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On the Profitability of Momentum Strategies and Optimal Leverage Rules

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To Alicia

Abstract

Paper [I] tests the success rate of trades and the returns of the Opening Range Breakout (ORB) day trading strategy. A trader that trades the ORB strategy seeks to identify large intraday price movements and trades only when the price moves beyond some predetermined threshold. We present an ORB strategy based on normally distributed returns to identify such days, and find that our ORB trading strategy result in significantly higher returns than zero as well as an increased success rate in relation to a fair game when applied to a long time series of crude oil futures contracts. The characteristics of such an approach over conventional statistical tests is that it involves the joint distribution of low, high, open and close over a given time horizon.

Paper [II] assesses the returns of the Opening Range Breakout (ORB) day trading strategy across volatility states of the underlying asset. We calculate the average daily returns of the ORB strategy for each volatility state when applied on long time series of crude oil and S&P 500 index futures contracts. We find an average difference in returns between the highest and lowest volatility state of around 200 basis points per day for crude oil, and of around 150 basis points per day for the S&P 500. Our result suggests that ORB strategy traders can be profitable, even in the long-run, but that the success in day trading to a large extent depend on the volatility of the underlying asset.

Paper [III] performs empirical analysis on short-term and long-term Commodity Trading Advisor (CTA) strategies regarding their exposures to unanticipated risk shocks. Previous research documents that CTA strategies in general offer diversification opportunities during equity market crisis situations when evaluated as a group, but do not separate between short-term and long-term CTA strategies. When separating between short-term and long-term CTA strategies, this paper finds that only short-term CTA strategies provide a significant, and consistent, exposure to unanticipated risk shocks while long-term CTA strategies do not. For the purpose of diversifying a portfolio during equity market crisis situations, our result suggests that an investor should allocate to short-term CTA strategies rather than to long-term CTA strategies.

Paper [IV] posits that it is possible to obtain an optimal leverage factor for financial instruments equipped with embedded leverage. By applying the Kelly criterion for optimal leverage, we show that there exists a uniquely optimal level of leverage for maximizing the long-run profit of embedded leverage instruments. The implication of an existing unique optimum is that a smaller leverage factor than optimal leads to a lower long-term profit than is feasible, but also that a *larger* leverage factor leads to a lower long-term profit than is feasible. Our empirical analysis shows how an optimal level of embedded leverage can increase the profitability of Exchange Traded Products.

Paper [V] systematically analyses the effect of leverage on long-run profit when trading the Opening Range Breakout (ORB) day trading strategy. This paper clarifies the relation to two optimal leverage rules proposed for maximizing trading profit; the Kelly criterion and the Optimal fraction criterion. Our empirical analysis shows how leverage can increase day trading profit in-sample and out-of-sample when applied to a long time series of DAX 30 index futures contracts.

Keywords: Bootstrap, Exchange Traded Products, Kelly criterion, Money management, Opening Range Breakout strategies, Optimal fraction criterion, Time series momentum.

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Stockholm in May 2020

Christian Lundström

This thesis consists of an introductory part and five self-contained papers related to the profitability of momentum strategies and optimal leverage rules.

Paper [I]

Holmberg, U., C. Lundström, and C. Lönnbark. ”Assessing the Profitability of Intra-day Opening Range Breakout Strategies.” *Finance Research Letters*, Vol. 10, No. 1 (2013), pp. 27-33.

Paper [II]

Lundström, C. ”Day Trading Returns Across Volatility States.” *IFTA Journal*, No. 19 (2019), pp. 75-87.

Paper [III]

Lundström, C. and J. Peltomäki. ”Beyond Trends: The Reconcilability of Short-Term CTA Strategies with Risk Shocks.” *Journal of Alternative Investments*, Vol. 18, No. 3 (2016), pp. 74-83.

Paper [IV]

Lundström, C. and J. Peltomäki. ”Optimal Embedded Leverage.” *Quantitative Finance*, Vol. 18, No. 7 (2018), pp. 1077-1085.

Paper [V]

Lundström, C. ”Optimal Leverage in Day trading.” *The Journal of Trading*, Vol. 13, No. 2 Spring (2018), pp. 57-68.

1. Introduction

This thesis consists of five papers separated into two different parts.

The first part of the thesis (papers [I], [II], and [III]) deals with technical trading strategies constructed to profit from trends that may appear in prices of financial assets. Technical strategies are strategies solely based on past information, and strategies constructed to profit from price trends are sometimes referred to as trend-following strategies or as momentum strategies. This part focuses on two major issues. First, can technical momentum strategies generate a positive expected return net of costs? Second, do the returns of such strategies correlate with market volatility? The second part of the thesis (papers [IV] and [V]) deals with the effects on long-run profit when trading with leverage, where leverage is the level of market exposure of the investment relative to the level of committed capital. This part focuses on optimal leverage rules or strategies for maximizing the long-run profit from trading with respect to leverage.

Paper [I] tests the success rate of trades and the returns of the Opening Range Breakout (ORB) day trading strategy. The ORB strategy is a technical strategy constructed to profit from intraday price trends, i.e., intraday momentum. Paper [II] measures the ORB strategy returns across volatility states of the traded asset. Paper [III] analyses the empirical returns of short-term and long-term Commodity Trading Advisor (CTA) funds and their correlation to market volatility. CTA funds aim to profit from price trends by trading a multiple of assets using technical momentum strategies. Paper [IV] proposes an optimal leverage rule for exchange-traded products equipped with leverage. Exchange-traded products with leverage are offered to investors who seek to obtain the leveraged daily performance of a particular asset or a portfolio of assets. Paper [V] studies the effects of optimal leverage on long-run profit when day trading the ORB strategy, and clarifies the relation between two optimal leverage rules both derived for maximizing trading profit.

The remaining part of this introductory chapter is organized as follows. Section 2 provides a background and an overview of the relevant literature for the first part of the thesis, as well as a summary of papers [I], [II], and [III]. Section 3 presents the background and a literature overview related to the second part of the thesis. Papers [IV] and [V] are summarized in this part.

2. The profitability of momentum strategies

2.1 Introduction

Financial economics is the study of how people allocate scarce resources over time. Two features that distinguish financial decisions from other resource allocation decisions are that the costs and benefits of financial decisions are (1) spread out over time and (2) usually not known with certainty in advance. One approach to model this decision problem is provided by Modern Portfolio Theory (MPT). Pioneered in Markowitz (1952), MPT is a theory on how rational, risk-averse, investors can construct portfolios of risky assets to optimize or maximize expected return based on a given level of risk, emphasizing that risk is an inherent part of higher return. According to the MPT, it is possible to construct optimal portfolios offering the maximum possible expected return for a given level of risk. Optimal portfolios are characterized by a tradeoff between expected return and risk and a rational investor should hence choose the portfolio that maximizes the expected return given the investor preference to risk.

