The Pricing Efficiency of Leveraged Exchange-Traded Funds

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Abstract

In this paper, we examine the pricing efficiency of leveraged exchange-traded funds (LETFs), which are a recent and very successful financial product. The goal of these funds is to generate *daily* returns that are in a positive or a negative multiple of the daily returns on an underlying benchmark. We find that although price deviations (from NAVs) are small on average, large deviations can occur, especially with funds that have high leverage multiples. Bull funds (i.e., those with positive multiples) tend to trade at a discount more often than bear funds (i.e., those with negative multiples) do. In addition, funds that are on the same side of the market have price deviations that are positively correlated with one another. We also find that price deviations of bull (bear) funds are negatively (positively) correlated with the returns on their own underlying index. These patterns of price deviations behavior are more pronounced in funds that are based on the Russell 2000 index than in funds that are based on the S&P 500 index and the Nasdaq 100 index. We then show that the observed behavior can be partly explained by the funds' daily exposure adjustments, which have to be done at the end of each trading day in order for the funds to maintain their leverage ratios. This is especially true for funds on the Russell 2000, which has the highest amounts of daily exposure adjustments (as a percentage of daily trading value in the index).

JEL classification: G10; G12; G24

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1. Introduction

Leveraged exchange-traded funds (LETFs) are a recent and very successful financial product. Their goal is to generate *daily* returns that are in a positive or a negative multiple of the daily returns on an underlying benchmark. Since their introduction in the U.S. market in 2006, their total assets under management have now (May 2011) grown to approximately $30 billion. There are now over 170 LETFs traded in the market with multiples of +2x, +3x, -2x or -3x. Their underlying benchmarks include equity indices, bond indices, currencies, commodities and real estate indices.

LETFs have also started to receive attention from academics. A few published studies have derived the return dynamics of LETFs (Cheng and Madhavan (2009), Giese (2010), Jarrow (2010)). These papers show that due to the fact that a LETF maintains a constant leverage multiple through time, its compounded return will deviate from the underlying benchmark return multiplied by the stated multiple. The difference will depend on the path that the underlying benchmark takes during the holding period, which, in turn, depends on the volatility of the underlying benchmark return.

On the empirical side, Charupat and Miu (2011) looks at the price deviations and tracking ability of selected LETFs traded in the Canadian market.[1] They find that price deviations are small on average, but large ones are prone to occur. The behavior of price deviations is different between bull (i.e., those with a positive multiple) and bear LETFs (i.e.,

[1] Price deviations are defined as the differences between the funds' closing prices and their net asset values (NAVs). Accordingly, a premium (discount) occurs when the closing price is higher (lower) than the corresponding NAV. Tracking ability is defined as the funds' ability to match the stated multiples of the underlying index returns over various holding periods.

those with a negative multiple). They also find that tracking errors of LETFs are small for short holding periods (up to a week), but become increasingly larger for longer horizons. That is, the longer the holding periods, the larger is the effect of compounding on LETFs' returns. Similar results are reported in Lu et al. (2009), who examine the tracking ability of twelve LETFs traded in the U.S. market.[2]

In this paper, we examine the trading characteristics and pricing efficiency of selected LETFs traded in the U.S. market. We concentrate on LETFs on three underlying indices – the S&P 500, the Nasdaq 100 and the Russell 2000. We choose these three indices because they are among the most-followed equity indices in the U.S. market. They all have well-established traditional (i.e., +1x) ETFs with large amounts of assets under management (AUM). More importantly, all the three indices have a full set of LETFs (i.e., +2x, -2x, +3x and -3x) and also an inverse (i.e., -1x) RTF on them. This enables us to compare the results to see whether the degrees of leverage affect the behavior of the premiums/discounts.[3]

Our findings are as follows. With respect to their trading characteristics, LETFs are traded mainly by short-term, retail traders with an average holding period of under six days, with the shortest being only marginally longer than one day. The average dollar values per trade are smaller for LETFs than for non-leveraged ETFs on the same side of the market, although the magnitude of the differences is generally less than proportional to the leverage ratios. In most cases, the values per trade of +3x and -3x LETFs are greater than those of their +2x and -2x counterparts.

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[2] In addition to these papers, there are a few others such as Avellaneda and Zhang (2009), Guedj et al. (2010), Trainor (2010) and Wang (2009). We will refer to them when appropriate.

[3] In this paper, "ETFs" will refer to +1x or -1x exchange-traded funds, while "LETFs" will refer to exchange-traded funds that use leverage (i.e., +2x -2x, +3x, -3x, etc.). In addition, the word "funds" will refer to both leveraged and non-leveraged ETFs.

With respect to their pricing, our results show that both LETFs and non-leveraged ETFs have price deviations (from NAVs) that, on average, are small and within transaction costs and bid-ask spreads. However, LETFs can sometimes have large premiums and/or discounts. The higher the leverage ratios, the more prone they are to large deviations.[4] In addition, there appears to be a difference between bull funds and bear funds in the behavior of their price deviations, with bull funds tending to trade at a discount more often than bear funds do.

Moreover, funds that are on the same side of the market have price deviations that are positively correlated with one another. That is, bull funds on the same underlying index tend to trade at a premium (or a discount) at the same time. The same is true for bear funds. As a result, bull and bear funds (on the same index) have price deviations that are negatively correlated with each other. Many of these correlations are strong, especially for funds on the S&P 500 index and the Russell 2000 index.

We also find that price deviations of bull (bear) funds are all negatively (positively) correlated with the returns on their own underlying index. That is, on days that the underlying index rises (which means bull funds are doing well), bull price deviations tend not to be as high as on days that the index declines. The reverse is true for bear funds. On days that the underlying index goes up (which means bear funds are doing poorly), bear price deviations tend to be higher than on days that the index decline. These correlations are strong for funds that are based on the Russell 2000 index, but not as strong for funds on the other two indices.

The behavior of price deviations that we observe is similar to, but less strong than, that reported by Charupat and Miu (2011) for the Canadian market. Charupat and Miu conjecture that the behavior could be the result of end-of-day trading (in the stocks comprising the

[4] As will be discussed later, these large premiums/discounts do not necessarily imply pure, executable arbitrage opportunities. This is because of the creation/redemption rules that fund issuers impose (See Section 3).

underlying index) that every LETF has to do in order to adjust its exposure to maintain its leverage ratio. The concentration of these trading activities at the very last minutes of each trading day could substantially move the index's closing level in a very short period of time, and thus amplify price deviations even if there is minimal non-synchronization in observations (More discussion in Section 4).

We test this conjecture in two ways. First, we show that the observed behavior of price deviations did not exist before LETFs were introduced. Secondly, we show that there is a statistically significant relationship between price deviations and end-of-day exposure adjustments (as a percentage of daily index trading value). However, exposure adjustments can only partly explain the variation in price deviations. Accordingly, we conclude that our results can only provide partial support for the conjecture.

The paper is organized as follows. In Section 2, we describe our sample. In Section 3, we measure the pricing efficiency of LETFs and their non-leveraged counterparts. Section 4 investigates the behavior of the observed price deviations. Section 5 concludes the paper.

2. Sample Description

Our sample consists of three sets of funds. In each set, there are six funds (i.e., three pairs) that are based on the same underlying index. The first pair consists of a bull and a bear non-leveraged ETFs (i.e., +1x and -1x). The second pair is a +2x and a -2x LETFs, while the third pair is a +3x and a -3x LETFs. The three underlying indices are S&P 500, Nasdaq 100 and Russell 2000. The names and description of the funds (eighteen in total) are shown in Table 1.

