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Review

The market impact of leveraged ETFs: A Survey of the literature

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Abstract: I survey the literature related to the potential for leveraged and inverse ETFs to influence late-day asset prices. The literature consistently reports statistically significant associations between ETF rebalancing demand and late-day returns and volatility. However, most of the available papers suffer from potentially serious methodological errors, and the economic associations appear to be insignificant. Moreover, the broader literature suggests that the market provides enough liquidity to satisfy LETF rebalancing demand with an insignificant degradation of market quality. Despite the potential for LETF rebalancing to affect late-day market conditions, concerns raised by policymakers and others are not supported by the overall empirical evidence.

Keywords: leveraged ETFs; late-day returns; volatility; price impact; trading volume

JEL Codes: G12, G23, G28

1. Introduction

First introduced in 2006, leveraged and inverse exchange-traded funds ("LETFs") are financial products that typically seek to generate a multiple (or inverse multiple) of the daily performance of an underlying index or asset. These funds provide valuable services by enabling investors to more easily obtain leveraged or inverse exposures to financial indexes at a relatively low cost. For example, leveraged ETFs permit investors to take positions using a relatively small amount of capital because a leveraged ETF requires a smaller capital investment than a traditional non-leveraged fund to obtain a given exposure. This benefits investors by, among other things, potentially enabling them to obtain higher exposure with less cash at risk or to avoid liquidating other positions, which could be subject to capital gains taxes. Additionally, inverse ETFs provide a natural hedge for equity positions held elsewhere in an investor's portfolio, and replicating the same hedge in a different way (e.g., by short-selling or trading derivatives) would be more complicated and likely more expensive.

LETFs occupy part of a much broader space that also includes leveraged and inverse exchange-traded notes ("ETNs"), which are debt instruments whose returns are typically tied to assets or economic risk factors. LETFs have exploded in popularity since their inception, with aggregate assets under management ("AUM") growing from $3 billion in 2006 to over $80 billion globally in 2023.[1] The number of LETFs on the market has also proliferated as fund sponsors continue to launch new funds to meet the rising demand. Despite their growing popularity and benefits for investors, some policymakers,[2] researchers,[3] and journalists[4] have identified undesirable market effects that might be associated with LETFs' daily rebalancing needs, namely, the potential to exacerbate late-day volatility and destabilize financial markets. These effects have been attributed to the inherent structure of LETFs and the dynamic trading strategies they typically implement to achieve their performance objectives.

To generate a multiple (or inverse multiple) of the daily performance of an underlying asset, an LETF must hold a leveraged position in the asset equivalent to its target performance multiple, and this leverage ratio must be maintained day-to-day. Maintaining a constant daily leverage ratio requires an LETF to adjust its exposure to the underlying asset by rebalancing its portfolio in the same direction as the daily return on the asset, so an LETF must increase its exposure to the underlying asset when the asset has experienced a positive return and decrease its exposure when the asset has experienced a negative return.[5] Because both leveraged and inverse ETFs must rebalance in the same direction as returns to maintain their target leverage ratios, the rebalancing activity of leveraged ETFs is not offset by the rebalancing activity of inverse ETFs. Furthermore, an LETF must rebalance as near to market close as possible to minimize the difference between its net-asset-value ("NAV") return and the target multiple of the underlying asset return.[6] This rebalancing activity tends to concentrate trades within a short time interval, when even information-less trades might affect market conditions. Many market observers have noted that the concentrated rebalancing by LETFs could create a temporary supply-demand imbalance near market close, which in turn could bias underlying asset prices and increase late-day volatility. Moreover, some have suggested that market movements that occur during the day could present an opportunity for predatory traders to try to front-run the end-of-day rebalancing by LETFs.

These potential consequences of LETF rebalancing—if they were corroborated by empirical evidence and other research on the topic—would be undesirable for several reasons. Temporary price distortions directly affect the parties involved in a given trade and can lead to wealth transfers among investors. This is of regulatory concern because the shareholders of an LETF could be harmed by investing in a fund that consistently trades at disadvantageous prices (i.e., a fund that buys at temporarily inflated prices and sells at temporarily depressed prices), especially if other traders further distort prices by attempting to front run LETF rebalancing. Trading at biased prices could also negatively impact a fund's ability to achieve its daily target multiple and, thereby, potentially make these funds less attractive to investors. Additionally, price distortions can create inefficiencies in the broader financial market that could reduce informational efficiency and lead to capital misallocation.

[1]While the first LETF was launched in 2006, leveraged mutual funds have existed in the U.S. since 1994.

[2]See, e.g., SEC press release 2010-45, Gensler (2021), and Lee and Crenshaw (2021).

[3]See, e.g., Cheng and Madhavan (2009) and Tuzun (2014).

[4]See, e.g., Lauricella et al. (2008), Zweig (2009), Lauricella (2011), Sorkin (2011), Light (2012), Flood (2021), and Wigglesworth (2023).

[5]Although leveraged and inverse ETNs are debt instruments and, therefore, do not hold underlying portfolios, the issuers of these types of products must rebalance their hedges similarly to LETFs.

[6]Conversations with fund sponsors indicate that some LETFs submit market-on-close orders to brokers at various times throughout the trading day as they learn about their rebalancing needs from early-day returns and creation or redemption orders. While an LETF's market-on-close order guarantees that it receives the closing price so that it can meet its investment objective, the broker has the ability to hedge the position before market close and, thereby, spread some of the LETF's late-day rebalancing demand over time to lessen the market impact.

Some academic studies have concluded that LETF rebalancing does distort market prices, whereas others find less distortion and conclude that it is economically unimportant. In this article, I survey the literature related to the potential for LETF rebalancing to impact late-day asset prices, evaluating the strengths and weaknesses of the methodologies and sample periods. I also explain how some articles with a broader perspective on market liquidity provide further context for understanding the potential for LETF rebalancing to impact the market. Despite some findings of a statistically significant association between LETF rebalancing demand and late-day returns, the price impact of LETF rebalancing appears to be economically insignificant and has declined over time, as the most recent articles (which use the most recent data) do not find that LETF rebalancing causes economically significant distortions.

It is important to distinguish statistical significance from economic significance. The former is determined simply by observing an estimated parameter's t-statistic: if the t-statistic is sufficiently large, then the variable is "statistically significant." However, the magnitude of a t-statistic is directly proportional to the number of observations included in a sample, so a sample with more observations is, *ceteris paribus*, more likely to generate a statistically significant result even if the estimated coefficient is small.

In contrast to statistical significance, economic significance depends on the estimated size of an effect relative to an appropriate baseline. Only effects that have a substantial economic impact on outcomes are considered to be economically significant. Within the context of the concerns raised by critics of LETFs, namely that rebalancing could meaningfully distort late-day asset prices, economic significance requires that any estimated effects of rebalancing cause substantial changes in prices that could nontrivially affect economic agents' profits or risk exposure or that could create nontrivial inefficiencies in the broader financial market.

Although some of the available evidence indicates a statistically significant association between LETF rebalancing demand and late-day prices, such statistical significance is not a valid basis for concern because the economic effects appear inconsequential. The analyses with the more appropriate methodologies and those with the most recent sample periods find that the impact of LETF rebalancing on late-day returns and volatility is small relative to their average values, even on days with unusually high rebalancing demand (Ivanov and Lenkey , 2018; Brøgger , 2021). The articles that estimate the greatest impact of LETF rebalancing (Tuzun , 2014; Bai et al. , 2015; Shum et al. , 2016) analyze older data and suffer from several methodological shortcomings that limit the reliability of their results. Furthermore, many of the articles' samples include an extremely large number of observations (intra-day returns spanning several years for thousands of underlying assets), which biases toward a finding of statistical (but not economic) significance. One notable example is Ivanov and Lenkey (2018), who report a statistically significant association between LETF rebalancing demand and late day returns at a confidence level greater than 99.99% (using a sample of over 2.6 million observations) but nevertheless conclude that the association is economically insignificant because rebalancing demand affects average late-day returns by less than a single basis point.

Articles which examine whether traders can earn abnormal returns by front running the predictable rebalancing activity near market close offer further evidence that the price impact of LETF rebalancing is economically insignificant and serves simply as reasonable compensation to liquidity providers. If speculators were able to earn abnormal returns by trading shares of the underlying assets ahead of LETF rebalancing, then that would suggest that rebalancing has an economically meaningful effect on prices. However, both Shum et al. (2016) and Brøgger (2021) find that trading based on LETF rebalancing demand does not generate significant profit (after accounting for transaction costs), and there is no evidence in the literature that supports the existence of profitable trading strategies constructed around LETF rebalancing. Instead, the limited price impact from rebalancing is apparently a sufficient incentive to attract enough liquidity suppliers to the market to meet LETF rebalancing demand without causing large price distortions.