So what return on capital can an investor expect in the long run when capital markets are in equilibrium? One answer to this question is provided by the Capital Asset Pricing Model (CAPM). Introduced in Sharpe (1964), Lintner (1965), and Mossin (1966), building on the MPT, the CAPM is used to determine an appropriate rate of return of an asset or a portfolio. The CAPM takes into account the asset's sensitivity to market risk, referred to as beta, as well as the expected return of the market and the expected return of a risk-free asset. In the CAPM, the beta of the portfolio is the defining factor in rewarding the exposure to market risk taken by an investor. According to the CAPM, the risk of a portfolio comprises systematic risk and unsystematic risk. Systematic risk refers to the risk associated to the market as a whole scaled by beta squared, and unsystematic risk is the risk associated with individual assets. The latter can be reduced by diversification, i.e., by including (uncorrelated) assets to the portfolio, while the former cannot be reduced in this manner. Importantly, the investor is only compensated by increased expected return when adding systematic risk to the portfolio, not unsystematic risk. Consequently, a rational investor should hence only take on systematic risk within the scope of this model.

From the premise that an investor should maximize expected return based on a given level of risk, it would be in the investors' interest to search for trading strategies able to improve the return of the invested capital. When an investor trades according to a trading strategy the investor actively buys and sells assets in financial markets for a profit following a predetermined decision rule. A technical strategy is a trading strategy solely based on past information (technical trading strategies are also known as filter rules, systematic strategies, or simply technical analysis). Technical strategies are typically based on past prices but could include trading volume and other quantifiable information (for an overview of technical trading strategies and the information that they use, see Katz and McCormick, 2000). The first part of the thesis (papers [I], [II], and [III]) studies the profitability of technical momentum strategies, i.e., technical strategies based on momentum.

2.2 Technical momentum strategies

Momentum is the tendency for rising asset prices to keep rising and falling prices to keep falling, which causes prices to trend (e.g., Jegadeesh and Titman, 1993). Technical momentum strategies, henceforth simply momentum strategies, are constructed to profit from price trends by using past information. Momentum strategies are sometimes referred to as trend-following strategies (e.g., Moskowitz *et al.*, 2012).

Momentum strategies are popular. The Opening Range Breakout (ORB) strategy is popular day trading strategy used to profit from intraday trends, i.e., intraday momentum, in asset prices (Crabel, 1990; Williams, 1999; Fisher, 2002). The ORB strategy is based on the premise that, if the price moves a certain percentage from the opening price level, the odds favor a continuation of that move until the closing price of that day. The trader should therefore establish a long (short) position at some predetermined threshold a certain percentage above (below) the opening price and exit the position at market close (Crabel, 1990). Further, Commodity Trading Advisor (CTA) funds constitute a particular class of investment funds, attracting a lot of assets under management, that aim to profit from price trends by trading a multiple of assets using trend-following or momentum strategies (e.g., Moskowitz *et al.*, 2012).[1] [2]

Momentum can be separated into two major types: cross-sectional momentum and time series momentum. Cross-sectional momentum focuses on the *relative* performance of assets in the cross-section and is based on the premise that assets that have relative outperformed their peers, over the most recent 3 to 12 months, will continue to outperform their peers during the next month (e.g., Jegadeesh and Titman, 1993; Chan *et al.*, 2000; Erb and Harvey, 2006; Miffre and Rallis, 2007; Fuertes *et al.*, 2010). Time series momentum, introduced for the first time in Moskowitz *et al.*, 2012, focuses instead on the assets own *absolute* performance. Time series momentum is based on the premise that assets that have increased (decreased) in price over the most recent time period will continue to increase (decrease) during the next time period (e.g., Moskowitz *et al.*, 2012, Pettersson, 2014).

Cross-sectional momentum and time series momentum differ in other aspects as well. For example, when trading a portfolio of multiple assets, time series momentum portfolios differ from cross-sectional momentum portfolios in terms of exposure to market risk. We remember that the CAPM beta gives the portfolio exposure to market risk. A cross-sectional momentum strategy is a portfolio with a zero beta in terms of market exposure; it invests long[3] in half of the assets *and* short-sells[4] the other half, netting the market exposure to roughly zero. This can be done by, for example, investing long in a particular stock while short-selling the stock market index (by the same exposure) and thereby extracting the stock-specific return without the market risk. On the other hand, a time series momentum portfolio, for example a CTA fund, is a portfolio of momentum strategies for individual assets, usually with a non-zero beta in terms of market exposure. That is, a time series momentum portfolio is either invested long in assets that have increased in value during the past year *or* it short-sells assets that have decreased in value during the past year. Thus,

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[1] Barclay Hedge estimates that CTA funds manage over USD 337 Billion in 2016 and that more than 90% of the CTA funds are classified as technical strategies (BarclayHedge.com 2017-02-15).
[2] We note that CTA funds are not limited to trading only commodities but other assets as well, such as fixed income, currencies, debt, and stock market indices.
[3] Invests long means that the investor buys futures contracts, speculating in a rising market.
[4] Short-sells means that the investor sells futures contracts, speculating in a falling market.

we would expect the beta in terms of market exposure of a time series momentum portfolio to vary over time from positive to negative, depending on the balance between long and short trades.

A relevant question to ask given the size of assets invested in CTA funds and the popularity of the ORB strategy, is whether CTA funds and ORB strategy traders actually generate profit? This question directly relates to the still on-going academic debate of whether technical strategies in general are able to generate a positive expected return and, in turn, if markets are efficient with respect to information. We now turn to this question by providing a brief summary of the vast literature on technical strategy profit testing and market efficiency.

2.3 The profitability of technical strategies and market efficiency

Assessing the returns of technical strategies has a long history and includes, among others, Alexander (1961), Fama and Blume (1966), Brock *et al.* (1992), Caginalp and Laurent (1998), Gencay (1998), Sullivan *et al.* (1999), Neely (2003), Park and Irwin (2007), Marshall *et al*. (2008a; 2008b), Schulmeister (2009), Aalto *et al.* (2011), and Yamamoto (2012). This issue can be related to the Efficient Market Hypothesis (EMH) of Fama (1965, 1970), which asserts that current asset prices fully reflect available information, implying that asset prices evolve as random walks over time. In particular, an assertion of the EMH is that it should not be possible to base a trading strategy on historical prices, such as technical trading strategies, and earn positive expected returns net of costs (see also Fama and Blume, 1966). Thus, assessing the empirical profit of technical trading strategies can be viewed as a test of EMH itself and in the massive literature on the subject, we find both acceptance and rejection of the EMH (for an overview, see Park and Irwin, 2007).

Fama and Blume (1966) argue that, because information on prices is readily available to anyone, the null hypothesis is that a technical trading strategy should generate a zero return on average when markets are efficient. If a technical trading strategy generates an average return significantly larger than the associated trading cost, this would consequently reject the null hypothesis of efficient markets (e.g., Fama and Blume, 1966). Thus, we note that ORB strategy traders and CTA funds should not be able to achieve positive returns net of costs.