The sample was chosen based on two primary reasons. First, the three underlying indices are among the most-followed equity indices in the U.S. market. They all have well-established traditional (+1x) ETFs with large amounts of assets under management (AUM). At the end of 2010, the AUM of the three +1x ETFs range from $18.4 billion (iShares Russell 2000) to $90.9 billion (SPDR S&P 500).[5] This ensures a substantial degree of familiarity in the underlying indices among investors. It should also generate trading interest in their LETFs, which ensures reasonable liquidity of their trading on the exchanges. Secondly, all the three indices have a full set of LETFs (i.e., +2x, -2x, +3x and -3x) and an inverse (i.e., -1x) on them. This allows us to compare the results to see whether the degrees of leverage affect the behavior of the premiums/discounts.

In case there are competing ETFs and/or LETFs on the same index, we choose the one with the highest value of AUM as of December 31, 2010. Again, this is to ensure that we pick the most liquid funds for our tests. For example, there are three +1x ETFs on the S&P 500 index (i.e., SPDR, iShares and Vanguard). We choose SPDR for our sample because its AUM are the highest (i.e., over 3 times the combined AUM of the other two ETFs). Similarly, there are two +2x (and also two -2x) LETFs on the S&P 500. The ones in our sample have higher AUM.

The total AUM of the twelve LETFs in our sample are $8.2 billion, which represents approximately 28% of the total AUM of all LETFs in the U.S. market. The largest one in the

[5] Indeed, SPDR S&P 500 is the largest exchange-traded funds (of any kind) in the U.S. market. The other two +1x ETFs in the sample are in the top 10 largest ETFs in terms of AUM.

sample is ProShares UltraShort S&P 500 (SDS) with AUM of about $2.7 billion, while the smallest one is ProShares UltraPro Shot QQQ (SQQQ) with AUM of $53 million.

Table 1 also displays the average dollar values per trade based on transactions in the month of December 2010. While the average dollar values per trade are smaller for LETFs than for non-leveraged ETFs on the same side of the market, the magnitude of the differences is generally less than proportional to the leverage ratios. In other words, LETF investors have, on average, greater investment exposure to the underlying indices than non-leveraged-ETF investors do (after taking into account the leverage ratios). In addition, in all but one cases, the values per trade of +3x and -3x LETFs are even greater than those of their +2x and -2x counterparts. Based on these numbers, it appears that the clienteles of LETFs and non-leveraged ETFs are different, and that LETFs with different leverage ratios attract different groups of investors.

Finally, the last column of Table 1 displays the average holding periods for the funds in our sample. These averages are obtained through the following steps. First, we divide the number of outstanding shares in a month by the number of shares traded in that month. This ratio is the holding period for that month (expressed in terms of months). We then multiply this ratio by 30 to express the period in terms of days. Finally, we average these ratios over the twelve months of 2010.[6] We caution, however, that this method of calculation, while common in the literature, does not distinguish between active traders (e.g., market makers and

[6] Reported trading volumes of securities traded on NASDAQ have historically been overstated relative to NYSE securities. This is due to the fact NASDAQ operates as a dealer market, while the NYSE is an auction market. In our sample, all but three funds are traded on the NYSE-Arca system. The three exceptions are QQQ, TQQQ and SQQQ. We do not make any adjustment to their reported volumes, as it is unclear what the adjustment factor should be (See Anderson and Dyl (2005, 2007). As a result, the holding periods that we calculate for the three funds may be understated.

arbitrageurs) and inactive traders (e.g., retail investors). The resulting numbers are the averages across both types of traders.

The holding periods for LETFs are generally very short. All of the LETFs in our sample have average holding periods of less than six days, with the shortest being only marginally longer than one day. The short holding periods for LETFs are not surprising. As has been shown in the literature (Cheng and Madhavan (2009), Giese (2010) and Jarrow (2010)), LETFs' compounded returns over any holding period longer than one day will deviate from the underlying benchmark return multiplied by the stated multiple (See also an example in Section 4 below).[7] This is due to the fact that these leveraged funds rebalance the dollar amount of leverage daily in order to maintain a constant leverage ratio from one day to the next. The more volatile the underlying index and/or the higher the leverage ratio, the larger will be the tracking errors due to rebalancing. (See Section 4 for our empirical investigation of the tracking errors.) In order to avoid tracking errors, investors should only hold LETFs for a short period of time. Our finding here suggests that *on average*, LETF investors are aware of the risk and they limit the holding periods accordingly.[8]

What surprises us, however, is that the holding periods of the +1x ETFs in our sample are also very short. They range from 4.81 days (SPY) to 7.40 days (QQQ), which are much shorter than should be expected for a product that appeals to long-term investors. While there is no doubt that these ETFs are held by a lot of buy-and-hold investors, we believe that the

[7] This fact is also emphasized in the funds' prospectuses.

[8] Guedj et al (2010) estimate the holding periods of four LETFs (two bulls and two bears, none of which is the same as those in our sample). The estimated holding periods range from 5.3 days to 22.7 days. We caution, however, that their numbers and our numbers are not directly comparable. This is because they use a different estimation method and also a different data period. Since their data come from a period earlier than ours, it is possible that traders gradually learnt about the risk of holding LETFs for a long period of time, and so subsequently adjusted their trading behavior accordingly.

short holding periods are caused by arbitrageurs and/or active traders who use the ETFs to speculate on macroeconomic or market/sector-wide trends. For this speculative purpose, ETFs are preferred to mutual funds because ETFs are traded on stock exchanges and have no short-term trading fees (which several mutual funds have). The fact that the three +1x ETFs in our sample are all based on broad indices and have very liquid markets, makes them appealing to speculators. Finally, we note that for all but one pairs of funds, the average holding period for the bull fund is shorter than that of its bear counterpart.

3. Pricing Efficiency

For all ETFs and LETFs, we define the daily price deviations as:

$$\pi_t^j = \frac{P_t^j - NAV_t^j}{NAV_t^j} \times 100, \tag{1}$$

where P_t^j is the closing price of fund *j* on day *t* and NAV_t^j is the net asset value (NAV) of the fund on the same day. Accordingly, π_t^j is the price deviation (in percentage term) observed on fund *j* on day *t*. If π_t^j is positive (negative), it is a premium (discount).

Market prices of an exchange-traded fund are kept in line with the fund's NAVs through the fund's creation and redemption process. The process enables certain traders (known as authorized participants) to buy (i.e., create) and sell (i.e., redeem) fund units in large blocks directly with the fund issuer (or sponsor) at the NAV.[9] The process establishes an arbitrage relationship between price and NAV. If, for example, the fund's market price is below its NAV, traders can buy fund units, redeem them for the NAV and capture the difference (minus transaction costs and imposed fees)

The creation and redemption process for non-leveraged (i.e., +1x) ETF is typically different from that for LETFs and -1x ETFs. For the vast majority of +1x ETFs traded in the U.S. market (including the three in our sample), creation and redemption are done in kind. That is, authorized participants buy fund units by giving the fund issuer a basket of securities specified by the issuer (usually one that approximates the holdings of the fund). The reverse occurs when they redeem fund units.