Furthermore, liquidity providers appear to respond relatively quickly to LETF rebalancing activity, as the price impact from rebalancing is short lived. Tuzun (2014) Bai et al. (2015), and Brøgger (2021) report that the price impact reverses overnight, but the price reversal could actually occur much sooner yet be unobservable due to a lack of available data after market close. In any case, the quick reversal implies that the effect of LETF rebalancing on late-day prices is unlikely to influence capital allocation or reduce the informational efficiency of the market.

Together, the lack of an ability to earn abnormal returns and the quick price reversal demonstrate that liquidity providers are able to supply a sufficient amount of liquidity for a fairly small cost—if there were no price impact from LETF rebalancing whatsoever, then market participants presumably would be reluctant to supply liquidity without some other form of compensation—and there is little reason to believe that they would be unable to provide an even greater amount of liquidity in the future should the LETF market continue to grow. It also suggests that there is likely ample liquidity available in the market to satisfy other traders' liquidity needs, so LETF rebalancing should not impose large externalities on other traders by using up all or most of the available liquidity.

Moreover, although LETFs aim to track a multiple of the daily return on an underlying index, over longer horizons rebalancing would tend to drive a fund's cumulative return away from the target multiple return on the index if rebalancing had an economically meaningful effect on prices. This is because pricing pressures would cause an LETF to transact at temporarily inflated (depressed) prices when increasing (decreasing) its index exposure following positive (negative) returns. However, Charupat and Miu (2011) report that LETFs' daily, weekly, monthly, and quarterly NAV returns are mostly not significantly different from their target returns while Tang and Xu (2013) find that any discrepancies are primarily due to short-term financing costs (i.e., overnight interest rates) rather than rebalancing. It thus appears that rebalancing does not have an economically significant effect on the prices LETFs pay for exposure to their underlying indexes.

Additionally, more recent research indicates that the price impact of LETF rebalancing has declined over time (Brøgger , 2021). This could be due to a number of factors. As market makers have become more engaged and allocated greater resources to LETF markets, they may be better positioned to provide liquidity to satisfy LETF rebalancing demand without detrimentally affecting market quality (Bessembinder , 2015; Bessembinder et al. , 2016; Brøgger , 2021). Also, Bogousslavsky and Muravyev (2023) and Jegadeesh and Wu (2022) document a dramatic shift in trading volume to market close over the last decade (arising from the growth of index investing and non-leveraged ETFs) with a corresponding increase in liquidity. Because LETFs must rebalance as near to market close as possible, the enhanced liquidity around closing may further reduce the price impact of rebalancing.

Last, the substantial growth of LETFs over the years provides additional evidence that their rebalancing activity has a limited impact on market quality. Figure 1 depicts the growth in aggregate AUM of LETFs from their inception in 2006 (data acquired from Bloomberg) and shows an almost threefold increase in AUM between 2011 and 2021. While early analyses led some researchers to conclude that "as [LETFs] gain assets, there likely will be a heightened impact on the liquidity and

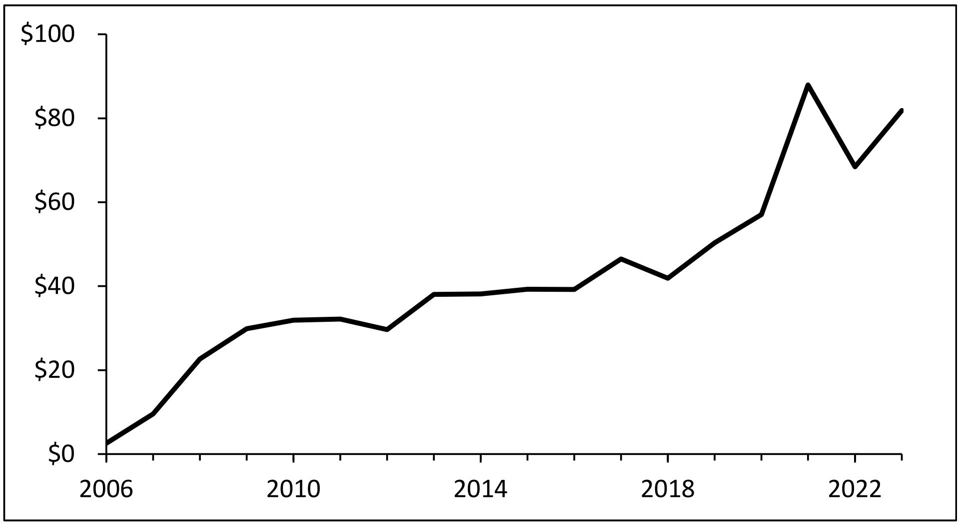

Figure 1. Annual aggregate AUM of U.S. LETFs (in billions).

volatility of the underlying index and the securities comprising the index" (Cheng and Madhavan , 2009, based on aggregate AUM of $19 billion) and others to conclude that if aggregate AUM of LETFs "doubles, they could be destabilizing for financial and small stocks" by causing large price distortions and if it triples, then there is "potential to pose risks for the broader stock market including large stocks" (Tuzun , 2014, based on aggregate AUM of $20.1 billion), such predictions have not come to fruition even with the current aggregate AUM exceeding $80 billion. Hence, past statements that could have influenced policy choices and investors' perceptions by sensationalizing the potential market impact of LETFs were apparently misguided in hindsight and based on limited evidence. Notably, studies which conclude that LETFs may have an economically significant effect on late-day prices (Cheng and Madhavan , 2009; Tuzun , 2014; Bai et al. , 2015; Shum et al. , 2016) rely on sample periods ending in 2011 or earlier, whereas studies which conclude that LETFs do not have an economically significant impact (Ivanov and Lenkey , 2018; Brøgger , 2021) use longer sample periods and more recent data.

The remainder of the article is organized as follows. In Section 2, I describe the theoretical framework used in the literature to explain the rebalancing dynamics of LETFs. In Section 3, I discuss the empirical literature that directly examines the impact of LETFs on late-day returns and volatility, overnight price reversals, and the (lack of) existence of predatory trading strategies that exploit predictable LETF rebalancing. In Section 4, I discuss the literature that does not address the impact of LETF rebalancing per se but nonetheless provides further context for better understanding the economic effects of rebalancing. In Section 5, I conclude the paper.

2. Theoretical framework

The potential for LETFs to affect late-day returns and volatility was first formally illustrated by Cheng and Madhavan (2009). Because most of the empirical literature relies on their model to estimate LETF rebalancing, In Section 2.1, I describe their derivation of LETF rebalancing demand in detail. While useful, the framework developed by Cheng and Madhavan (2009) is incomplete and results in mismeasured LETF rebalancing demand because it overlooks how capital flows affect an LETF's need to rebalance, as shown by Ivanov and Lenkey (2018). In Section 2.2, I describe the effect of capital flows on LETF rebalancing demand and discuss their empirical significance.

2.1. The Cheng and Madhavan model

Consider an underlying index that generates a per-period return r_t and an ETF that seeks to generate a multiple m of the return. In today's market, the vast majority of leveraged ETFs have adopted daily target multiples of +2 or +3, whereas most inverse ETFs have adopted daily target multiples of −1, −2, or −3. Although some other recently launched products have adopted daily target multiples of 1.5 or seek to replicate a multiple of the return of a single stock rather than an index, the theoretical framework developed by Cheng and Madhavan (2009) is fairly general and can be used to describe the rebalancing process for any LETF regardless of the underlying asset, return period, or leverage ratio, provided that $m \notin \{0, 1\}$. For ease of exposition, the return period is hereafter referred to as daily and the underlying asset is referred to as an index.

The ETF's AUM at time-t is denoted by A_t. To generate m-times the daily return r_t of the underlying index, the ETF's time-t exposure to the index must be

$$I_t = mA_t, \tag{1}$$

which implies an exposure of

$$C_t = (1 - m)A_t \tag{2}$$

to the short-term lending market, i.e., cash.[7] Hence, the ETF's AUM evolves according to

$$\begin{aligned} A_{t+1} &= I_t(1 + r_t) + C_t \qquad (3)\\ &= (1 + mr_t)A_t, \qquad (4) \end{aligned}$$

where (4) follows from substituting (1) and (2) into (3) (and assuming the overnight return on cash is negligible). For the ETF to maintain its target leverage ratio, it typically must rebalance its portfolio before the next trading day. The daily rebalancing demand is given by

$$\begin{aligned} \Delta I_t &\equiv I_{t+1} - I_t(1 + r_t) \qquad (5)\\ &= m(m - 1)r_t A_t, \qquad (6) \end{aligned}$$

where (6) follows immediately from (1), (4), and (5).