Recent studies argue, however, that significantly positive returns net of costs are not enough to reject the EMH, for a number of reasons. For example, it is argued that the returns of a technical trading strategy should also, when applicable, be larger than the returns from buying and holding the underlying asset (e.g., Park and Irwin, 2007) and when adjusted for risk/volatility (e.g., Neely, 2003). This is because efficient markets rewards investors who take more systematic risk with higher expected returns, according to MPT and CAPM. Thus, markets are efficient as long as the expected return of a technical trading strategy, given a certain risk level, equal the beta-adjusted expected return of a buy and hold strategy, i.e., with equal systematic risk (see the discussion in Neely, 2003). One could therefore argue from a risk-return perspective that ORB strategy traders and CTA funds can achieve positive returns net of costs up to the point they are rewarded for carrying the level of systematic risk associated with trading without necessarily rejecting the EMH.

Significant positive returns in empirical testing do not necessarily have to reject the EMH for methodological reasons as well. When assessing the returns of a technical trading strategy, the researcher could potentially over-fit the strategy to the data and, in turn, over-estimate the actual strategy returns. This relates to the problem of data snooping when the researcher both develop the trading strategy and evaluate the strategy returns and profit based on the same data set (e.g., Brock *et al.* 1992; Sullivan *et al*. 1999; White, 2000). Thus, to reject the EMH, the technical trading strategy must be able to generate significantly positive returns but also have been developed and evaluated using data from non-overlapping sub-periods (e.g., Brock *et al.* 1992). Brock *et al.* (1992) tests two simple and popular technical trading strategies when applied to a long time series of the Dow Jones Index from 1897 to 1986 where standard statistical analysis is extended with bootstrap techniques. This bootstrap technique deals with the data snooping problem by attaching importance to the robustness of results across various non-overlapping sub-periods for statistical inference. Overall, Brock *et al.* (1992) shows that the returns obtained from these strategies are significantly positive and not consistent with the returns of a random walk. Further, the returns are significantly positive also when adjusted for the possibility that returns experience positive linear serial correlation and correlates with previous levels of volatility[5]. Overall, the results of Brock *et al.* (1992) provide strong empirical support for the tested technical strategies.

[5] The returns obtained from the tested strategies are not consistent with four popular null hypothesis models: the random walk model, the AR(1) model (positive linear serial correlation), the GARCH-M model and the

However, even if a technical strategy generates significant positive returns when evaluated with standard statistical analysis or a bootstrap technique, one could argue that other traders would soon use such a strategy, the profit would diminish, and the strategy would self-destruct. This argument leads some authors to suggest that the technical trading strategy able to achieve significantly positive returns must also be known to, as well as used by, traders at the time of their trading decisions in order to reject the EMH (see the discussion in Coval *et al*., 2005). Thus, the strategies evaluated in Brock *et al.* (1992) and other studies must have known to and used among investors throughout the full sample starting at 1897.

Returning to the question at hand - can momentum strategies generate a positive expected return net of costs - the EMH gives a bleak prediction for the ability of momentum strategies to generate a positive expected return net of costs and the random-walk-postulation of asset prices does not leave much room for explaining momentum. Before we turn to the empirical profitability of momentum strategies, we proceed by briefly considering possible behavioral motivations behind momentum.

2.4 Behavioral motivations behind momentum

The explanation of why momentum may appear in asset prices is typically motivated from a psychological perspective. The field of economics that studies behavioral errors is referred to as "behavioral finance," and notable work includes Kahneman and Tversky (1979), Barberis *et al.* (1998), Daniel *et al*. (1998) and Lo (2004). This literature proposes that momentum is the result of investors trading coordinately, thus creating a trend, and is typically attributed to cognitive biases from irrational investors and traders such as investor over- or under-reaction to news. Over-reaction can be caused by herding (e.g., Bikhchandani *et al.*, 1992), over-confidence and self-attribution confirmation biases (e.g., Daniel *et al*., 1998), the representativeness heuristic (e.g., Barberis *et al.*, 1998), positive feedback trading (e.g., Hong and Stein, 1999), or investor sentiment (e.g., Baker and Wurgler, 2006). Under-reaction can result from the disposition effect which reflects the

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Exponential GARCH model (heteroscedasticity/volatility clusters). Specifically, buy signals consistently generate higher returns than sell signals, the returns following buy signals are less volatile than returns following sell signals and, further, the returns following buy signals are less volatile than returns following sell signals. Moreover, returns following sell signals are negative.

tendency to realize the wins of winning trades too soon and hold on to losing trades too long (e.g., Shefrin and Statman, 1985), conservativeness and anchoring biases (e.g., Barberis *et al.*, 1998), or slow diffusion of news (e.g., Hong and Stein, 1999).

We note that momentum does not necessarily have to be the result of irrational behavior among investors. As discussed in Crombez (2001), momentum can be observed with rational investors if we assume noise in the experts' information. Also, we note that the Adaptive Market Hypothesis (AMH), introduced in Lo (2004), attempts to reconcile economic theories based on the EMH with behavioral economics by applying the principles of evolution to financial decision-making. Under this approach, the EMH can coexist with behavioral models. Lo (2004) argues that much of what behaviorists cite as counterexamples to economic rationality - over-reaction, over-confidence, loss aversion, and other behavioral biases that may explain momentum - are, in fact, consistent with an evolutionary model of individuals adapting to a changing environment using simple heuristics. Thus, momentum can be attributed to rational investor behavior according to the AMH.

However, this thesis does not study why momentum may exist, only the effects momentum may have on trading profit. As previously stated, momentum strategies are popular in the trading community, but what do we know about empirical returns and profitability of momentum strategies? We now turn to this question by relating papers [I] and [II] to the existing literature on the profitability of ORB strategy traders, and paper [III] to the profitability of CTA funds.

2.5 The profitability of momentum strategies; ORB traders and CTA funds, and their relation to volatility

This thesis focus on the profitability of CTA funds and ORB strategy trading. Being built to profit from trends in absolute asset price performance, and not on the relative performance between assets in cross-section, both CTA funds and ORB strategy trading relates to time series momentum. Thus, this thesis restricts its study to the profitability of only time series momentum strategies. We henceforth refer to time series momentum strategies and portfolios simply as "momentum strategies" and "momentum portfolios" if not otherwise stated.

We start by the profitability of ORB strategy traders. Introduced in Crabel (1990), the ORB strategy is supposedly used by self-proclaimed profitable day traders (e.g., Williams, 1999; Fisher, 2002), but its profitability has not been academically verified. Instead, most studies of day trading profit have been conducted using transaction records of individual trading accounts for various stock and futures exchanges. See, for example, the studies of Harris and Schultz (1998), Jordan and Diltz (2003), Garvey and Murphy (2005), Linnainmaa (2005), Coval *et al*. (2005), Barber *et al*. (2006, 2014) and Kuo and Lin (2013).

When measuring the returns of day traders using transaction records, average returns are calculated from trades initiated and executed on the same trading day. We note that most of these studies report empirical evidence that some day traders are profitable, i.e., able to achieve average returns significantly larger than zero after adjusting for transaction costs, but that profitable day traders are relatively few – only one in five or fewer (e.g., Harris and Schultz, 1998; Garvey and Murphy, 2005; Coval *et al*., 2005; Barber *et al.*, 2006; Barber *et al.*, 2014; Kuo and Lin, 2013). Linnainmaa (2005), on the other hand, finds no evidence of positive returns from day trading.