In contrast, LETFs and -1x ETFs mainly use an in-cash process. That is, blocks of fund units are exchanged for cash. This process is used because LETFs and -1x ETFs usually do not hold the securities in the underlying indices. Rather, they generate their returns primarily by using derivatives on the underlying benchmarks such as total return swaps and futures contracts.

It should be noted that arbitraging between price and NAV may not be immediate and can involve a certain degree of risk. This is because fund issuers may require creation/redemption orders to be submitted prior to the end of a trading day in order for the orders to be executed at that day's NAV (which is determined at the end of a trading day). In such a case, arbitragers will have to hedge the price risk (e.g. by using futures contracts on the underlying index).[10]

[9] Typically, a block (or creation unit) consists of between 50,000 and 75,000 fund shares.
[10] The creation/redemption requirements can differ from one fund company to another. For example, according to the document entitled "Statement of Additional Information" by ProShares Trust, creation/redemption orders

Previous studies have examined the pricing efficiency of +1x ETFs. These include Ackert and Tian (2000, 2008); Chu and Hsieh (2002) and Engle and Sarkar (2006). They find that price deviations are generally small on +1x ETFs with domestic underlying indices. In contrast, +1x ETFs with international underlying indices often have large and positive premiums. However, the observed premiums are still mostly within transaction costs and so arbitrage is not likely.

To our knowledge, the pricing efficiency of LETFs and -1x ETFs in the U.S. market has not been documented before. In the Canadian market, Charupat and Miu (2011) measure the price deviations of +2x and -2x LETFs (Triple-leverage LETFs are not available there.). They find that on average, deviations are small. However, large premiums and large discounts are not uncommon. In addition, the behavior of price deviations is different between the +2x (i.e., bull) and the -2x LETFs (i.e., bear) on the same underlying index. Bear LETFs trade at a premium (i.e., positive deviation) more often than bull LETFs do. As a result, the average price deviations on bear LETFs are greater than the average price deviations on bull LETFs.

Moreover, they report that the price deviations of bull (bear) ETFs are negatively (positively) correlated with the returns on their underlying indices. They point out that the observed correlations are consistent with the argument that the end-of-day rebalancing of the funds' exposures increases trading volume and market volatility at the close of a trading day (see Section 4.2 for detailed discussion of the possible impact of end-of-day rebalancing on price deviations).

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submitted by phones or other electronic means must be received by 15:30 of a trading day in order to receive that day's NAV. In contrast, Direxion set the cutoff time at 16:00.

3.1. Results

The price deviations are calculated using data on closing prices and NAVs obtained from the Center for Research in Security Prices (CRSP). In order to compare the results within each set of funds, we use the same data period for the funds in each set. In other words, the length of the sample period for each set is determined by the ETF or LETF that was most recently introduced in that set (See Table 1 for their listing dates).

The results are presented in Panels A – C of Table 2. For all ETFs and LETFs in the sample, the average price deviations are small (not exceeding 0.10% of NAVs). The only exception is TNA (i.e., +3x LETF on Russell 2000), which is -0.13%. While many of these averages are significant in the statistical sense, they are within or close to the bid-ask spreads and transaction costs.[11]

There are several patterns that are generally consistent across the three sets of funds. First, all bull funds (i.e., +1x, +2x and +3x funds) have negative average price deviations (i.e., discounts). With only one exception (i.e., TQQQ – the +3x LETF on Nasdaq 100), the higher the bull funds' leverage, the deeper the discounts they have. In contrast, all except one bear funds trade on average at premiums. The only exception is SDS (i.e., -2x on S&P 500). Also, in general, the higher the bear funds' leverage, the larger the premiums they have.

Secondly (and as a related matter), for each pair of funds, the average price deviation is lower (i.e., being more negative or less positive) for the bull fund than for the bear fund. This is true for all pairs of funds regardless of the underlying index and the leverage ratios.

[11] We calculated the average bid-ask spreads using daily closing bid and closing ask prices over the sample period. The average spreads, as percentages of closing mid prices, range from 0.0082% (for SPY) to 0.1402% (for TZA), with fourteen out of the eighteen funds in the sample having average spreads of less then 0.10%.

Both of the above patterns are consistent with the fact that bear funds tend to have positive price deviations (i.e., premiums) more often than their bull counterparts do (columns 8 and 9 of Table 2). This is true for all pairs of funds. The results of Wilcoxon tests (not shown) indicate that there are indeed statistically significant differences in the distributions of price deviations between bull and bear funds for all pairs.

Finally, the higher the fund's leverage, the larger is the variation of their price deviations. In other words, funds with higher leverage ratios are more prone to having large premiums or discounts than funds with lower leverage ratios. This is evidenced by the fact that for all underlying indices, both the standard deviations of price deviations and the gaps between the values of the 5^{th} and 95^{th} percentiles are increasing in the funds' leverage ratios (when comparing among the funds on the same side).

This last pattern is consistent with Engle and Sarkar's (2006) argument that the volatility of price deviations is related to the volatility of the underlying NAV. As shown in the last column of Table 2, the volatilities of the funds' NAVs are approximately proportional to the funds' leverage ratios. This results in the observed relationship between leverage ratios and the volatility of price deviations.

In summary, our results show that both leveraged and non-leveraged ETFs have price deviations (from NAVs) that, on average, are small and within transaction costs and bid-ask spreads. However, leveraged funds are prone to having large premiums and/or discounts (that exceed the bid-ask spreads and transaction costs). The higher the leverage ratios, the more prone they are. However, due to the funds' creation/redemption rules, which can require creation/redemption orders to be submitted before the transaction price (i.e., the end-of-day

NAV) is known, arbitraging between prices and NAVs may not be straightforward and can entail risk.

In addition, there appears to be a difference between bull funds and bear funds in the behavior of their price deviations, with bull funds tending to trade at a discount more often than bear funds do. We will investigate these behaviors further in the next subsection.

3.2. Behavior of Price Deviations

The results in the previous subsection suggest that there is a difference in the behavior of price deviations between bull and bear funds. To investigate further, we calculate the correlations of price deviations of the funds that are based on the same underlying index. The results are displayed in Table 3.

We can see that funds that are on the same side of the market have price deviations that are positively correlated with one another. That is, bull funds on the same underlying index tend to trade at a premium (or a discount) at the same time. The same is true for bear funds. As a result, bull and bear funds (on the same index) have price deviations that are negatively correlated with each other. That is, when bull funds trade at a premium, bear funds will tend to trade at a discount. All of these correlations are significantly different from zero at the 1% level. Many of them are strong, with absolute values greater than 0.50. This is especially true in Panels A (S&P 500) and C (Russell 2000).

The observed correlations suggest that price deviations may be driven by some common factors. To investigate this, we calculate the correlations between price deviations and the underlying index returns. The results are shown in the last column of each Panel in Table 3.

For bull funds, their price deviations are negatively correlated with the underlying index returns. The correlations are significantly different from zero at the 1% level, except for QQQ (i.e., the +1x fund on Nasdaq 100), which is significant at the 5% level. Note, however, that the correlations are not particularly strong (i.e., less than 0.30). The exceptions are as the +3x fund on the Nasdaq 100 (in Panel B) and all bull funds that are based on the Russell 2000 index (in panel C). Our interpretation of this result is that on days when the underlying index does well, bull funds (which also do well on such days) have a slight tendency to trade at a discount. On the other hand, on days when the underlying index falls, bull funds (which also do poorly on such days) tend slightly to trade at a premium.