The daily rebalancing demand characterized by (6) is equivalent to Equation (11) in Cheng and Madhavan (2009). In this framework, the amount of rebalancing—or the adjustment of the ETF portfolio's exposure to the index—required to maintain a constant leverage ratio depends on the ETF leverage multiple, the daily index return, and the size of the ETF. ETFs that are bigger, experience larger returns, and/or have higher leverage multiples must make larger trades to rebalance their portfolios.

[7]Overnight lending rates are typically very low and, therefore, are not explicitly modeled. In practice, most LETFs enter into swap agreements to gain exposure to their target indexes rather than directly holding the indexes' underlying assets. The impact of LETF rebalancing is nevertheless conveyed to the market for the underlying assets because the swap counterparties must adjust their own portfolios to maintain their hedges (Tuzun , 2014; Bai et al. , 2015; Shum et al. , 2016), although some swap counterparties may have offsetting positions which would reduce net rebalancing (Charupat and Miu , 2011).

Notably, the direction of rebalancing is independent of the leverage multiple and depends on only the direction of the daily index return, as $m(m-1) > 0$ for $m \notin [0, 1]$. Following positive (negative) index returns, leveraged ETFs must increase (decrease) their exposure to the index while inverse ETFs must decrease (increase) their short position, so both leveraged and inverse ETFs must rebalance in the same direction as the index return. Hence, rebalancing by leveraged ETFs is not partially offset by rebalancing by inverse ETFs, and vice versa.

Based on the implication that LETFs must rebalance their portfolios in the same direction as returns, Cheng and Madhavan (2009) argue that such rebalancing activity "can exacerbate same-day volatility, add momentum effects, and induce serial correlation in returns," which in turn could lead to biased asset prices and create opportunities for predatory front running. Although these concerns are prima facie valid, they are based on an incomplete theoretical framework that overlooks the important effects of LETF capital flows. As discussed in the following section, capital flows substantially reduce LETF rebalancing demand and, thus, considerably mitigate the potential for LETFs to affect returns and exacerbate volatility.

2.2. *Effects of capital flows*

Ivanov and Lenkey (2018) extend the Cheng and Madhavan model by allowing for capital to flow into or out of the ETF. In practice, capital flows occur whenever ETF shares are created or redeemed and could arise from investors increasing or decreasing their exposure to the ETF. Although these daily capital flows can either increase of decrease LETF rebalancing demand, Ivanov and Lenkey (2018) find that capital flows typically decrease it and, hence, reduce the potential market impact of LETFs.

Building on the Cheng and Madhavan framework described in Section 2.1, suppose the ETF experiences a time-t capital flow f_t as a fraction of AUM. With the capital flow, AUM evolves according to

$$A_{t+1} = I_t(1 + r_t) + C_t + f_t A_t \tag{7}$$

$$= (1 + mr_t + f_t)A_t, \tag{8}$$

and ETF rebalancing demand is given by

$$\Delta I_t = m[(m-1)r_t + f_t]A_t. \tag{9}$$

This expression is equivalent to Equation (6) in Ivanov and Lenkey (2018).

If the ETF does not experience any capital flows ($f_t = 0$), then (9) reduces to (6) and the ETF must rebalance its portfolio in the same direction as the index return. However, (9) indicates that nonzero capital flows may either increase or decrease rebalancing demand, depending on the relation between the direction of the flow and the index return. Capital flows increase rebalancing demand for leveraged ETFs ($m > 1$) when they occur in the same direction as the index return but reduce rebalancing demand when they occur in the opposite direction of the return. Conversely, capital flows decrease rebalancing demand for inverse ETFs ($m < 0$) when they occur in the same direction as the index return but intensify rebalancing demand when they occur in the opposite direction of the index return (see Table 1).

Ivanov and Lenkey (2018) provide strong empirical evidence that capital flows tend to mitigate the amount of rebalancing required for LETFs to maintain their target leverage ratios. The authors document that LETFs with higher leverage ratios experience larger capital flows, which is noteworthy because larger capital flows are needed to offset the greater rebalancing demand for LETFs with higher

Table 1. Effect of capital flows on rebalancing demand. The effect of capital flows on LETF rebalancing demand is listed as a function of the relation between the direction of flows and returns.

	Leveraged ETFs		Inverse ETFs	
	Positive return	Negative return	Positive return	Negative return
Inflow	increase	decrease	decrease	increase
Outflow	decrease	increase	increase	decrease

leverage ratios. They also find that capital flows for leveraged ETFs are positively (negatively) correlated with the magnitude of negative (positive) index returns and that capital flows for inverse ETFs are negatively (positively) correlated with the magnitude of negative (positive) index returns. The finding that leveraged (inverse) ETFs tend to experience capital flows in the opposite (same) direction as index returns holds even during periods of market stress and on days with large negative index returns when investors may be liquidity constrained. Hence, the mitigating effects of capital flows seem to be robust to various market conditions.

Moreover, the observed correlations are likely to persist going forward; if the correlations were reversed (i.e., opposite signs), then capital flows would increase rather than decrease LETF rebalancing demand. The authors note that the observed correlations could result from trades made by market participants who use LETFs for hedging purposes (e.g., market makers or financial intermediaries) or to implement a mean-reversion trading strategy (e.g., actively managed mutual funds) and argue that institutional investors are more likely than retail investors to engage in such behavior. Finding that the observed correlations are statistically and economically significant when their sample is restricted to only institutional trades, the authors infer that the above stated economic rationales for trading are empirically supported. It is, therefore, not unreasonable to conclude that the observed correlations should continue in the future.

To more directly assess the impact of capital flows on LETF rebalancing demand, the authors regress rebalancing demand as implied by (9) on target index returns. Based on the coefficient estimates, the authors find that capital flows have a substantial impact on rebalancing demand, especially when LETFs would otherwise be most prone to affect late-day returns. Specifically, on the quintile of days with the largest magnitude of index returns, the authors calculate that capital flows reduce LETF rebalancing demand by 85% for ETFs with a leverage ratio of +3 and by 66% for ETFs with a leverage ratio of +2. They find a similar effect for inverse ETFs, with capital flows reducing LETF rebalancing demand by 58% for ETFs with a leverage ratio of −3 and by 29% for ETFs with a leverage ratio of −2. The impact on ETFs with leverage ratios of −1 is only marginally significant but may increase rebalancing demand by 9%. Thus, with the exception of −1x ETFs, which hold only about 13% of the total AUM of all LETFs during the authors' sample period, capital flows appear to have a substantial mitigating impact on LETF rebalancing activity.

Given the documented empirical relations between capital flows and index returns, analyses that neglect to account for the mitigating effects of capital flows presumably overestimate the impact of LETF rebalancing on late-day returns and volatility. This is especially so because Ivanov and Lenkey (2018) show that larger capital flows tend to occur on days with larger absolute index returns, that is, on days where LETFs could otherwise have the biggest effect on market prices in the absence of capital flows.

3. Empirical evidence

The empirical evidence regarding the market impact of LETF rebalancing is mixed. In Section 3.1, I review the individual articles that have directly investigated the economic effects of LETF rebalancing. In Section 3.2, I aggregate and summarize the articles' findings. Notably, studies that rely on shorter and earlier sample periods tend to conclude that LETF rebalancing has an economically significant effect on late-day prices whereas studies with longer and more recent sample periods—that also coincide with a documented shift in liquidity toward market close—conclude the opposite.

3.1. Discussion of the articles

The relevant articles are addressed in chronological order according to their publication dates. Table 2 summarizes the data analyzed in each of the articles and highlights the considerable heterogeneity in the articles' sample periods, underlying assets, and methodologies. The primary empirical specification implemented by the articles is ordinary least squares:

$$Y = \beta X + Controls + \varepsilon, \tag{10}$$

with Y representing the market attribute being investigated (e.g., late-day returns or volatility, or some normalized measure thereof) and X representing LETF rebalancing demand (or some normalized measure of rebalancing demand).

Table 2. Articles. A summary of the data used in the various articles that directly analyze the impact of LETFs is listed.