The empirical observation that some day traders are able to achieve average returns significantly larger than zero after adjusting for transaction costs is interesting considering that day traders should lose money on average after adjusting for transaction costs when markets are efficient with respect to information (Statman, 2002). However, we expect that some day traders will achieve profitability by mere chance given that the sample of traders is large enough. Further, the account studies of Harris and Schultz (1998), Jordan and Diltz (2003), Garvey and Murphy (2005), Linnainmaa (2005), Coval *et al*. (2005), Barber *et al*. (2006, 2014) and Kuo and Lin (2013) do not relate trading success to any specific assets or to any specific trading strategy. Harris and Schultz (1998) and Garvey and Murphy (2005) report that profitable day traders react quickly to market information, but they do not investigate the underlying strategy of the traders studied. Without detailed knowledge if their strategy is based on momentum we cannot address whether momentum strategies, such as the ORB strategy, are able to generate positive returns net of costs from the existing literature on day trading profitability.

Papers [I] and [II] study the hypothetical returns of a day trader using the ORB strategy and, in effect, the existence of intraday (time series) momentum. By assessing the returns of a hypothetical day trader trading a technical strategy contributes the account studies as it enables us to study day trading returns over a long time period. Being able to study ORB strategy returns over long periods could provide insights on the characteristics of day traders' profitability, such as average daily returns, possible correlation to macroeconomic factors, robustness over time, etc., but also effectively avoid possible small sample biases that may be a problem in account studies.

Further, assessing the returns of a technical trading strategy enables the use of bootstrapping technique to generate even longer time series, with more observations, than the actual series of empirical data when testing the profitability of day traders. This would naturally improve the accuracy of the profitability tests. We note that assessing the hypothetical returns of a day trader using technical strategies applied intraday can be found in, for example, Marshall *et al*. (2008b), Schulmeister (2009), and Yamamoto (2012), but that these strategies are developed by researchers and not necessarily used among day traders during the tested time period. Because the ORB is actually used among day traders, assessing the ORB returns complements the studies of Marshall *et al*. (2008b), Schulmeister (2009), and Yamamoto (2012).

Built to profit from intraday price trends, we note a resemblance between ORB profit and volatility clustering of the underlying asset. That is, when intraday prices trend up or down from open to close – daily volatility should be high – suggesting a positive relation between ORB profit and the volatility of the traded asset. Paper [II] therefore proposes that ORB profit may be positive correlated to the volatility of the traded asset, and studies this correlation over time. Analyzing the returns of momentum trading strategies over time relates to the literature that tests whether market efficiency may vary over time in correlation with specific economic factors (see Lim and Brooks, 2011, for a survey of the literature on time-varying market inefficiency). In particular, Lo (2004) and Self and Mathur (2006) emphasize that, because trader rationality and institutions evolve over time, financial markets may experience a long period of inefficiency followed by a long period of efficiency and vice versa. The possible existence of time-varying market inefficiency is of interest for the fundamental understanding of financial markets but it also relates to how we view long-run profitable day traders. If profit is related to volatility, we expect profit in day trading to be the result of relatively infrequent trades that are of relatively large magnitude and are carried out during the infrequent periods of high volatility. If so, we could view positive returns from day trading as a tail event during time periods of high volatility in an otherwise efficient market.

Now, turning our attention to the profitability of CTA funds, studies of the returns and profit of CTA funds and other time series momentum portfolios can, for example, be found in Moskowitz *et al.* (2012), Kaminski (2011a; 2011b; 2011c), and Pettersson (2014).

Moskowitz *et al.* (2012) find that futures contracts that increased (decreased) in price over the most recent 12 months continued to increase (decrease) on average during the next month, for nearly every contract tested out of 58 different contracts, including equity indices, currencies, and commodities, over more than 25 years of data. Kaminski (2011a; 2011b; 2011c) find that CTA funds tend to increase in value as the value of stocks tend to fall, and finds empirical support that CTA funds generate positive average returns during equity market crisis situations - classifying CTA strategies as long volatility investment strategies with a positive, so called, *crisis alpha*. In this literature, crisis alpha refers to the ability for strategies to earn superior risk-adjusted returns during equity market crises. As an investment, CTA funds may therefore serve as a type of hedge against risk shocks, or equity-tail-risk-events, during periods of equity market crisis. If so, CTA funds could prove useful from a diversification perspective in a portfolio construction for investors to add to a portfolio of stocks or other assets. However, we note that the ability to hedge against risk shocks or equity-tail-risk-events is ultimately based on the correlation relationship between the returns of CTA funds and market volatility. Pettersson (2014) studies the relation between the returns of time series momentum portfolios and market volatility. In contrast to the results of Kaminski (2011a; 2011b; 2011c), Pettersson (2014) reports that momentum portfolios actually produce *lower* average returns during periods of high volatility, which would indicate a negative crisis alpha for CTA funds.

Possibly equipped with crisis alpha, CTA funds and other momentum portfolios could potentially serve as an important asset to hold for its diversification properties in both MPT and CAPM contexts. Thus, the contradictory empirical results of Kaminski (2011c) and Pettersson (2014) regarding the relation between the returns of momentum portfolios and volatility point to the need for more studies. Being able to select momentum portfolios, for example CTA funds, that correlate positively with volatility can offer valuable diversification opportunities for investors searching beyond the traditional asset classes to counterbalance the poorly performing traditional assets during equity market crises situations.

Paper [III] studies the returns of CTA funds and their correlation relationship to market volatility, and proposes one possible explanation of why different CTA funds may correlate differently with volatility. Recognizing that CTA funds uses trend-following strategies, positioned either long or short in price trends, Paper [III] posits that the path properties of the trend, i.e., the volatility of the trend, matters for the funds profitability and ability to generate crisis alpha. If the volatility of the trend is too high, CTA funds may suffer from losses due to stopped-out trades.

Paper [III] argues further that CTA funds may vary considerably in their ability to deliver crisis alpha, and, in turn, in their capacity to hedge equity tail risk, depending on the strategy of the fund, the frequency of the trading, holding period of trades, and so on. Therefore, even if the returns of CTA funds evaluated as a group yield a significant crisis alpha on average, as reported in Kaminski (2011c), the individual contribution of alpha may vary among different sub-classes of CTA funds. This could imply that one momentum portfolio or CTA fund may serve as a decent hedge of equity tail risk, while another does not, depending on the frequency of the underlying strategy or strategies used.

One way to group CTA funds into different sub-classes is by their holding period of trades. CTA funds that have a holding period shorter than 10 days is typically classified into short-term CTA funds and holding period of 10 days, or longer, into long-term CTA funds. As a consequence of the holding period, short-term CTA funds trades more frequent than long-term CTA funds, and should hence be able to react more quickly to changes in the market. The holding period of trades could therefore effect the long-run returns of the CTA fund as well as the relationship between returns and market volatility and other properties.