For bear funds, their price deviations are positively correlated with the underlying index returns. The correlations are significantly different from zero at the 1% level, except for SH (i.e., the -1x fund on S&P 500), which is insignificant, and PSQ (i.e., the -1x fund on Nasdaq 100), which is significant at the 5% level. As before, the correlations are not very strong. This implies that on days when the underlying index rises, bear funds (which do poorly on such days) have a small tendency to trade at a premium. On the other hand, on days when the underlying index drops, bear funds (which do well on such days) tend to trade at a discount.

To gain a further insight into the relationship between price deviations and the underlying index returns, we calculate average price deviations conditional on the direction of the underlying index. The results, displayed in Table 4, are consistent with what the correlations in Table 3 suggest. As the numbers show, price deviations behave differently between the days when the underlying indices go up and the days they drop. For all bull funds, average price deviations are negative on the "up" days, and positive (or only marginally negative) on the "down" days. On the other hand, all bear funds have average price deviations that are positive (i.e., premiums) on the "up" days, and negative (i.e., discounts) on the "down" days. The pattern is very pronounced for funds on the Russell 2000 index in Panel C. A Wilcoxon-Mann-Whitney test confirms the differences in the distributions of premiums between the "up" and "down" days for all funds.

4. Possible Explanations for the Observed Behavior of Price Deviations

In this section, we examine two possible reasons for the observed behavior of price deviations. The first reason is based on trader behavior and bid-ask spreads, while the second reason involves the end-of-day trading activity from LETFs' exposure adjustments.

4.1. Trader Behavior and the Bid-Ask Spreads

As reported in Table 1, almost every fund in our sample has a very short holding period (i.e., generally only a few days). This indicates that there are many short-term traders and/or day traders who trade these funds. To realize their profits, these traders will want to sell their holdings on days that the funds make money. That is, they will sell bull (bear) funds on days that their underlying index goes up (down). If these sale orders are submitted close to or at the end of those days, the closing prices will be the bid prices, and thus the measured price deviations for both bull and bear funds will be downwardly biased by half of the bid-ask spreads.[12] This leads to negative (positive) correlations between bull (bear) fund price deviations and their underling index returns.

On the other direction, short-term traders are reportedly loss-averse and thus are reluctant to sell their holdings on days that their funds lose money (see Linnainmaa (2003) and Locke and Mann (2005)). This behavior increases the likelihood that on those days the closing prices will come from buyer-initiated trades and thus will be on the ask side. This creates an upward bias by half of the bid-ask spreads to price deviations on bull (bear) funds on days that their underlying index declines (increases). Again, this leads to negative (positive) correlations between bull (bear) price deviations and their underling index returns.

However, as mentioned earlier, the bid-ask spreads of the funds in our sample are very small, with fourteen out of the eighteen funds having spreads of less than 0.10% on average. Therefore, it is unlikely that (half of) the spreads can explain much of the observed price deviations in Table 4. In addition, we also repeat the calculations of price deviations and correlations using closing mid prices (i.e., averages of closing bid and closing ask prices). Even though the price deviations (not shown) are slightly lower in magnitude than the numbers in Table 4, they still exhibit similar correlations to those in Table 3. As a result, we conclude that the observed patterns of price deviations are unlikely to be caused by the trading of short-term traders and the bid-ask spreads.

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[12] Short-term traders prefer to close their positions by the end of each trading day. As a result, they are very active in the closing period (see Linnainmaa (2011) and Locke and Mann (2005)). Given the increased risk due to the embedded leverage, short-term traders may prefer not to hold an LETF position overnight.

4.2. End-of-Day Exposure Adjustments

In this subsection, we will test the conjecture by Charupat and Miu (2011) that the observed behavior of price deviations are the result of end-of-day trading activity (in the underlying indices) from LETFs' exposure adjustments. To understand the conjecture, note that every LETF and inverse ETF has to adjust (the dollar value of) its exposure at the end of every day to correspond to the movement in the underlying index in order to maintain its constant percentage leverage ratio. As shown by Cheng and Madhavan (2009), the dollar amount of exposure adjustment for fund *j* on day *t* can be calculated as follows:

$$\Delta_t^j = \left(\beta_j^2 - \beta_j\right) \cdot \mathrm{AUM}_{t-1}^j \cdot i_{t-1,t}, \qquad (2)$$

where β_j is the fund's leverage ratio, AUM_{t-1}^j is the fund's assets under management on day $t - 1$, and $i_{t-1,t}$ is the return on the fund's underlying index between day $t - 1$ and day t.

Note that the amount of adjustment can be more than proportional to the fund's leverage ratio (except when $\beta_j = +2$). For example, for a -2x LETF, $\beta_j^2 - \beta_j$ is 6.

In addition, equation (2) suggests that the daily exposure adjustments of both bull and bear LETFs (on the same underlying index) are always in the same direction as the index's movement. In other words, there is no offsetting adjustment between bull and bear LETFs on the same index. For example, on days where the underlying index rises, bull funds (which have positive exposures to the benchmark) do well and have to further increase their exposures. At the same time, bear funds (which have negative exposures to the benchmark) do poorly and have to reduce their negative exposures (i.e., make them more positive). Both actions result in buy orders for the stocks comprising the benchmark. The reverse is true for days where the underlying benchmark declines.[13]

Generally, the adjustments are done close to the end of each trading day, and so their impact on the underlying index will be felt at that time. To see how these adjustments can cause the observed behavior of price deviations reported in the previous subsection, consider the following scenarios. On days when the underlying index rises, fund issuers (or, if derivatives such as swaps are used to generate the returns, their swap counterparties) need to purchase more of the securities comprising the underlying index, thus further increasing the index level right at the last minutes of those trading days. As a result, the LETFs' closing prices, which are likely to come from an earlier time, do not fully reflect the increase in the index.[14] This creates a downward bias in the price deviations of bull funds (i.e., closing prices being lower than NAVs), and an upward bias in the price deviations of bear funds (i.e., closing prices being higher than NAVs). Similarly, on days where the underlying index falls, the exposure adjustments require that the fund issuers sell some of the securities in the underlying index, putting further downward pressure on the index at closing. In this case, the LETFs' closing prices do not fully incorporate the decline in the index due to the rebalancing trading activities, creating an upward bias in the price deviations of bull funds and a downward bias in the price deviations of bear funds. Consequently, price deviations of bull funds are negatively correlated with the index returns, while the opposite is true for bear funds.

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[13] It should be noted, however, that the actual amount of exposure adjustments can be less than specified by equation (2). This is because most funds use derivatives to generate their returns. It is possible that the counterparties to the derivatives may have offsetting positions from their other obligations.

[14] It is reasonable to expect the closing price of an underlying index to come from a later time than the closing price of the funds that are based on it. This is because trading in an index is much more liquid than in the funds.

A few studies have examined the nature of trading at market close and the impact of order flows on closing prices on the New York Stock Exchange (NYSE) and the Nasdaq market. For example, Cushing and Madhavan (2000) find that the demand for immediacy is greater during the closing period, especially from institutional investors who shift their block orders from the "upstairs" market to the regular "downstairs" market. They also find that prices become more sensitive to (non-block) order flows near the close. Bacidore and Lipson (2001) report that closing prices can be affected by temporary liquidity pressures, especially when market-on-close orders create order imbalances.[15] Taken together, these findings lend a support to the above conjecture that trading due to exposure adjustments can indeed move prices considerably and, as a result, may explain the observed behavior of price deviations (from NAVs).