Article	Sample period	# ETFs	Assets	# Indexes	# Stocks	Capital flows
Cheng and Madhavan (2009)	2/2009	84	U.S. equity	-	-	no
Tuzun (2014)	6/2006 – 12/2011	58	U.S. equity	16	5,042	no
Bai et al. (2015)	10/2008 – 10/2010	6	finance/real estate	3	63	no
Shum et al. (2016)	6/2006 – 7/2011	52	U.S equity	17	346	no
Ivanov and Lenkey (2018)	6/2006 – 5/2014	72	U.S. equity	26	-	yes
Brøgger (2021)	11/2010 – 12/2017	4	VIX	1	-	partially

3.1.1. Cheng and Madhavan (2009)

Although their primary contribution is the development of a theoretical framework for understanding the rebalancing and return dynamics of LETFs, Cheng and Madhavan (2009) also calculate hypothetical rebalancing demand based on their model and the aggregate AUM of 84 U.S. equity LETFs as of the end of February 2009. Specifically, they compute the total dollar volume and the percentage of median market-on-close ("MOC") volume attributable to LETF rebalancing, as implied by (6), for various levels of index returns. They find that a 1% (5%) index return would result in an aggregate rebalancing demand of $787 million ($3.934 billion) and constitute 16.8% (50.2%) of median MOC volume.

While such a large amount of rebalancing could potentially bias underlying prices, increase late-day volatility, and present opportunities for predatory front running, the findings are based on two counterfactual assumptions that likely result in overestimation of LETF rebalancing volume. First, they neglect to account for capital flows. As discussed in Section 2.2, the large offsetting effects of capital flows would reduce LETF rebalancing activity, especially on days with larger index returns. Second, the authors incorrectly assume that all of the indexes tracked by the LETFs in their sample experience identical returns. Assuming that the underlying assets are perfectly correlated similarly overstates the need for LETFs to rebalance because it is unlikely that all indexes will experience large returns at the same time, even if they are (imperfectly) correlated. Thus, the actual rebalancing volume is likely much lower than the quantities and percentages reported by the authors.

3.1.2. Tuzun (2014)

Tuzun (2014) analyzes the potential price impact of rebalancing on LETFs' underlying equity holdings. His sample consists of 58 U.S. equity LETFs from June 2006 to December 2011, and he finds that LETF rebalancing biases late-day stock returns and increases late-day volatility. Although he reports effects that appear to be economically significant, his analysis relies on two strong counterfactual assumptions (discussed below) that undermine the veracity of the findings. Additionally, he uses data from an early sample period covering the handful of years shortly after LETFs were first introduced, and the economic significance of the findings conflict with later studies that use data from longer and more recent sample periods and which find that LETF rebalancing demand has economically insignificant effects on late-day prices.

To assess the relation between LETF rebalancing demand and late-day (3:00pm–4:00pm) stock returns, Tuzun (2014) first calculates the aggregate rebalancing demand for an individual stock:

$$\sum_j w_{i,j,t} m(m-1) r_{j,t} A_{j,t}, \tag{11}$$

where $w_{i,j,t}$ denotes the day-t portfolio weight assigned to stock i in the index (assumed to be)[8] targeted by ETF j, $r_{j,t}$ denotes the early-day-t return[9] for ETF j, and $A_{j,t}$ denotes ETF j's AUM on day t. He then regresses the late-day stock returns normalized by each stock's daily volatility on LETF rebalancing demand as predicted by (11) normalized by each stock's average daily volume. In terms of the general regression specification described by (10), $Y = \frac{\text{late-day stock return}}{\text{daily stock volatility}}$ and $X = \frac{\text{rebalancing demand}}{\text{daily stock volume}}$. He finds

[8] As discussed below, the author assumes that a majority of the LETFs in his sample target an index different from the ones they actually follow.

[9] For this analysis, $r_{j,t}$ is the return between market close on day $t-1$ and 3:00pm on day t.

a statistically significant positive association between late-day stock returns and LETF rebalancing demand. He also states that if all tracked indexes experience a 1% return, then LETF rebalancing increases average late-day stock returns anywhere from 5.5bps for mid-cap stocks to 12.9bps for financial stocks. Although the author does not report average stock returns, these estimates are about 14% of the average hourly volatility for mid-cap stocks and 29% for financial stocks during the sample period.[10]

Similarly, the author assesses the relation between LETF rebalancing demand and late-day stock volatility by regressing squared late-day stock returns normalized by the stock's daily return variance on absolute LETF rebalancing demand normalized by the stocks' average daily volume, i.e., $Y = (\frac{\text{late-day stock return}}{\text{daily stock volatility}})^2$ and $X = \left|\frac{\text{rebalancing demand}}{\text{daily stock volume}}\right|$. Like the impact on returns, he finds a statistically significant association between late-day stock volatility and LETF rebalancing demand and reports that if all tracked indexes experience a 1% return, then LETF rebalancing demand increases average late-day stock volatility anywhere from 22.7bps for large-cap stocks to 50.5bps for small stocks. These (perhaps implausibly large) estimates constitute about 64% of the average hourly volatility for large-cap stocks and 96% for small-cap stocks during the sample period.

Tuzun (2014) repeats the analysis over two sub-periods spanning 2006–2009 and 2010–2011. The earlier sub-period covers a time shortly after LETFs were first introduced, when market participants were in the early stages of learning about these types of financial products. It also includes the Global Financial Crisis, so volatility is likely to be much higher during the early sub-period than the later one, especially for financial stocks which are most affected by LETF rebalancing over the full sample period. Hence, the impact of LETF rebalancing during the early sub-period (and the full sample period) is less representative of the long-run effects than their impact during the later sub-period in which the regression coefficient estimates are mostly smaller. Therefore, the impact of LETF rebalancing on late-day stock returns and volatility over the long run is likely to be smaller than the reported impact during the full sample period discussed above (i.e., the 5.5–12.9bps return deviation and 22.7–50.5bps volatility deviation).

The author also finds that late-day returns tend to reverse over the course of the next trading day; he does not report whether returns may reverse over shorter time horizons. In particular, he finds a negative association between LETF rebalancing demand and early-next-day stock returns (from market close on day t to 3:00pm on day $t + 1$), which he attributes to the "resilience of the market." Thus, the reported price distortions from LETF rebalancing appear to be short-lived, and other articles discussed below show that price reversals occur even sooner.

Although the documented effects on late-day returns and volatility over the full sample period appear to be economically significant because they would likely have a meaningful impact on the profitability of late-day trades, there are two methodological shortcomings that raise questions about the study's conclusions. First, the author does not account for capital flows, so the reported quantitative economic effects of LETF rebalancing are likely overstated. Second, he assumes that 30 of the 58 LETFs in his sample target an index different from the ones they actually follow.[11] This assumption results in mis-measured rebalancing demand and could lead to biased regression estimates because

[10]The author reports an average daily volatility of 260bps for mid-cap stocks (5.5bps per hour ÷ (260bps per day ÷ 6.5 hours per day) ≈ 14%), 290bps for financial stocks, 230bps for large stocks, and 340bps for small stocks.

[11]Specially, he assumes that all large-cap LETFs track the S&P 500 (7 of the 19 large-cap LETFs in his sample track a different index), all mid-cap LETFs track the Russell Mid-Cap Stock Index (9 of 11 track a different index), all small-cap LETFs track the Russell 2000 (7 of 14 track a different index), all financial LETFs track the Russell 100 Financial Services Index (3 of 5 track a different index), and all technology LETFs track the NASDAQ 100 (4 of 9 track a different index).

the rebalancing demand assigned to an individual stock based on its weight in the assumed index generally differs from the rebalancing demand that should be assigned according its weight in the index actually followed by the LETF. Even though many of the documented statistical associations between LETF rebalancing demand and late-day returns have also been detected by subsequent analyses, these two counterfactual assumptions along with the early sample period raise concerns about the overall informativeness of the quantitative results.

3.1.3. Bai et al. (2015)

Bai et al. (2015) examine the effect of LETF rebalancing on financial and real estate sector stocks. They focus on these types of stocks because, as the authors note, "if [LETFs] do induce trading-related effects, it is most likely to be detected in sectors which have a higher percentage of smaller, less frequently traded stocks." Their sample comprises 6 LETFs with 63 individual stocks tracking 3 indexes from October 2008 to October 2010.

The authors first compare the behavior of the 63 stocks in the main sample to a control sample formed by minimizing the sum of the percentage squared differences in share trading volume and market capitalization between the main sample and the control. The authors find that compared to the control sample, only 27% of which consists of finance or real estate stocks, stocks in the main sample experience higher trading volume, especially during the 10 minutes immediately before market close. Despite the much higher volume, which the authors state provides "some circumstantial evidence" of large LETF rebalancing activity, there appears to be only a small difference in late-day volatility between the two samples. Moreover, early-morning volatility (9:30am–10:30am) is higher than late-day volatility for both samples, so factors other than LETF rebalancing could be affecting late-day volatility.[12]

The authors then regress late-day (3:00pm–4:00pm) stock returns on daily LETF rebalancing demand as implied by (11) using the daily index return, i.e., Y = late-day stock return and X = rebalancing demand, and report a statistically significant positive coefficient on rebalancing demand. They infer that \$1 million of rebalancing demand moves late-day returns by 12.9bps on average and report a median stock-level LETF rebalancing demand of \$1.27 million. This suggests that LETF rebalancing may have a slightly greater impact on illiquid assets when compared to the estimates of Tuzun (2014) discussed above (5.5bps for mid-cap stocks and 12.9bps for financial stocks), but it is unclear just how economically significant the effect is.