By studying short-term and long-term CTA strategies separately, Paper [III] analyzes whether the holding period and the frequency of the trading generate different returns and different correlations to market risk. Further, since CTA funds are time series momentum portfolios that we actually can observe empirically, analyzing historical returns of CTA funds complements the studies of time series momentum in Moskowitz *et al.* (2012) and Pettersson (2014), where researchers have developed the momentum strategies employed.

2.6 Summary of papers [I], [II], and [III]

Paper [I]: Assessing the profitability of intra-day opening range breakout strategies

This paper links the returns of a popular day trading strategy, the Opening Range Breakout (ORB) strategy, to intraday momentum in asset prices. The ORB strategy is based on the premise that, if the price moves a certain percentage from the opening price level, the odds favor a continuation of that move until the closing price of that day. The trader should therefore establish a long (short) position at some predetermined threshold a certain percentage above (below) the opening price and exit the position at market close. To determine the thresholds from the opening price in the ORB strategy, the trader uses a so-called range, which is added to (subtracted from) the opening price for long (short) trades. As positive ORB returns are based on intraday trends, the range should be small enough to enter the market when the move still is small, but large enough to avoid market noise that does not result in trends. The advantage of testing the returns of the ORB strategy, relative to the returns of the day trading strategies reported in previous studies, is that the ORB strategy is used among self-proclaimed and seemingly profitable day traders and not developed by researchers.

This paper presents an ORB strategy where the range is based on normally distributed returns and proposes an approach of assessing the returns of such a strategy when long records of daily opening, high, low, and closing prices are available. The advantage of such an approach over conventional statistical tests is that it involves the joint distribution of low, high, open and close over a given time horizon. To assess statistical significance, we rely on bootstrap technique of Brock *et al.* (1992). Here, we face additional challenges when assessing the returns of technical trading strategies compared to the study of Brock *et al.* (1992) because the case at hand is multivariate, with natural ordering of the level series: low, high, open and close. To meet these additional challenges, this paper expands the bootstrap approach used in Brock *et al.* (1992) to test the profit of technical trading strategies in a multivariate setting.

In an empirical application, we apply our test to a long time series of US crude oil futures from 1983-03-30 to 2011-01-26. Using the full sample of years, we find remarkable success of the ORB trading strategy, resulting in significantly higher returns than zero, as well as an increased success rate relative to a fair game. When we split the data series into shorter time periods, we find significantly positive returns only in the last time period, ranging from 2001-10-12 to 2011-01-26. This time period includes the sub-prime market crisis, which leads us to suggest that positive ORB returns, and in turn intraday momentum, are perhaps positively correlated with market volatility.

Paper [II]: Day trading returns across volatility states

This paper links positive expected returns of the Opening Range Breakout (ORB) day trading strategy to the volatility of the underlying asset price returns, and assesses the ORB strategy returns across volatility states. We calculate the average daily returns of the ORB strategy for each volatility state of the underlying asset when applied to a long time series of crude oil and S&P 500 futures contracts.

This paper contributes to the literature on day trading profitability in general by studying the returns of a day trading strategy for different volatility states. This paper contributes to Paper [I] by assessing, to some extent, more realistic ORB strategy returns. First, by allowing the ORB trader to trade both long and short positions the same trading day we, in effect, allow the trader to benefit from stopping intraday losses from growing too large, as we would expect in actual trading. Second, this paper also studies the returns when applying the ORB strategy out-of-sample. Because the ORB strategy is defined by only one parameter – the range – this paper avoids the problem of data snooping by assessing the out-of-sample strategy returns for a large number of ranges. Also, the range used in this paper is not restricted to any particular returns density function assumption.

This paper finds that the differences in average returns between the highest and lowest volatility states are around 200 basis points per day for crude oil, and around 150 basis points per day for S&P 500. This finding explains the significantly positive ORB returns in the period 2001-10-12 to 2011-01-26 reported in Paper [I]. Perhaps more importantly, the finding of this paper affects the way we may perceive profitable day traders. Even if our result suggests that ORB strategy traders can be profitable in the long-run, this is not the same as earning steady and constant profit over time. The findings of this paper suggest instead that long-run profitability in day trading can be the result of trades that are relatively infrequent, but of relatively large magnitude, associated with the infrequent time periods of high volatility. Positive expected returns in day trading can hence be seen as a relative improbable occurrence, clustered to times of high volatility, in a mostly efficient market.

The implication of this is that a day trader, profitable in the long run, could still experience time periods of zero, or even negative, average returns during periods of normal, or low, volatility. Thus, even if long-run profitability in day trading could be achieved, it is most likely achieved only by the trader committed to trade every day for a very long time, or by the opportunistic trader able to restrict his trading to periods of high volatility. Further, this finding highlights the need for using a relatively long time series that contains a wide range of volatility states when evaluating the returns of day traders, in order to avoid possible volatility bias.

When analyzing the returns from trading ORB strategies out-of-sample, this paper finds that out-of-sample profitability depends on the choice of asset and range, and that not all ranges are profitable. Further, profitability is not robust to time. A point to note is that ORB strategy trading may result in relatively few trades, which restricts potential wealth accumulation over a given time period. Most likely, the ORB trader simultaneously monitors and trades on several different markets, thereby increasing the frequency of trading. Further, this paper studies the profitability when trading ORB strategies without leverage, which also may restrict potential wealth accumulation over time. Most likely, the ORB trader uses leverage to scale-up the relatively small returns from intraday price moves to increase profitability. Moreover, we find that adding trading costs do not affect the average daily returns in a qualitative way even if costs decrease annual returns considerably.

Paper [III]: Beyond Trends: The Reconcilability of Short-Term CTA Strategies with Risk Shocks

This paper performs empirical analysis on the returns of short-term and long-term Commodity Trading Advisor (CTA) strategies and their exposures to unanticipated risk shocks. This paper calculates the unanticipated risk shocks based on the VIX index and uses such shocks as a proxy for market risk. Previous research documents that CTA strategies offer diversification opportunities during equity market crisis situations when evaluated as a group, but these earlier studies do not separate between short-term and long-term CTA strategies.

This paper recognizes that CTA strategies may vary considerably in their ability to deliver crisis alpha, and, in turn, in their capacity to hedge equity tail risk, depending on the strategy of the fund, the frequency of the trading, and so on. So, even if CTA strategies produce a significant crisis alpha on average when evaluated as a group, the individual contribution of alpha may vary considerably among different sub-classes of CTA strategies.

When separating between short-term CTA funds and long-term CTA funds, this paper finds that only short-term CTA funds provide a significant, and consistent, exposure to unanticipated risk shocks, while long-term CTA funds do not. "Consistent" means that the exposures to risk shocks are prevalent in different states of the risk cycle. This finding contributes to the CTA literature by showing that only short-term CTA funds offer diversification opportunities during equity market crisis situations, i.e., crisis alpha. Thus, the returns of short-term CTA funds seems to be positively correlated to volatility similar to the returns of the ORB day trading strategy reported in Papers [I] and [II]. We note that the ORB strategy, or variants of it, may actually be used as strategies within the short-term CTA funds.