In addition, some media outlets and market makers have reported anecdotal evidence that suggested that exposure adjustments by LETFs and inverse ETFs have increased market volatility, especially at the end of each day (e.g., Lauricella et al (2008) and Zweig (2009)). Regulatory bodies have also been concerned about the impact. In September 2011, the *Wall Street Journal* reported that the Securities and Exchange Commission (SEC) has had discussions with firms that trade LETFs to get a better understanding of the volatility effect (see Patterson (2011)).

There are, however, traders who do not believe that the impact is currently significant (e.g., Keefe, 2009). In addition, Trainor (2010) examines the volatility of the S&P 500 index

[15] A market-on-close order is a market order that is to be executed as near to the end of a trading day as possible. In many case, these orders are executed after 16:00 at prices that clear the market. These prices become the official closing prices of that day. When there is a significant order imbalance (between buy and sell), the closing prices can be considerably different from the prices observed at 16:00.

in the half-hour period between 15:30 and 16:00 of a trading day over the period from January 1998 to April 2010. He concludes that there is no evidence that end-of-day rebalancing of LETFs' exposures has caused the volatility of the S&P 500 index to increase in a systematic manner. He adds, however, that the S&P 500 is a large market relative to its LETFs, and that the impact of the rebalancing could exist for other indices whose LETFs make up a greater percentage of the index values.

Accordingly, whether or not the above conjecture can explain the observed behavior of price deviations is an empirical question and will likely depend on which underlying index one investigates. For our sample, we will test the conjecture in two ways. First, we check whether the observed behavior also existed in the +1x ETFs in the period before the LETFs were introduced. If the observed behavior is caused by the exposure adjustments, then we should not observe it when LETFs did not yet exist. Table 5 displays the average price deviations of the three +1x ETFs on the "up" days and "down" days during the two-year period ending one month before the introduction of the first LETF (or -1x ETF) on the same underlying indices (henceforth referred to as the "prior" period). As the numbers show, the pattern of price deviations for the "up" and "down" days in this prior period is the reverse of what we observe in Table 4 for SPY (S&P 500) and IWM (Russell 2000). Here, price deviations are positive (or less negative) when the underlying indices go up. For QQQ (Nasdaq 100), the pattern in the prior period appears to be the same as in the sample period.[16] Thus, the results appear to provide support for the above conjecture for funds that are based on the S&P 500 and the Russell 2000 indices, but not those on the Nasdaq 100 index.

[16] The Wilcoxon-Mann-Whitney test shows that the differences between the "up" and "down" days in Table 5 (i.e., prior period) are not significant for SPY, but are significant at the 1% level for IWM and QQQ.

Secondly, we test the conjecture by running the regression between price deviations and exposure adjustments normalized by the amounts of trading in the underlying index as follows:

$$\pi_t^j = a + b \frac{\Delta_t}{INDTRADE_t} + \varepsilon_t^j , \tag{3}$$

where π_t^j is the price deviation (in percentage term) observed on fund *j* on day *t*, Δ_t is the sum of the amounts of day-*t* exposure adjustments of *all* LETFs and inverse ETFs that are based on fund *j*'s underlying index and that are traded in the U.S market, $INDTRADE_t$ is the total trading value of the fund's underlying index on day *t* (i.e., sum of the daily dollar trading values across all the index's constituents), and ε_t^j is the residual term.[17] Accordingly, the independent variable in the regression is the *normalized* amount of exposure adjustments (i.e., after taking into account the trading activity in the underlying index), expressed in percentage terms. The normalization is required because a given amount of adjustments will have different impacts on the underlying index depending on how liquid the underlying index is on any particular day. The value of Δ_t is estimated using equation (2) above.

Before we present the regression results, we report in Table 6 summary statistics on the total AUM of *all* the LETFs and inverse ETFs for each underlying index, the index's market capitalization, the absolute value of daily exposure adjustments ($|\Delta_t|$), and the daily trading

[17] To clarify, for each underlying index, Δ_t includes the amount of exposure adjustments of not only the LETFs and inverse ETF in our sample that are based on that index, but also other LETFs and inverse ETFs traded in the U.S. market that are based on the same index. Therefore, Δ_t captures the total amount of exposure adjustments on that index on day *t*.

value of the index ($INDTRADE_t$).[18] The values shown in the table are the averages of daily values of these variables over the sample period. For example, consider the S&P 500 index. The average total AUM of all the LETFs on it is $7.33 billion, while the average market capitalization of the S&P 500 during the same period is $10,197 billion. The average of the ratio between the two (henceforth referred to as the AUM-to-index-cap ratio) is only 0.07%, which suggests that the S&P 500 is very large relative to its LETFs. With respect to exposure adjustments, since Δ_t can be positive or negative depending on the index return on day *t*, we take absolute value of them first before we calculate the average.[19] That average is $253 million, compared to the average *INDTRADE* of $29.48 billion. The average of the ratio between these two numbers is 0.85%. This means that on average, the exposure adjustments for all the LETFs account for 0.85% of the S&P 500's daily trading value, which is much higher than what the AUM-to-index-cap ratio would suggest (i.e., 0.07%). This is due to the fact that, as mentioned earlier, the amounts of exposure adjustments are not linear in AUM and can be more than proportional to the funds' leverage ratios.

While the average exposure adjustments of 0.85% may not sound significant, it is important to remember that these trades come into the market at once near the close of each trading day. Hence, depending on the liquidity at the end of a day, these trades can have an impact on the price and volatility of the index.

The numbers for the Nasdaq 100 index are qualitatively similar to those of the S&P 500. Again, even though the LETFs on it have an average AUM-to-index-cap ratio of only

[18] For brevity, for the rest of this section, we will use the term "LETFs" to include both LETFs and inverse ETFs.

[19] Absolute value is taken only for the purpose of calculating the numbers in Table 6. It is not taken when we run the regression in equation (3).

0.08%, their exposure adjustments account for, on average, 0.69% of the index's daily trading value.

Finally, the Russell 2000 index has the largest AUM-to-index-cap ratio (i.e., 0.15%). More importantly, its average exposure-adjustments ratio is 3.54%, while the number for the 95^{th} percentile is 9.80%. In this case, exposure adjustments account for a much larger portion of trading in the index at the end of a day than in the other two indices.

If the observed behavior of price deviations can be attributed to the end-of-day exposure adjustments, we expect the results of the regression in equation (3) to show a significant relationship between premiums and normalized exposure adjustments, especially for LETFs on the Russell 2000 index. This is indeed what we find. Table 7 reports the results of the regression. There are a few things to note from the results. First, the slope coefficients are statistically significant for all funds, all but one of which are significant at the 1% level. They are also of the correct signs. For all bull (bear) funds, the slope coefficients are negative (positive). This is consistent with our prior findings that price deviations of bull (bear) funds are negatively (positively) correlated with the underlying index returns (which, as shown in equation (2), determines the sign of Δ_t and, by extension, the sign of the normalized exposure adjustments). To make sense of the magnitude of the slope coefficients, consider, for example, the coefficient for SQQQ (i.e., 0.1268). This value means that every one percent of normalized exposure adjustments is related to a price deviation of +0.1268%. Suppose that on day *t*, the normalized exposure adjustments are 0.69% (see Table 6). This will translate to a price deviation for SQQQ of +0.0875% on that day.