While understanding the relation between LETF rebalancing demand and the pricing of illiquid assets is important, there are a few noteworthy methodological drawbacks to studying such a selective sample. The sample consists of only 63 individual stocks, and the small sample size may raise concerns about the accuracy of the results. The authors also find that LETF rebalancing has a greater impact on stocks in their sample that are more thinly traded, more volatile, and have a smaller market capitalization. This suggests that the results may not be generalizable to the broader market, where the effects on prices are likely to be smaller. Furthermore, the sample covers a period of tremendous volatility for financial and real estate stocks, and different patterns could emerge during less tumultuous times.

In addition to the drawbacks of the selective sample, there are also two serious shortcomings of the statistical methodology. First, the authors' analysis suffers from simultaneity bias that likely

[12]The authors do not exclude stocks included in indexes tracked by other LETFs from the control sample, which could potentially lead to downward-biased estimates of the impact of LETF rebalancing if such rebalancing exerts a smaller influence over the control sample. Nevertheless, there does not appear to be much difference in late-day volatility between the two samples.

generates an upward-biased coefficient estimate. There are two components of the simultaneity bias: (i) The LETF rebalancing demand variable is calculated using returns from market close on day $t-1$ to market close on day t, which includes the 3:00pm–4:00pm period over which the late-day stock returns are measured, and (ii) early-day (9:30am–3:00pm) stock and market returns are included as control variables, which counteract the portion of LETF rebalancing demand attributable to early-day returns.[13] Because the residual component of LETF rebalancing demand, i.e., the portion of LETF rebalancing demand attributable to late-day returns, is a linear combination of the late-day stock returns on the left-hand-side of the regression and the returns of the individual stocks in the specialized indexes are highly correlated with each other, there could be a substantial mechanical element that positively biases the estimated coefficient and contributes to the observed relation between LETF rebalancing demand and late-day returns. Second, the authors do not account for capital flows, so the LETF rebalancing demand variable itself is mismeasured.

The authors also evaluate the impact of LETF rebalancing on late-day volatility by regressing absolute late-day stock returns on absolute LETF rebalancing demand, i.e., $Y = |\text{late-day stock return}|$ and $X = |\text{rebalancing demand}|$, and find a statistically significant positive association between the two variables. They interpret their estimate to mean that \$1 million of absolute rebalancing demand increases absolute late-day returns by 3.2bps on average. However, the analysis suffers from the same two shortcomings discussed above, namely simultaneity bias and neglecting to account for capital flows, and it is again unclear how economically significant the effect is because the authors do not report the average magnitude of late-day returns.

Finally, the authors examine the impact of LETF rebalancing on next-day returns. They find that LETF rebalancing demand is negatively associated with stock returns between 9:30am and 11:30am on the subsequent trading day.[14] However, the magnitude of the reversal is much smaller than the magnitude of the late-day price impact, and the authors do not report the size of the price reversal between market close and next-day market open. Although their analysis suggests that any pricing impacts are (at least partially) reversed by early the next day, such reversals could occur sooner. Thus, LETF rebalancing should not materially affect the informational efficiency of the market.

3.1.4. Shum et al. (2016)

Shum et al. (2016) study the effects of LETF rebalancing on the late-day volatility of large-cap U.S. equities. Their sample includes 52 LETFs with 346 underlying stocks that “closely track the S&P 500 index” from June 2006 to July 2011.

The authors divide the trading day into 15-minute windows between 9:30am and 4:15pm and compute a stock’s realized variance during each window. They then compare the intraday volatility with “relative rebalancing volume,” which they define as the ratio of LETF rebalancing demand as implied by equation (6) based on the daily return (until 3:45pm) of a hypothetical portfolio of the underlying 346 stocks in their sample to the total dollar volume of the portfolio during the 3:45pm–4:00pm window.[15] They find that late-day realized volatility is higher on days with larger relative

[13]The coefficient estimates for early day stock and market returns are each negative (opposite sign of the LETF rebalancing demand coefficient) and statistically significant.

[14]Notably, there is no simultaneity bias in this portion of the analysis because the next-day returns are not included in the LETF rebalancing-demand computation.

[15]The authors do not base their estimate of LETF rebalancing demand on the actual index returns (see footnote 16), so they do not weight the rebalancing demand for a stock by the stock’s weight in an index. Thus, LETF rebalancing demand is calculated using (6)

rebalancing volume. However, days with larger relative rebalancing volume also experience greater realized volatility throughout the trading day, and the realized volatility spread between days with high and low relative rebalancing volume is larger in the morning than during the 3:45pm–4:00pm window. Thus, it appears as though much of the late-day realized volatility could be driven by factors other than LETF rebalancing.

To formally assess the impact of LETF rebalancing on volatility, the authors regress the volume-weighted realized volatility of the 346 stocks in their sample for a given 15-minute window on LETF rebalancing demand based on the daily returns of the 346 stocks in their sample through the end of the previous window, i.e., Y = volume-weighted volatility and X = rebalancing demand. The authors find a statistically significant positive association between realized late-day volatility and LETF rebalancing demand, with the strongest association occurring over the 4:00pm–4:15pm window. Based on the regression coefficient estimates, the authors compute the impact of a one-standard-deviation change in LETF rebalancing demand on volatility. During the 4:00pm–4:15pm window, they find that a one-standard-deviation change in LETF rebalancing demand increases volatility by about 34% on average and by up to 57% on the top decile of days with the largest relative rebalancing volume.

While these estimates are quite large, they likely overstate the impact of LETF rebalancing for two main reasons.[16] First, like the other articles discussed hitherto, the authors do not account for the mitigating effects of capital flows. Second, the volatility estimates are computed over the 4:00pm–4:15pm window when “volume drops precipitously while volatility spikes,” which, the authors acknowledge, “can occur because when volume is lower, bid-ask spreads can widen due to the scarcity of market participants.” Hence, it is extremely unlikely that LETFs would undertake much rebalancing after market close. During the 3:45pm–4:00pm window, the authors find that a one-standard-deviation change in LETF rebalancing demand increases volatility by less than 20% on average and by about 33% on the top decile of days with the largest relative rebalancing volume.[17] While smaller, these estimates appear to be economically significant because such a large impact on volatility would have a nontrivial effect on an investor’s risk exposure and could reduce the informativeness of market prices.

The authors also explore whether a predatory trading strategy that exploits the predictable trading pattern of LETFs can generate abnormal returns. Ignoring transaction costs, the authors find that a strategy which involves buying either a 2x leveraged or −2x inverse S&P 500 ETF (depending on whether the market is up or down) at 2:30pm and unwinding the position at market close on days with absolute LETF rebalancing demand in the top decile can generate an average daily return of 66bps. However, an alternative type of momentum strategy which ignores LETF rebalancing demand but instead involves trading the same ETFs on days when the market either rises or falls by at least 2% as of 2:45pm and unwinding the position at market close would generate an average daily return of 60bps. Because these returns are not significantly different from one another,[18] it appears that a trading strategy designed to front-run LETF rebalancing does not generate abnormal returns relative to a pure momentum strategy. Additionally, the front-running strategy suffers from look-ahead bias because

rather than (11).

[16]The authors also mismeasure LETF rebalancing demand by (i) basing their rebalancing-demand computation on the returns of a hypothetical portfolio of the 346 sample stocks rather than the actual returns of the indexes targeted by the sample LETFs and (ii) not weighting their sample stocks according to the weights assigned by the various indexes.

[17]The volatility impact is about 1% compared to an average volatility of approximately 6%, and on the top decile of days the volatility impact is about 3.5% compared to an average volatility of approximately 11%.

[18]The authors do not report statistical significance, but inspection of the reported means, standard deviations, and sample sizes of the two strategies indicates a lack of significance.

it requires trading on the decile of days with the most rebalancing demand but those exact days are unknown at the times when the trades must be executed.