The result of this paper suggests that an investor should allocate to short-term CTA funds rather than to long-term CTA funds for diversifying a portfolio during equity market crisis situations. The implication of this finding differs depending on whether the investor is passive or active. A passive investor should buy and hold short-term CTA funds for a part of the portfolio assets to hedge equity tail risk. An active investor should instead try to allocate to short-term CTA funds in an early state of the risk cycle, when the risk level trends up, and should reallocate the assets to, for example, long-term CTA funds or (more) equities in a later state of the risk cycle, when the risk level trends down.

This concludes the first part of this thesis, and we now continue with the second part that deals with optimal leverage rules in investing, not necessarily limited to momentum strategies.

3. Optimal leverage rules

3.1 Introduction

This part of the thesis (papers [IV] and [V]) deals with the effects on long-run profit when investing with leverage. Leverage is here defined as the level of market exposure of the investment relative to the level of committed capital (e.g., Frazzini and Pedersen, 2012) and can be obtained via derivatives contracts, such as futures, forwards, options, and other contracts. In effect, investing with leverage scales the returns of the underlying asset and therefore affects long-run profit. Leverage may hence serve as a useful tool to increase investment returns and profit, but at the expense of increased risk. Thus, increasing the expected return in investing by applying leverage, do not necessarily leave the investor better off in terms of utility. This is because risk naturally increases with the level of leverage, and from the MPT we know that the possible increase in utility from an increased expected return, must be weighed against the particular aversion to risk individual investors may have.

While the MPT provides a model for analyzing the increase in expected return, relative the increase in risk, it is perhaps mainly suitable for risk-averse investors. But what if some investors do not care about risk – they only care about maximizing the expected return and profit from investing? Such investors are sometimes referred to as risk-neutral investors and they would arguably use leverage as an essential tool for maximizing profit.

Some investors display risk-neutral behavior. We know that day traders trade for profit seemingly without concerns for risk, displaying a potential risk-neutral (or even risk-seeking) behavior (e.g. Statman, 2002; Jordan and Diltz, 2003). We also know that some investors - notable for their high profitability and investment success - use leverage to increase investment profit, displaying a potential risk-neutral behavior. For example, Warren Buffett and Bill Gross use leverage to increase their investment profit (Thorp, 1997; Ziemba, 2005; Ziemba and Ziemba, 2007). Further, we observe a growing number of financial products with built-in leverage are being offered to the public, such as exchange-traded products (ETPs) equipped with leverage, offering the possibility for retail investors to use leverage to increase investment returns and profit. The fact that leveraged ETPs have become increasingly popular in recent years, and have attracted significant assets under management (Giese, 2010), may indicate risk-neutral behavior among investors.

Given that investors are risk-neutral and free to use leverage without costs or restrictions, how much leverage should an investor use in order to maximize the profit from investing? This thesis focus on optimal leverage rules for leveraged ETPs (paper [IV]) and ORB strategy day traders (paper [V]), so the challenges we face here are to derive the optimal leverage factor for leveraged ETPs and to derive the optimal leverage factor when trading the ORB strategy. Before we relate papers [IV] and [V] to the relevant literature, we start by introducing the literature on optimal leverage rules.

3.2 Optimal leverage rules in investing, the Kelly and Optimal fraction criteria

We now provide a brief introduction to the literature on optimal leverage rules for investment applications, and also define and explain the terminology central to papers [IV] and [V]. The notable papers in this field of research include Kelly (1956), Thorp (1969), Vince (1990), among others. For overviews, see MacLean et al. (2010) and Sewell (2011).

When studying leverage in investing, the basic idea is that an investor apply leverage on each trade to scale the returns by a fixed factor, and can be outlined as follows: Suppose that an investor trades a large but finite number of $n > 0$ days, yielding a daily return series after cost of $x_1, x_2, \dots, x_n$ from an identically distributed returns density function with a finite, constant, and positive mean and variance. The accumulation of wealth, i.e., capital growth, from investing with leverage can then be written as the investors wealth after n trades, w_n, relative to the initial wealth, w_0, by:

$$\frac{w_n}{w_0} = \prod_{t=1}^{n} (1 + \theta x_t) \tag{1}$$

where $\theta > 0$ is the constant leverage factor applied on each trade.

A leverage factor of $0 < \theta < 1$, $\theta = 1$, or $\theta > 1$ corresponds to a smaller, equal, or larger market exposure, respectively, relative to the committed capital.

We note that optimal leverage rules are restricted to constant and positive leverage factors ($\theta > 0$), which directly follows from the assumption of a constant and positive mean of the returns x (e.g., Kelly 1956; Thorp, 1969; Vince, 1990).

Further, optimal leverage rules are restricted to only *favorable* strategies (e.g., MacLean et al. 2010). By a favorable strategy we mean one such that; $\Pr(\lim_{n\to\infty} w_n = +\infty) > 0$. From its definition, favorable strategies can never experience financial ruin ($w_n \leq 0$) for some n, as this would imply that: $\Pr(\lim_{n\to\infty} w_n = +\infty) = 0$.

This implies that favorable strategies restricts the use of leverage so that θ is always small enough to satisfy; $1 + \theta a > 0$, where $a < 0$ is the smallest attainable return of the returns density function. Thus, from rearranging this expression, we find that leverage factors for favorable strategies are effectively limited to the range: $0 < \theta < -1 / a$.

The perhaps most famous optimal leverage rule is the Kelly criterion. Introduced for the first time in Kelly (1956), the Kelly criterion maximizes the expected value of the logarithm of capital growth. The Kelly criterion is typically used to maximize portfolio profit (e.g., Bodie et al., 2014) and is arguably therefore suitable for risk-neutral investors. In fact, Breiman (1961) show that rational investors with a log utility function maximizes both expected profit and utility when applying the Kelly criterion in investing. However, we note that rational investors with other utility functions typically find the Kelly criterion too aggressive leverage rule to use as it leads to high volatility and temporary large drawdowns in wealth (for overviews, see MacLean et al. 2010).

Nevertheless, using the Kelly criterion has many valuable long-run properties for investors. In the long run, Breiman (1961) showed that the Kelly criterion maximizes long-term growth and asymptotically outperforms any other essentially different leverage rule. Breiman (1961) also showed that the Kelly criterion minimizes the expected time it takes to reach a certain level of capital, which can be valuable to investors that experienced a severe drawdown and would like to use leverage to minimize the time to get back to the previous high.

Thorp (1969) expands the Kelly criterion to derivatives trading. While the criterion in Kelly (1956) gives the optimal portfolio weights to maximize the profit when holding a number of assets, the criterion in Thorp (1969) gives the optimal leverage factor to apply on each trade when trading in one asset at the time (for overviews, see MacLean et al. 2010, Sewell 2011). The relation between the Kelly criterion by Thorp (1969) and Eq. (1) is straightforward: The Kelly criterion maximizes the expected value of the logarithm of capital growth per trade, i.e., the expected profit per trade, given by;

$$\underset{wrt\ \theta}{Max}\left\{E\left[\frac{1}{n}\ln\left(\frac{w_n}{w_0}\right)\right]=E\left[\frac{1}{n}\sum_{t=1}^{n}\ln(1+\theta x_t)\right]\right\} \quad (2)$$

at $\theta = \theta^*$.