Secondly, the slope coefficients are higher (in absolute terms) for funds with higher leverage ratios. This suggests that end-of-day exposure adjustments have a greater impact on high-leverage funds than on low-leverage funds and non-leveraged funds. This is consistent with the above-mentioned conjecture. To see why, consider the following argument. Suppose that for all funds on the same index, their prices just before the end of a trading day are exactly the same as their NAVs (i.e., no deviations). Then, if end-of-day exposure adjustments cause the index value to move away, the NAVs of those funds will change. Because of their leverage, the NAVs of LETFs will change by more than the NAVs of +1x funds. The higher the funds' leverage ratios, the larger are the changes. Therefore, we should expect to see higher slope coefficients for higher-leverage funds.

Thirdly, the R-squares of the regressions differ from one underlying index to another. For funds on the S&P 500 index (Panel A), the R-squares are generally low, ranging from 0.02 to 0.09. Therefore, it appears that end-of-day exposures adjustments cannot explain much of the variation in price deviations of the funds that are based on the S&P 500. In contrast, the R-squares are highest for funds on the Russell 2000 index (ranging from 0.15 to 0.23). This is as predicted by the conjecture since this is the index whose exposure adjustments account for the largest (among the three indices) portion of trading in the index at the end of a day.

In summary, the regression results provide some support for the conjecture that the observed behavior of price deviations is caused by end-of-day exposure adjustments. This is especially true for funds that are based on the Russell 2000 index. For funds on the other two indices, the low R-squares suggest that there are other factors that also influence the pattern of their price deviations (or that the relationship between price deviations and exposure adjustments is not linear).

Finally, the behavior of price deviations that we observe is similar, but less strong than that reported by Charupat and Miu (2011) for the Canadian market. This is perhaps due to the fact that U.S. LETFs exposure as a percentage of the market capitalization of their underlying indices is much smaller. As a result, the U.S. market can better absorb the impact of the end-of-day exposure adjustments.

5. Conclusions

In this paper, we examine the pricing efficiency and the tracking error of selected LETFs traded in the U.S. market. Our sample consists of LETFs on three underlying indices that are widely followed by investors – the S&P 500, the Nasdaq 100 and the Russell 2000. We also compare the results to those of non-leverage ETFs (i.e., +1x) and non-leveraged inverse ETFs (i.e., -1x) that are based on the same indices.

With respect to their pricing, our results show that both LETFs and non-leveraged ETFs have price deviations (from NAVs) that, on average, are small and within transaction costs and bid-ask spreads. However, LETFs can sometimes have large premiums and/or discounts. The higher the leverage ratios, the more prone they are to large deviations. In addition, there appears to be a difference between bull funds and bear funds in the behavior of their price deviations, with bull funds tending to trade at a discount more often than bear funds do.

Moreover, funds that are on the same side of the market have price deviations that are positively correlated with one another. That is, bull funds on the same underlying index tend to trade at a premium (or a discount) at the same time. The same is true for bear funds. As a result, bull and bear funds (on the same index) have price deviations that are negatively correlated with each other. Many of these correlations are strong, especially for funds on the S&P 500 index and the Russell 2000 index.

We also find that price deviations of bull (bear) funds are all negatively (positively) correlated with the returns on their own underlying index. These correlations are strong for funds that are based on the Russell 2000 index, but not as strong for funds on the other two indices.

The behavior of price deviations that we observe is consistent with the conjecture proposed by Charupat and Miu (2011) that price deviations are caused by the funds' end-of-day exposure adjustments. Out of the three underlying indices in our sample, the Russell 2000 index has the highest percentage of LETFs exposure and thus should be most prone to the impact of the end-of-day exposure adjustments. The behavior of its LETFs' price deviations supports the conjecture.

References

Ackert, L. F., Tian, Y. S., 2000. Arbitrage and valuation in the market for Standard and Poor's Depositary Receipts. Financial Management 29, 71-87.

Ackert, L. F., Tian, Y. S., 2008. Arbitrage, liquidity, and the valuation of exchange traded funds. Financial Markets, Institutions & Instruments 17, 331-362.

Anderson, A. M., Dyl, E. A., 2005. Market structure and trading volume. Journal of Financial Research 28, 115-131.

Anderson, A. M., Dyl, E. A., 2007. Trading volume: NASDAQ and the NYSE. Financial Analyst Journal 63, 79-86

Avellaneda, M., Zhang, S. J., 2009. Path-dependence of leveraged ETF returns. Working paper, SSRN.

Bacidore, J. M., Lipson, M. L., 2001. The effects of opening and closing procedures on the NYSE and Nasdaq, Working paper, SSRN.

Charupat, N., Miu, P., 2011. The pricing and performance of leveraged exchange-traded funds. Journal of Banking and Finance 35, 966-977.

Cheng, M., Madhavan, A., 2009. The dynamics of leveraged and inverse exchange-traded funds. Journal of Investment Management 7, 43-62.

Chu, Q. C., Hsieh, W. G., 2002. Price efficiency of the S&P500 index market: Evidence from the Standard and Poor's Depositary Receipts. Journal of Futures Markets 22, 877-900.

Cushing, D., Madhavan, A., 2000. Stock returns and trading at close. Journal of Financial Markets 3, 45-67

Engle, R. F., Sarkar, D., 2006. Premiums-discounts and exchange traded funds. Journal of Derivatives 13, 27-45.

Giese, G., 2010. On the risk-return profile of leveraged and inverse ETFs. Journal of Asset Management 11, 219-228.

Guedj, I., Li, G., McCann, C., 2010. Leveraged and inverse ETFs, holding periods, and investment shortfalls, Journal of Index Investing 1 (3), 44-57.

Jarrow, R. A., 2010. Understand the risk of leveraged ETFs. Finance Research Letters 7 (3), 135-139.

Keefe, J., 2009. Strange end-of-day phenomenon sets pundits thinking. Financial Times, May 10, 2009.

Linnainmaa, J. 2003. The anatomy of day traders. Working paper. University of California, Los Angeles.

Locke, P. R., Mann, S. C. 2005. Professional trader discipline and trade disposition. Journal of Financial Economics 76, 401-444.

Lu., L., Wang, J., Zhang, G. 2009. Long term performance of leveraged ETFs. Working paper, SSRN

Lauricella, T., Pulliam, S., Gullapalli,, D. 2008. Are ETFs driving late-day turns? Wall Street Journal, December 15, 2008.

Patterson, S. 2011. SEC looks into effect of ETFs on market volatility. Wall Street Journal, September 6, 2011.

Trainor, W. J. 2010. Do leveraged ETFs increase volatility? Technology and Investment 1, 215-220.

Wang, Z. 2009. Market efficiency and leveraged ETFs. Working Paper.

Zweig, J. 2009. Will leveraged ETFs put cracks in market close? The Wall Street Journal, April 18, 2009.

Table 1

Descriptive statistics. This table provides summary statistics of the funds in the sample. The average holding period is calculated over the 12 months of 2010 in two steps. First, the average number of outstanding shares in each month is divided by the number of fund units traded in that month, and then multiplied by 30 to obtain the holding period (in terms of days) in that month. These holding periods are then averaged to arrive at the figures in the table. The value per trade is calculated by dividing the total dollar trading value for the month of December 2010 by the number of trades in the month.