3.1.5. Ivanov and Lenkey (2018)

Recognizing the critical importance of capital flows on LETF rebalancing demand, Ivanov and Lenkey (2018) examine the relations between capital flows, LETF rebalancing demand, and late-day returns. Their sample includes 72 LETFs that track 26 U.S. equity indexes from June 2006 to May 2014. As discussed in Section 2.2, Ivanov and Lenkey (2018) find strong empirical evidence that capital flows tend to mitigate LETF rebalancing. This section discusses their findings related to the effect of capital-flow-adjusted LETF rebalancing demand on late-day returns and volatility.

To investigate the extent to which LETF rebalancing may affect late-day stock returns, the authors first calculate the aggregate capital-flow-adjusted rebalancing demand for an individual stock:

$$\sum_j w_{i,j,t}[m(m-1)r_{j,t} + f_{j,t}]A_{j,t}, \tag{12}$$

where $f_{j,t}$ is the day-t capital flow experienced by ETF j. As the authors note, most LETFs know their daily capital flows well before they rebalance their portfolios because creation and redemption orders typically must be received by 3:30pm or earlier. Ivanov and Lenkey (2018) then regress late-day stock returns on capital-flow-adjusted LETF rebalancing demand as predicted by (12), normalized by each stock's average daily trading volume, i.e., Y = late-day stock return and $X = \frac{\text{rebalancing demand}}{\text{daily stock volume}}$.[19] They find a statistically significant positive association between late-day returns and LETF rebalancing demand. Using the coefficient estimates from the regression to calculate the average fraction of late-day stock returns attributable to LETF rebalancing, they find that anywhere from 0.5% to 1.8% of late-day stock returns are attributable to LETF rebalancing. Because the average magnitude of late-day stock returns is less than 50bps, the authors conclude that LETF rebalancing has an economically insignificant effect on late-day returns (50bps × 1.8% = 0.9bps).

Similarly, the authors regress late-day stock volatility on capital-flow-adjusted absolute LETF rebalancing demand (normalized by each stock's average daily volume), i.e., $Y = \frac{\text{highest price} - \text{lowest price}}{\text{average price}}$ and $X = \left|\frac{\text{rebalancing demand}}{\text{daily stock volume}}\right|$, and find a statistically significant positive association between late-day return volatility and LETF rebalancing demand. Based on these coefficient estimates, they infer that anywhere from 1.2% to 6.6% of average late-day stock volatility is attributable to LETF rebalancing. Because average late-day volatility is less than 90bps, the authors conclude that LETF rebalancing has an economically insignificant effect on late-day volatility (90bps × 6.6% = 5.9bps) for a typical stock. The authors note that the economically insignificant relations between LETF rebalancing demand and both late-day returns and late-day volatility are robust to the top decile of days with the most LETF rebalancing demand and the top decile of stocks with the largest bid-ask spreads.

Finally, the authors conduct a counterfactual analysis by estimating what the effect of LETF rebalancing on late-day returns and volatility would be in the absence of capital flows. They find that capital flows reduce the impact of LETF rebalancing on late-day returns by 55% and on late-day volatility by 34%. These large reductions further emphasize the importance of capital flows and

[19]The authors analyze multiple specifications with late-day cutoff times ranging from 3:00pm to 3:50pm and report coefficients of similar magnitudes for each specification.

suggest that other analyses which neglect to account for them may severely overestimate the impact of LETF rebalancing.

3.1.6. Brøgger (2021)

While equity LETFs have received most of the attention from policymakers and others, Brøgger (2021) analyzes the effect of VIX LETF rebalancing on VIX futures prices. Even though the supply of equities is fixed whereas the supply of futures contracts is flexible, supply-demand imbalances in the VIX futures market are likely to have analogous effects on late-day returns as supply-demand imbalances in equity markets because prices in both markets must adjust to attract liquidity and equate supply with demand. Thus, examining the impact of VIX LETFs can provide insight into the market's general ability to absorb predictable demand shocks.

While informative, the impact of LETF rebalancing on VIX futures prices may not be representative of (and likely overstates) the impact on the broader market because ETF holdings constitute a much larger share of the VIX futures market than the U.S. equity market. Moreover, most VIX ETFs target an index that maintains an average time to expiration of one month between the two VIX futures contracts nearest to expiration (i.e., the first- and second-month contracts). Consequently, in addition to rebalancing to maintain a target leverage ratio, VIX LETFs must also undergo daily rebalancing by rolling their exposure from the first-month contract to the second-month contract to maintain a constant one-month average time to expiration, independent of the daily index return.

The author's sample includes 4 VIX LETFs from November 2010 to December 2017. He regresses the late-day (3:30pm–4:15pm) S&P 500 Short-Term Volatility Index (SPVXSP) return on LETF rebalancing demand as implied by (6), normalized by the open interest of the first two futures contracts to control for the size of the market, i.e., Y = late-day return and $X = \frac{\text{rebalancing demand}}{\text{open interest}}$. He finds a statistically significant positive relation between LETF rebalancing demand and late-day returns. The author also conducts a placebo analysis and finds that LETF rebalancing demand is not significantly associated with the average return on the third through sixth VIX futures contracts, which are typically not traded by VIX ETFs.

Although the analysis provides reasonably strong evidence of a statistically significant relation between LETF rebalancing demand and late-day VIX futures returns, the association appears to be economically insignificant. The author reports that the average late-day price impact of LETF rebalancing is 5.9bps and that a one-standard-deviation increase in LETF rebalancing demand is associated with a 10bps increase in late-day returns. Because both of these amounts are substantially smaller than the average half-spread of 14.3bps, which is the average cost a trader would incur to rebalance VIX futures in his own portfolio, the author concludes that investors are better off investing in LETFs and incurring a small cost via a slight price distortion from LETF rebalancing than they would be by trading VIX futures directly and incurring a much larger transaction cost in the form of the bid-ask spread. In other words, a price impact smaller than the half-spread indicates that VIX LETF rebalancing has an economically insignificant effect on returns because such a minor distortion would only trivially affect the profitability of late-day trades.

Furthermore, the author finds that the slight price impact from LETF rebalancing completely reverses prior to the next-day market open. This result is distinct from other analyses that detect next-day price reversals (Tuzun , 2014; Bai et al. , 2015) and implies that most of the reversal may actually occur much sooner than the next trading day.

The author also examines the profitability of a hypothetical predatory trading strategy that attempts to exploit predictable LETF rebalancing near market close. The strategy involves buying (selling) VIX futures contracts when SPVSXP is up (down) at 3:30pm and subsequently unwinding the position at 4:15pm. The profitability of such a strategy is highly dependent on transaction costs, generating an annual abnormal return of 402% if there are no transaction costs but −59% if transaction costs equal the average bid-ask spread of the first- and second-month VIX futures contracts. Based on this analysis, the author concludes that speculators cannot earn abnormal profits by front-running LETF rebalancing, implying that any price distortions are insubstantial and serve as reasonable compensation to liquidity providers. Consequently, the small and temporary price impact should not affect the informational efficiency of the market.

Additionally, Brøgger (2021) shows that any front-running of LETF rebalancing is likely motivated by liquidity provision rather than predatory trading. He finds that the per-unit price impact of LETF rebalancing is smaller when there is more rebalancing demand, which is consistent with "arbitrageurs that increase liquidity provision in anticipation of large rebalancing flows" (a similar conclusion is drawn by Bessembinder et al. , 2016). He also finds that more predictable rebalancing demand (based on early-day returns up to 3:00pm) has a smaller price impact than less predictable rebalancing demand (based on returns from 3:00pm to 3:30pm), which is consistent with liquidity provision because market makers have more time to adjust their inventory in anticipation of rebalancing trades when returns occur earlier in the day. The finding that anticipatory trades are motivated by liquidity provision rather than predatory trading is important because it alleviates concerns that long-term investors in LETFs could be harmed by other traders who could attempt to take advantage of the predictable LETF rebalancing.

Finally, Brøgger (2021) finds that the price impact of LETF rebalancing declines over time. Specifically, the interaction of LETF rebalancing demand with the number of years since the beginning of his sample period is significantly negatively associated with late-day returns (Y = late-day return and X = rebalancing demand × years since start of sample). He attributes this relation to "arbitrageurs increasing liquidity provision to rebalancing flows over time."

3.2. Summary of the evidence

In this section, I summarize the effects of LETF rebalancing on late-day returns and volatility reported in the literature as well as the evidence regarding whether such rebalancing presents predatory trading opportunities that could harm LETF investors. The conclusions from the articles regarding the economic significance of the impact of LETF rebalancing are listed in Table 3. Unfortunately, the quantitative effects documented in the literature are not readily comparable because many of the articles condition their results on different thresholds of rebalancing demand and do not provide enough information to translate the results to other corresponding thresholds.[20] By contrast, the studies that contain more suitable methodologies by accounting for capital flows and use longer and more recent sample periods (Ivanov and Lenkey , 2018; Brøgger , 2021) likely produce more reliable estimates.