Because we assume that $1 + \theta a > 0$ for favorable strategies, the logarithm $\ln(1 + \theta x)$ in Eq. (2) is always defined, and optimal leverage factors are limited to the range: $0 < \theta^* < -1 / a$. Thus, we can maximize Eq. (2) without restrictions on θ.

Based on the results in Kelly (1959), Thorp (1969) shows that the profit in the form of Eq. (1) is concave with respect to θ and has a unique optimum at θ^*. The implication of an existing unique optimum at $\theta^*$is that a smaller leverage factor ($\theta < \theta^*$) leads to a lower long-term profit than is feasible, but also that a *larger* leverage factor ($\theta > \theta^*$) leads to a lower long-term profit than is feasible. In fact, using too large leverage factors in trading may lead to *negative* expected profit per trade (even for trading strategies with positive expected returns), suggesting that leverage can have crucial effect on long-run profit (e.g., Thorp, 1969). The intuition is that a too large leverage factor leads to severe drawdowns in capital that takes too long time to recover from even if the strategy has a positive expected return per trade and the number of trades are very large. Rotando and Thorp (1992) report sizable trading profit when buying and holding S&P 500 contracts with optimal leverage θ^* using the Kelly criterion rebalanced annually.

Despite the promising profit maximizing properties of the Kelly criterion described above, the Kelly criterion is not the only leverage rule suggested for maximizing trading profit among practitioners. Independent of the Kelly criterion, Vince (1990, 2011) suggests an alternative leverage rule for maximizing long-run profit (when trading favorable strategies); the Optimal fraction criterion. This particular leverage rule maximizes the expected value of the logarithm of profit per trade with respect to the position size, f, *relative* to the largest loss of the trading returns, a (not the leverage factor *per se*), as follows:

$$\underset{wrt\ f}{Max} \left\{ E\left[\frac{1}{n}\ln\left(\frac{w_n}{w_0}\right)\right] = E\left[\frac{1}{n}\sum_{t=1}^{n}\ln\left(1+\frac{f}{|a|}x_t\right)\right]\right\} \quad (3)$$

at $f = f^*$.

Anderson and Faff (2004) assess the profitability of a popular trading strategy in five futures markets reinvesting profits using the Optimal fraction criterion. They conclude that leverage (in the form of position size f) plays a more important role for the profitability in investing than previously realized with large differences in profits depending on what position size is applied.

The careful reader may note that from the identify; $\theta = f/|a|$, we have identical objective functions in Eq. (2) and Eq. (3), with identical first order conditions with respect to θ and f, respectively, that should result in identical profit levels. Despite this insight, we note that the Kelly and the Optimal fraction criteria are treated as essentially different leverage rules in the optimal leverage literature (e.g., Gehm, 1983; Balsara, 1992; Vince, 2011) and we recognize an ongoing debate over which leverage rule to use for maximizing the expected profit in trading (e.g., Vince, 2011). This debate may have arisen due to differences in terminology and assumptions. For example, the Optimal fraction criterion typically assumes that returns follow a continuous probability density function suitable for investing applications, while the Kelly criterion is typically suggested for gambling applications with binary outcomes (e.g., Vince, 2011). Furthermore, Thorp (1969) and Rotando and Thorp (1992) somewhat unfortunately denote the Kelly criterion leverage factor, θ, a "fraction of capital" but, as Vince (2011) correctly points out, does not have to be a fraction at all.

Even if both criteria may yield identical profit, we note some value-added information when applying the Optimal fraction criterion. For example, the worst expected loss when trading with leverage is neatly limited to the position size; $(f/|a|)a = -f$. Further, we note that the position size is a fraction by construction: $0 < f < 1$. To see this, we have from the identity $\theta = f/|a|$ that $(0 < \theta < -1\ /\ a) = (0 < f/|a| < -1\ /\ a)$ and, by multiplying throughout with $|a|$, we obtain $0 < f < 1$. Thus, the position size f of the Optimal fraction criterion reveals the largest proportion of wealth the trader risk to lose on any given trade, whereas the leverage factor θ of the Kelly criterion only informs us of the scaling multiple.

We now continue this thesis by relating papers [IV] and [V] to the relevant literature on the profit of leveraged ETPs and on the profit of ORB strategy traders using leverage, starting with the former.

3.3 The profitability of leveraged ETPs and ORB traders using leverage

Leveraged ETPs are built for returning the daily performance of the underlying asset scaled by a fixed leverage factor larger than one. Referred to as embedded leverage when the leverage is built-in and managed within the product, leverage is an important feature of financial instruments as it reduces investors' constraints for outright leverage making it useful for both hedging and increasing investment returns (Frazzini and Pedersen, 2012). The key feature of leveraged ETPs and the main difference to other leveraged products, such as mini-futures, is the rebalancing of the product to ensure that the leverage factor remains constant (Giese, 2010). ETPs with leverage can be attractive for investors because leveraged ETPs should never lose more than 100 % of their value by construction, and are hence not subject to margin requirements as opposed to other products with leverage.

Since leveraged ETPs rebalance their positions daily within the product to maintain a constant leverage factor and since the profit from each trade is reinvested, the capital growth from buying and holding a leveraged ETP is directly related to our definition of capital growth given by Eq. (1). As it turns out, however, investing with leverage give rise to a complex pay-off characteristic and somewhat erratic growth-path of profit by Eq. (1) over time and is not easily foreseeable by the ETP investor. For example, the capital growth from investing in a leveraged ETP using a leverage factor of θ times the daily return of the underlying asset does not necessarily equal θ times the long-term holding return of the underlying asset (e.g., Giese, 2010; Frazzini and Pedersen, 2012). This is basically because of the daily rebalancing frequency of the leverage factor that also separates leveraged ETPs from other products with leverage such as mini-futures or futures.

We note that previous research on the empirical profit of leveraged ETPs such as Avallaneda and Zhang (2009), Cheng and Madhavan (2009) and Frazzini and Pedersen (2012), in general find that leveraged ETPs are, in fact, undesirable for long-term investors. Cheng and Madhavan's study (2009) claims that daily re-leveraging of leveraged ETPs can exacerbate market volatility. Could it be the case that a non-optimal use of leverage, ($\theta \neq \theta^*$) in Eq. (1), is one reason behind the reported unsatisfying profit levels of leveraged ETPs, and, if so, could long-run profits be improved by adjusting the leverage according to optimal leverage rules?

Paper [IV] analyses the profit of ETPs with respect to leverage and, based on the Kelly criterion, derives an optimal leverage factor for maximizing the profit of ETPs equipped with leverage. While leverage can offer certain benefits to investors, the nature of optimal leverage means that the use of leverage cannot improve long-term profitability beyond its optimal level. While Frazzini and Pedersen (2012) and others report that leveraged ETPs underperform, paper [IV] posits that the use of leverage do not undermine investment profitability *per se*, only non-optimal use of leverage (non-optimal in a Kelly criterion context). Contrary to the current literature on ETP profitability, paper [IV] argues that leverage could be beneficial for long-run buy-and-hold investors when an optimal level of leverage relative to their underlying indices is used. Thus, if leveraged ETPs underperform relative their underlying indices it could be because managers and developers systematically over-use leverage beyond its optimal level. By highlighting the existence of an optimal leverage factor for leveraged ETPs could possibly help investors to better understand the complex pay-off characteristic of leveraged ETPs and also improve the construction of leveraged ETPs going forward.