Panel A: Underlying Index = S&P 500 Total Return Index

Name	Symbol	Multiple	Listing Date	AUM as of 12/10 ($ millions)	Average Dollar Value per Trade (12/10)	Avg. Holding Period (days)
SPDR S&P 500	SPY	+1x	29 Jan 93	$90,924	$52,995	4.81
ProShares Short S&P 500	SH	-1x	21 Jun 06	$1,554	$19,588	18.69
ProShares Ultra S&P 500	SSO	+2x	21 Jun 06	$1,590	$15,175	3.21
ProShares UltraShort S&P 500	SDS	-2x	13 Jul 06	$2,730	$17,534	4.39
ProShares UltraPro S&P 500	UPRO	+3x	25 Jun 09	$205	$37,795	1.22
ProShares UltraPro Short S&P 500	SPXU	-3x	25 Jun 09	$290	$7,911	2.45

Panel B: Underlying Index = Nasdaq 100

Name	Symbol	Multiple	Listing Date	AUM as of 12/10 ($ millions)	Average Dollar Value per Trade (12/10)	Avg. Holding Period (days)
PowerShares QQQ (See Note 1)	QQQ	+1x	10 Mar 99	$22,061	$34,117	7.40
ProShares Short QQQ	PSQ	-1x	21 Jun 06	$200	$23,708	20.55
ProShares Ultra QQQ	QLD	+2x	21 Jun 06	$842	$15,749	2.79
ProShares UltraShort QQQ	QID	-2x	13 Jul 06	$630	$10,806	5.17
ProShares UltraPro QQQ	TQQQ	+3x	11 Feb 10	$125	$32,484	3.31
ProShares UltraPro Short QQQ	SQQQ	-3x	11 Feb 10	$53	$11,446	3.04

Panel C: Underlying Index = Russell 2000

Name	Symbol	Multiple	Listing Date	AUM as of 12/10 ($ millions)	Average Dollar Value per Trade (12/10)	Avg. Holding Period (days)
iShares Russell 2000	IWM	+1x	22 May 00	$18,403	$33,486	4.84
ProShares Short Russell 2000	RWM	-1x	25 Jan 07	$225	$11,828	19.40
ProShares Ultra Russell 2000	UWM	+2x	25 Jan 07	$276	$12,292	3.50
ProShares UltraShort Russell 2000	TWM	-2x	25 Jan 07	$297	$7,279	4.80
Direxion Daily Small Cap Bull	TNA	+3x	5 Nov 08	$565	$17,530	1.13
Direxion Daily Small Cap Bear	TZA	-3x	5 Nov 08	$634	$8,397	2.60

Note: The ticker for PowerShares QQQ Nasdaq 100 ETF was changed from QQQQ to QQQ on March 23, 2011.

Table 2

Price deviations. This table displays summary statistics for deviations between the closing prices of the funds in the sample and their end-of-day NAVs. The data period for each underlying index is the common period for all six funds (i.e., from the inception date of the most recent fund in each set to December 31, 2010). The annualized volatility of NAV returns are calculated by annualizing the standard deviations of the funds' daily NAV returns during the data periods. * denotes significance at the 5% level, while ** denotes significance at the 1% level.

Panel A: Underlying Index = S&P 500 Total Return Index

		Price Deviations							
Fund	**Multiple**	**N**	**Average (%)**	**5th Percentile (%)**	**95th Percentile (%)**	**Std. dev. (%)**	**% Positive (Premium)**	**% Negative (Discount)**	**Annualized volatility of NAV returns (%)**
SPY	+1x	384	-0.0115**	-0.1012	0.0649	0.0562	42.45	57.55	17.65
SH	-1x	384	0.0057*	-0.0726	0.0960	0.0535	51.30	47.92	17.68
SSO	+2x	384	-0.0460**	-0.2271	0.1233	0.1120	29.95	69.79	35.42
SDS	-2x	384	-0.0163**	-0.1541	0.1271	0.0975	38.80	60.68	35.37
UPRO	+3x	384	-0.0523**	-0.3000	0.1812	0.2340	36.46	63.54	53.17
SPXU	-3x	384	0.0022	-0.2304	0.2247	0.2847	47.14	52.86	53.15

Table 2

Price deviations (*continued*)

Panel B: Underlying Index = Nasdaq 100									
		Price Deviations							
Fund	**Multiple**	**N**	**Average (%)**	**5th Percentile (%)**	**95th Percentile (%)**	**Std. dev. (%)**	**% Positive (Premium)**	**% Negative (Discount)**	**Annualized volatility of NAV returns (%)**
QQQ	+1x	225	-0.0158**	-0.0854	0.0628	0.0645	38.67	61.33	19.41
PSQ	-1x	225	0.0080*	-0.0751	0.1079	0.0544	51.56	48.00	19.27
QLD	+2x	225	-0.0395**	-0.2146	0.1347	0.1658	40.00	60.00	38.52
QID	-2x	225	0.0167	-0.1584	0.1694	0.1402	54.67	42.67	38.64
TQQQ	+3x	225	-0.0216	-0.3161	0.3302	0.2558	42.22	57.78	57.86
SQQQ	-3x	225	0.0173	-0.3519	0.4163	0.3108	51.56	48.00	58.09

Table 2

Price deviations (*continued*)

Panel C: Underlying Index = Russell 2000

Fund	Multiple	N	Average (%)	5th Percentile (%)	95th Percentile (%)	Std. dev. (%)	% Positive (Premium)	% Negative (Discount)	Annualized volatility of NAV returns (%)
		Price Deviations							
IWM	+1x	543	-0.0303**	-0.2874	0.2226	0.1662	40.15	59.85	35.98
RWM	-1x	543	0.0287**	-0.1667	0.2536	0.1379	59.12	40.88	35.88
UWM	+2x	543	-0.0797**	-0.5970	0.4132	0.3656	35.73	63.72	72.41
TWM	-2x	543	0.0292*	-0.4930	0.5981	0.3444	55.43	44.01	72.06
TNA	+3x	543	-0.1315**	-1.0332	0.7068	0.5462	35.36	64.46	108.14
TZA	-3x	543	0.0635**	-0.7030	0.9967	0.5129	54.51	45.30	108.34

Table 3

Correlations among price deviations. This table presents the correlations among the daily price deviations (premiums/discounts) of the funds in the sample. For each underling index, the correlations are calculated over the common data period (i.e., from the inception date of the most recent fund in each set to December 31, 2010). Except for the greyed-out numbers, all correlations in the table are significantly different from zero at the 1% level.

Panel A: Underlying Index = S&P 500 Total Return Index

	SPY (+1x)	SH (-1x)	SSO (+2x)	SDS (-2x)	UPRO (+3x)	SPXU (-3x)	S&P 500
SPY (+1x)	1.00	-0.55	0.76	-0.76	0.60	-0.49	-0.14
SH (-1x)		1.00	-0.57	0.62	-0.55	0.52	0.09
SSO (+2x)			1.00	-0.75	0.62	-0.49	-0.29
SDS (-2x)				1.00	-0.51	0.42	0.18
UPRO (+3x)					1.00	-0.88	-0.21
SPXU (-3x)						1.00	0.19
S&P 500							1.00

Panel B: Underlying Index = Nasdaq 100

	QQQ (+1x)	PSQ (-1x)	QLD (+2x)	QID (-2x)	TQQQ (+3x)	SQQQ (-3x)	Nasdaq 100
QQQ (+1x)	1.00	-0.41	0.57	-0.77	0.48	-0.44	-0.16
PSQ (-1x)		1.00	-0.30	0.43	-0.29	0.33	0.16
QLD (+2x)			1.00	-0.63	0.42	-0.40	-0.27
QID (-2x)				1.00	-0.49	0.54	0.28
TQQQ (+3x)					1.00	-0.67	-0.52
SQQQ (-3x)						1.00	0.39
Nasdaq 100							1.00