[20]For instance, Tuzun (2014) reports his findings conditional on a 1% return but does not report the corresponding amount or distribution of rebalancing demand. Bai et al. (2015) report their findings conditional on $1 million worth of rebalancing demand but do not report how that relates to underlying asset returns. Shum et al. (2016) report their findings conditional on a one-standard-deviation change in LETF rebalancing demand but do not report the corresponding dollar value or distribution of rebalancing demand. Brøgger (2021) analyzes the impact of LETF rebalancing in VIX futures markets, so his results are not directly comparable to the effects of rebalancing in equity markets.

Table 3. Summary of Findings. A summary of the findings regarding the economic significance of LETF rebalancing demand on late-day returns, late-day volatility, and the creation of opportunities for predatory trading is listed.

		Economically Significant Effect		
Article	Sample period	Returns	Volatility	Trading
Tuzun (2014)	6/2006 – 12/2011	Yes	Yes	-
Bai et al. (2015)	10/2008 – 10/2010	Yes	Yes	-
Shum et al. (2016)	6/2006 – 7/2011	-	Yes	No
Ivanov and Lenkey (2018)	6/2006 – 5/2014	No	No	-
Brøgger (2021)	11/2010 – 12/2017	No	No	No

3.2.1. Late-day returns

The literature consistently reports a statistically significant positive association between LETF rebalancing demand and late-day returns that is robust across time and various asset markets (Tuzun , 2014; Bai et al. , 2015; Ivanov and Lenkey , 2018; Brøgger , 2021). However, there are conflicting findings regarding the economic significance of this association, and Brøgger (2021) notes that the size of the price impact has declined over time.

Tuzun (2014) and Bai et al. (2015) find that LETF rebalancing has a large economic effect on late-day returns, but, as discussed in Section 3.1, both of these articles have shortcomings that raise questions about the reliability of their estimates. For instance, Tuzun (2014) reports that LETF rebalancing demand in response to an index return of 1% increases late-day returns by up to 12.9bps (or 29%), but his estimates are based on a counterfactual assumption that a majority of the LETFs in his sample track an index different from the ones they actually target. Likewise, Bai et al. (2015) report that \$1 million of LETF rebalancing demand increases late-day returns by an average of 12.9bps, but their analysis suffers from simultaneity bias, which likely inflates their estimate. Additionally, neither of these analyses account for capital flows, so they each overstate the rebalancing demand of LETFs.

Conversely, Ivanov and Lenkey (2018) and Brøgger (2021) find that the association between LETF rebalancing demand and late-day returns is economically insignificant. After taking into account the effect of capital flows on LETFs' rebalancing needs, Ivanov and Lenkey (2018) report that less than 1.8% of late-day returns are attributable to LETF rebalancing. Given that total late-day returns are 50bps on average, their results imply that LETF rebalancing amplifies average late-day returns by less than 50bps $\times$ 1.8% = 0.9bps. Similarly, Brøgger (2021) finds that LETF rebalancing moves VIX futures prices by 5.9bps on average, which is only about 40% of the half-spread, implying that LETF rebalancing has a much smaller impact on prices than the spread does. Thus, even traders seeking to invest in the market over a longer horizon (i.e., not a round-trip trader attempting to exploit temporary mispricing) would be much less affected by the price impact of LETF rebalancing than they would be by the half-spread.

Additionally, none of these studies account for the time-varying nature of volatility when interpreting their results. While some report their results as a percentage of sample-wide average returns, failing to condition on the daily volatility level may overstate the impact of LETF rebalancing for the following reason. LETF rebalancing demand is higher, *ceteris paribus*, on days where the market has experienced larger early-day returns (see (12)). These same days tend to exhibit greater than average volatility throughout the day (Shum et al. , 2016), which often coincides with larger than average late-day returns. Consequently, the impact of LETF rebalancing may appear to be more substantial relative to the (smaller) sample-wide average late-day return than it would compared to the late-day returns on high-volatility days.

Despite the conflicting claims regarding the economic significance of LETF rebalancing on late-day returns, there is ample evidence that the effect on prices is short-lived and, therefore, unlikely to affect capital allocation or the informational efficiency of the market. Tuzun (2014), Bai et al. (2015), and Brøgger (2021) all find that the price impact from rebalancing reverses overnight, although the precise duration is unknown because the market is closed. This suggests that the long-term effect of LETF rebalancing on both individual asset returns and the broader market is negligible and that the small short-term effect may simply reflect the cost of attracting liquidity providers. The fact that the price impact quickly reverses and abnormal trading profits cannot be earned are signs of a well-functioning market and suggest that there is an ample amount of liquidity to satisfy LETF rebalancing demand.

3.2.2. Late-day volatility

Like the effect on late-day returns, the literature consistently reports a statistically significant positive association between LETF rebalancing demand and late-day volatility in the equity market (Tuzun , 2014; Bai et al. , 2015; Shum et al. , 2016; Ivanov and Lenkey , 2018). However, there are conflicting findings about whether the association is economically meaningful.

Tuzun (2014), Bai et al. (2015), and Shum et al. (2016) find that LETF rebalancing has a substantial economic effect on late-day volatility. Tuzun (2014) reports that late-day volatility rises by up to 50bps (or 96%) when LETFs rebalance in response to a 1% index return, and Bai et al. (2015) find that \$1 million of LETF rebalancing demand increases late-day volatility by about 3bps. Both of these analyses likely overstate the effect of LETF rebalancing on volatility for the same reasons that they overstate the effect on late-day returns.[21] Shum et al. (2016) report that a one-standard-deviation change in rebalancing demand increases volatility by up to 57% in the 15 minutes after market close, but their analysis mismeasures LETF rebalancing demand by failing to properly weight the returns or account for capital flows.[22] They also estimate a substantially smaller effect in the 15 minutes before market close when LETFs are much more likely to rebalance.

In contrast, Ivanov and Lenkey (2018) find that the association between LETF rebalancing demand and late-day volatility is economically insignificant after accounting for capital flows. They report that less than 6.6% of late-day volatility is attributable to LETF rebalancing. Given that average late-day volatility is less than 90bps, their analysis implies that LETF rebalancing increases late-day volatility by less than $90\text{bps} \times 6.6\% = 5.9\text{bps}$.

[21] As stated above, Tuzun (2014) assumes that a majority of LETFs in his sample track an index different from the ones they actually target, the analysis by Bai et al. (2015) suffers from simultaneity bias, and both studies fail to account for capital flows.

[22] The mismeasurement of LETF rebalancing demand systematically overweights (underweights) smaller and likely less liquid (larger and likely more liquid) stocks, so the measurement error should not bias the estimated coefficients toward zero.

3.2.3. Trading strategies

There is no documented evidence that predictable LETF rebalancing trades present an opportunity to earn significant abnormal returns. Shum et al. (2016) find that a trading strategy based on predatory front running of equity LETF rebalancing on days with the greatest rebalancing demand does not generate returns (statistically or economically) significantly different from an analogous strategy based instead on early-day market returns. Similarly, Brøgger (2021) finds that a strategy based on predatory front running of VIX LETF rebalancing fails to generate an economically or statistically significant profit once accounting for transaction costs.

The absence of profitable trading strategies built around LETF rebalancing provides further evidence that the price impact of such rebalancing is not economically significant. If LETF rebalancing moves prices in an economically meaningful way, then investors should be able to capitalize on it. The inability to do so suggests that the limited price impact acts as compensation for supplying liquidity during a brief period of high predictable demand, as noted by Brøgger (2021). He further notes that the per-unit price impact is smaller when there is more LETF rebalancing demand and when rebalancing demand is more predictable, which suggests that market participants are not broadly engaging in predatory trading strategies. Thus, claims (see, e.g., Lauricella et al. , 2008; Cheng and Madhavan , 2009; Tuzun , 2014) that predictable LETF rebalancing could lead to predatory front running and, thereby, harm long-term investors appear to lack empirical support.

4. Related literature

As discussed in Section 3, the literature that analyzes the price impact of LETF rebalancing finds a robust statistically significant association between rebalancing demand and late-day prices, though the effects appear to be insignificant in economic terms, overall. In this section, I discuss some additional articles that do not directly analyze the price impact of LETF rebalancing but nonetheless provide further context for understanding the economic effects of rebalancing.

