p-Values for the intraday MA strategy are printed along each figure.

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