Table 3

Correlations among ETF price deviations (*continued*)

Panel C: Underlying Index = Russell 2000							
	IWM (+1x)	RWM (-1x)	UWM (+2x)	TWM (-2x)	TNA (+3x)	TZA (-3x)	Russell 2000
IWM (+1x)	1.00	-0.77	0.83	-0.86	0.86	-0.85	-0.48
RWM (-1x)		1.00	-0.74	0.79	-0.77	0.80	0.45
UWM (+2x)			1.00	-0.85	0.84	-0.83	-0.50
TWM (-2x)				1.00	-0.88	0.86	0.49
TNA (+3x)					1.00	-0.86	-0.55
TZA (-3x)						1.00	0.51
Russell 2000							1.00

Table 4

Price deviations based on the returns on their underlying indices. This table displays the average price deviations of the funds in the sample when the returns on their underlying benchmarks are positive and negative. The data period for each underlying index is the common period for all six funds (i.e., from the inception date of the most recent fund in each set to December 31, 2010). For all funds, a Wilcoxon-Mann-Whitney test shows that there is a statistically significant difference in the distributions of their premiums between the positive and the negative days at the 1% level.

Panel A: Underlying Index = S&P 500 Total Return Index					
		When underlying benchmark increases		**When underlying benchmark declines**	
Fund	**Multiple**	**N**	**Average price deviation (%)**	**N**	**Average price deviation (%)**
SPY	+1x	224	-0.0199	160	0.0003
SH	-1x		0.0111		-0.0018
SSO	+2x	224	-0.0731	160	-0.0080
SDS	-2x		-0.0052		-0.0318
UPRO	+3x	224	-0.0942	160	0.0063
SPXU	-3x		0.0466		-0.0599

Table 4

Price deviations based on the returns on their underlying indices (*continued*).

Panel B: Underlying Index = Nasdaq 100

		When underlying benchmark increases		When underlying benchmark declines	
Fund	**Multiple**	**N**	**Average price deviation (%)**	**N**	**Average price deviation (%)**
QQQ	+1x	133	-0.0237	92	-0.0045
PSQ	-1x		0.0147		-0.0018
QLD	+2x	133	-0.0674	92	0.0008
QID	-2x		0.0398		-0.0167
TQQQ	+3x	133	-0.1056	92	0.0998
SQQQ	-3x		0.0966		-0.0973

Panel C: Underlying Index = Russell 2000

		When underlying benchmark increases		When underlying benchmark declines	
Fund	**Multiple**	**N**	**Average price deviation (%)**	**N**	**Average price deviation (%)**
IWM	+1x	285	-0.0919	258	0.0378
RWM	-1x		0.0741		-0.0215
UWM	+2x	285	-0.2150	258	0.0697
TWM	-2x		0.1604		-0.1158
TNA	+3x	285	-0.3545	258	0.1147
TZA	-3x		0.2595		-0.1532

Table 5

Traditional ETF price deviations based on the returns on their underlying indices prior to the introduction of LETFs. This table displays the average price deviations of the +1x ETFs in the sample when the returns on their underlying indices are positive and negative. For each underlying index, the data period is the two-year period ending one month before the introduction of the first LETF or the -1x ETF on the index. Except for SPY, a Wilcoxon-Mann-Whitney test shows that there is a statistically significant difference in the distributions of the price deviations between the positive and the negative days at the 1% level.

		When underlying benchmark increases		When underlying benchmark declines	
Fund	**Multiple**	**N**	**Average price deviation (%)**	**N**	**Average price deviation (%)**
SPY	+1x	285	0.0046	218	-0.0140
QQQ	+1x	272	-0.0176	231	0.0234
IWM	+1x	273	-0.0038	232	-0.0468

Table 6

Relative size of LEFTs and inversed ETFs. This table displays the average aggregate amount of assets under management (AUM) of LETFs and inverse ETFs for each underlying index, together with the average market capitalization of the underlying index. Also displayed is the average of the absolute value of daily exposure adjustments, together with the average daily trading value of the underlying index. For each underlying index, the figures in each column are the averages of daily numbers over the data period, which is the common period for all six funds (i.e., from the inception date of the most recent fund in each set to December 31, 2010).

Underlying Index	Avg. Total AUM of LETFs and -1x ETFs (million)	Avg. Index Market Capitalization (million)	Avg. Ratio bet. AUM and Index Market Capitalization	Average $\lvert\Delta_t\rvert$ (million)	Avg. $\boldsymbol{INDTRADE_t}$ (million)	$\lvert\Delta_t\rvert$ as % of $\boldsymbol{INDTRADE_t}$		
						Average	5th Percentile	95th Percentile
S&P 500	$7,333	$10,197,355	0.07%	$253.34	$29,479.68	0.85%	0.04%	2.42%
Nasdaq 100	$1,933	$2,391,112	0.08%	$69.40	$9,738.37	0.69%	0.03%	2.01%
Russell 2000	$1,582	$1,044,823	0.15%	$140.99	$3,978.48	3.54%	0.21%	9.80%

Table 7

Regression estimates. This table displays the results of the following regression:

$$\pi_t^j = a + b\frac{\Delta_t}{INDTRADE_t} + \varepsilon_t^j,$$

where π_t^j is the price deviation (in percentage terms) observed on fund *j* on day *t*, Δ_t is the sum of the amounts of day-*t* exposure adjustments of *all* LETFs and inverse ETFs on the underlying index that are traded in the U.S market, $INDTRADE_t$ is the total trading value of the fund's underlying index on day *t*, and ε_t^j is the residual term. The independent variable is expressed in percentage terms. The data period for each underlying index is the common period for all six funds (i.e., from the inception date of the most recent fund in each set to December 31, 2010).

Panel A: Underlying Index = S&P 500 Total Return Index

Fund	**Multiple**	***a***	***b***	**R-square**
SPY	+1x	-0.0102**	-0.0081**	0.03
SH	-1x	0.0047	0.0064**	0.02
SSO	+2x	-0.0414**	-0.0297**	0.09
SDS	-2x	-0.0190**	0.0181**	0.05
UPRO	+3x	-0.0456**	-0.0436**	0.05
SPXU	-3x	-0.0054	0.0499**	0.04

Panel B: Underlying Index = Nasdaq 100

Fund	**Multiple**	***a***	***b***	**R-square**
QQQ	+1x	-0.0141**	-0.0120**	0.03
PSQ	-1x	0.0066	0.0100*	0.03
QLD	+2x	-0.0331**	-0.0453**	0.06
QID	-2x	0.0113	0.0383**	0.06
TQQQ	+3x	-0.0027	-0.1326**	0.23
SQQQ	-3x	-0.0008	0.1268**	0.14

Panel C: Underlying Index = Russell 2000

Fund	**Multiple**	***a***	***b***	**R-square**
IWM	+1x	-0.0254**	-0.0145**	0.16
RWM	-1x	0.0248**	0.0116**	0.15
UWM	+2x	-0.0682**	-0.0341**	0.19
TWM	-2x	0.0188	0.0308**	0.17
TNA	+3x	-0.1126**	-0.0563**	0.23
TZA	-3x	0.0462*	0.0513**	0.21