4.1. Longer-horizon returns

Because an LETF must rebalance its portfolio on a daily basis to achieve its objective of generating a multiple of the daily return on its underlying index, the longer-run correlation between LETF NAV returns and underlying index returns depends on whether LETF rebalancing has an economically significant effect on late-day prices. If rebalancing resulted in an LETF overpaying for greater index exposure on days when the index return is positive and receiving an underpayment for shedding index exposure on days when the index return is negative, then the LETF's NAV would dissipate over time and create a significant drag on returns, as noted by Cheng and Madhavan (2009). Therefore, a preponderance of large cumulative differences between NAV returns and the target multiple of the underlying index return would suggest that LETF rebalancing has an economically significant effect on late-day prices. Conversely, small deviations would suggest that it does not. Two articles that analyze longer-term LETF performance imply that rebalancing does not have an economically significant effect on late-day returns.

Charupat and Miu (2011) analyze the long-term performance of LETFs. Their sample encompasses 8 Canadian equity LETFs which follow a total of 4 indexes from 2007 to 2009. To examine whether

LETFs are able to successfully track their target indexes with minimal tracking error, the authors regress daily, weekly, monthly, and quarterly LETF NAV returns on target index returns. Despite an extremely volatile sample period, the authors find that NAV returns are mostly not significantly different from the target multiple of underlying index returns.

Likewise, Tang and Xu (2013) examine the performance of 12 U.S. equity LETFs following 4 indexes from July 2006 to December 2010. While they report a nontrivial average difference between NAV returns and daily target returns, they find that the deviations between NAV returns and target returns are mostly driven by the holding-period interest rate, which reflects a portion of the cost of trading the equity swaps that LETFs use to maintain their target leverage ratios. Notably, they find a statistically insignificant association between underlying index returns and the deviation of NAV returns from target returns, which implies that rebalancing is not the source of such deviations and, therefore, does not impair the ability of LETFs to achieve their performance objectives.[23]

4.2. Predictable order flows

One concern about LETF rebalancing raised by both researchers and policymakers is that predatory front running by other traders could potentially harm LETF shareholders by amplifying the price impact of rebalancing and, thereby, cause LETFs to rebalance at less favorable prices. While Shum et al. (2016) and Brøgger (2021) provide evidence that attempting to front run LETF rebalancing is not a profitable trading strategy, Bessembinder et al. (2016) develop a general theory of front running predictable order flows to directly assess how traders' optimal front-running strategies may affect prices.

In their model, an investor must liquidate a known quantity of stock at a specific time. Strategic traders, who are aware of the pending liquidation, may trade in advance of, simultaneously with, or following the liquidation. The authors show that the optimal strategy for strategic traders is to purchase the stock when the liquidator sells and to unwind these positions either before or after the liquidation. Even though the liquidation temporarily depresses the stock price, the front-running behavior of strategic traders benefits the liquidator. If the strategic trader is a monopolist, front running increases the liquidator's proceeds and decreases the price impact of the liquidating trade, provided that the market is sufficiently resilient. If there are many competitive strategic traders, front running results in even greater benefits to the liquidator unless the price impacts are permanent. Essentially, front running benefits the liquidator by spreading the price impact of the liquidation trades over time.

Although their theory does not specifically model the behavior of LETFs, it nonetheless has important implications for understanding how LETF rebalancing may impact market prices. Because LETFs must rebalance known quantities of their underlying assets to maintain their target leverage ratios, the liquidator in the model can be interpreted as an LETF and the strategic traders can be interpreted as authorized participants ("APs"), market makers, arbitrageurs, or other types of traders. Moreover, because there are several APs and market makers for each LETF and there are little, if any, barriers to entry for arbitrageurs who may act as liquidity providers, the nature of the market for LETF rebalancing trades is likely to be more competitive than monopolistic. Hence, given the ample empirical evidence that any price impact arising from LETF rebalancing reverses overnight and is, therefore, only temporary

[23]Both Charupat and Miu (2011) and Tang and Xu (2013) examine unconditional daily tracking error rather than separating their samples according to the direction of the daily index return. Nonetheless, the upward price pressure from buying when the index is up and the downward price pressure from selling when the index is down would not have offsetting effects on an LETF's multi-day NAV return because both purchases and sales would occur at disadvantageous prices if LETF rebalancing had an economically significant effect on late-day returns.

(Bai et al. , 2015; Brøgger , 2021), the theory suggests that potential front running does not harm but benefits LETF shareholders.

Empirically, Bessembinder et al. (2016) test their theory by analyzing the price impact of oil futures roll trades undertaken by a single ETF. Despite a substantial rise in order imbalance due to roll trades during the settlement period, the authors find that the futures market is able to absorb the large increase in demand without a significant disruption to market quality. The authors find evidence of enhanced liquidity provision on roll days in the form of smaller spreads. Notably, they also find that a greater number of trading accounts provide liquidity on roll days compared to non-roll days, indicating that large trades made for non-informational reasons attract additional liquidity providers to the market.

The similarities between the predictability of order flow on roll days in the futures market and the predictability of order flow resulting from LETF rebalancing suggest that market participants could effectively provide liquidity to satisfy LETF rebalancing demand without a significant degradation of market quality. After all, Bessembinder et al. (2016) document that roll-trade volume sometimes exceeds 15% of total roll day volume, whereas LETF rebalancing typically constitutes a much smaller percentage of equity trading volume. As discussed in Section 3, the price impact of LETF rebalancing reverses overnight, which supports the notion that the typically small price impact serves as compensation for liquidity providers. Brøgger (2021) also reports that LETF rebalancing that is more predictable has a smaller impact on late-day returns, which is consistent with the ability of market participants to effectively provide enhanced liquidity to satisfy LETFs' rebalancing needs.

4.3. *Trading volume near market close*

To maintain their target leverage ratios and minimize tracking error, LETFs must rebalance their portfolios as near to market close as possible. This concentration of rebalancing trades at the end of the day is the source of concerns that LETFs could amplify late-day returns and volatility. However, market conditions have changed since these concerns were first raised by policymakers and other commentators. In particular, the market has become more liquid near the close due to the growth of index investing and an accompanying shift in trades made by liquidity providers. This suggests that the effect of LETF rebalancing today may be lower than it was in the past.

Bogousslavsky and Muravyev (2023) document a recent substantial rise in closing auction volume, which more than doubled from an average of 3.1% of daily dollar volume in 2010 to 7.5% in 2018.[24] They also report a more modest increase in volume during the last 5 minutes of trading, from 4.6% to 5.2%. While some of the increase in closing volume is due to rebalancing by LETFs and other passive funds, the authors find that "other traders shift their trades to the close and provide liquidity." Hence, the gradual shift in trading volume to market close should mitigate the future price impact of LETF rebalancing, which is consistent with the finding by Brøgger (2021) that the price impact of LETF rebalancing has declined over time.

In addition to a rise in closing volume, Bogousslavsky and Muravyev (2023) observe that there is relatively little price impact from trades made at the close. They report that over 75% of auctions settle (weakly) within the bid-ask spread, which means that a vast majority of trades made at the close do not have an economically significant effect on prices. They also find that large price deviations are rare and reverse almost fully overnight.

[24] Jegadeesh and Wu (2022) document a similar increase in closing auction volume from about 3% in 2010 to about 10% in 2019.

The recent shift in trading volume to market close may also influence the interpretation of the existing studies that directly analyze the impact of LETF rebalancing on late-day returns and volatility. As described in Table 2, many of these articles use data from 2011 and earlier. Given the dramatic shift in trading volume and corresponding increase in closing auction liquidity that has occurred since then, it is probable that the economic impact of LETF rebalancing in today's market is less substantial than implied by the earlier literature, especially because more recent analyses find that the effects of LETF rebalancing are economically insignificant (see Table 3).

5. Conclusions

Market observers have recognized that the daily rebalancing activity of LETFs has the potential to negatively impact late-day prices and volatility. While some early articles find statistically significant associations between LETF rebalancing demand and late-day prices, more recent articles that analyze more recent data find the associations to be economically insignificant. Additionally, there is no evidence in the literature that investors are able to earn abnormal returns by front running LETF rebalancing, and rebalancing does not systematically depress LETF NAV returns relative to the daily target multiples of their underlying index returns.

The broader literature on market microstructure also suggests that predictable rebalancing transactions should not have economically meaningful effects on asset prices. The predictable nature of LETF rebalancing enables market participants to effectively provide enhanced liquidity to satisfy the rebalancing demand near market close while reducing the price impact of such trades. Moreover, empirical evidence shows a recent large shift in trading volume to market close, and some of the increased volume near close could be driven by greater liquidity provision. The lack of an economically significant price impact implies that the concerns about LETF rebalancing raised by some policymakers, researchers, and journalists are unsupported.

Use of AI tools declaration

The author has not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The author declares no conflicts of interest in this paper.

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