Now turning our attention to the profit of ORB strategy day traders using leverage, there are reasons to believe that day traders in general are prone to use leverage. First, we know that day traders trade for profit, displaying a risk-neutral (or even risk-seeking) behavior (e.g. Statman, 2002; Jordan and Diltz, 2003). Second, we recognize that day traders are likely to use leverage to increase profit, as day trading returns are naturally restricted to relatively small intraday price moves. Third, day traders are relatively few in number – approximately 1% of market participants – but account for a relatively large part of the traded volume in the marketplace, ranging from 20% to 50% depending on the marketplace and the time of measurement (e.g., Barber and Odean, 1999; Barber *et al.*, 2014; Kuo and Lin, 2013).

Paper [V] analyzes the effect on profit when trading the ORB strategy with leverage. To the best of this author's knowledge, the effects of leverage on day trading profit have never been explicitly studied. This can be viewed as a limitation of current studies as day traders should benefit from an optimal leverage rule applicable to day trading - perhaps more than most other traders -

given their proneness toward using leverage and because a high frequency of trades add to the overall capital accumulation when reinvesting profit onto the next trade, as in Eq. (1). Further, assessing the ORB strategy returns and profit with leverage provides, perhaps, a more realistic estimation of the returns and profit of real-life ORB strategy traders. Further, when it comes to applying leverage to any trading strategy, not only when trading the ORB strategy, a trader must decide between at least two supposedly different optimal leverage rules; the Kelly and the Optimal fraction criteria. The difference between the Kelly criterion and the Optimal fraction criterion should therefore be addressed and systematically analyzed.

Based on the Kelly criterion, Paper [V] derives the optimal leverage factor when trading the ORB strategy for maximum profit. By highlighting the existence of an optimal leverage factor in day trading could, besides increasing the profit in trading and help day traders to avoid excessive use of leverage, possibly improve the general understanding of day trading profitability. For example, the profit may be leverage-dependent and the profit levels reported in empirical studies (e.g., Harris and Schultz, 1998, and others) could be from applying too little, optimal, or too large leverage factors. Moreover, by studying the leveraged profit of the ORB strategy complements the empirical profit without leverage reported in papers [I] and [II].

Paper [V] also provides a systematic comparison between the Kelly criterion and Optimal fraction criterion and the possible difference in profit levels. By comparing the profit between these two criteria will hopefully improve our understanding of what leverage rule to prefer when maximizing investment profit. Further, on a methodological note, we recognize that previous studies such as Rotando and Thorp (1992) and Anderson and Faff (2004) make use of all observations in the data when evaluating optimal leverage rules in empirical applications. Consequently, previous studies on optimal leverage rules in investing, both when evaluating the Kelly criterion and the Optimal fraction criterion, are restricted to only in-sample results and consistent with the assumption that investors are *a priori* aware of the returns density function. In actual investing, however, the investor is not *a priori* aware of the returns density function and must rely on forecasting techniques. Thus, forecasting errors related to, for example, estimation errors in small samples and/or non-stationary processes could affect the results.

Finally, to bring more light on the performance of leverage strategies in actual trading, paper [V] investigates the effects on profit from applying optimal leverage also out-of-sample. Being the first paper to apply optimal leverage out-of-sample adds insight into the performance of leverage strategies in actual trading where investors do not know the returns density function.

3.4 Summary of papers [IV] and [V]

Paper [IV]: Optimal Embedded Leverage

This paper posits that it is possible to obtain an optimal leverage factor for ETPs equipped with leverage based on the Kelly criterion. While leverage can offer certain benefits to investors, the nature of optimal leverage means that the use of leverage cannot improve long-term profitability beyond its optimal level. While Frazzini and Pedersen (2012) present evidence that embedded leverage securities such as leveraged ETPs underperform, this paper shows that the use of leverage in fact does not necessarily undermine investment profitability. Thus, if the negative impact of the transaction costs on leveraged ETPs (see Cheng and Madhavan 2009) is excluded, leverage could be beneficial even for buy-and-hold investors when an appropriate level of leverage is used. We confirm that too high leverage can lead to negative profits even with a positive average return of the underlying index, but our study suggests that much more focus should be put on finding and using the optimal level of leverage. If leveraged ETPs underperform relative their underlying indices, it could be because managers and developers systematically over-use leverage beyond its optimal level.

This paper presents an empirical application of investing in three different ETPs with leverage, demonstrating that different ETPs obtain different levels of optimal leverage, which may be even less than one. The study of this paper shows three important features of ETPs for investors: First, the existence of the concave relation between profit and leverage can serve as an important insight for investors as it, in turn, implies the existence of a unique level of leverage that maximizes long-run profitability. Second, leverage should be used for diversified portfolios rather than individual securities and sector portfolios. The reason for doing so is that diversification reduces returns volatility without necessarily reducing the expected returns. Increased returns volatility leads to reduction of the optimal leverage, *ceteris paribus*. Third, from a tactical perspective, it can be beneficial to use lower levels of optimal leverage, even less than one, in volatile markets in order to increase investment profit. In future studies, it would be interesting to apply the optimal leverage by using different volatility forecasting methods.

Paper [V]: Optimal Leverage in Day Trading

This paper analyses the effect of leverage on profit when trading the Opening Range Breakout (ORB) day trading strategy. While papers [I] and [II] assesses ORB strategy profit without leverage, this paper estimates the profit from trading the ORB strategy with optimal leverage based on the Kelly criterion. This paper also clarifies the relation between the Kelly criterion and the Optimal fraction criterion. An empirical application is then provided to demonstrate how leverage can increase trading profit in-sample and out-of-sample. Leverage is recalculated on a daily basis and profit is estimated using a polynomial regression approach.

There are two main contributions of this paper related to the optimal leverage literature. First, providing a systematic comparison between the profits generated by the Kelly criterion and the Optimal fraction criterion can possibly settle the debate over which criterion to use for maximizing profit in trading. Second, being the first paper to apply optimal leverage out-of-sample adds insight into the performance of leverage strategies in actual trading. A minor contribution related to the ORB strategy literature is that the hourly-format-data enables this paper to assess ORB returns when intraday trailing losses are added.

This paper shows theoretically that the Kelly and Optimal fraction criteria produce identical profit when evaluated under the same assumptions. When applied to a long time series of DAX 30 futures, we find that optimal leverage increases the long-run profit substantially when applied in-sample, and that the long-run profit still increases, but is considerably reduced, when applied out-of-sample. Further, we find that the profit from applying optimal leverage out-of-sample is time dependent and actually underperforms the profit of the unleveraged strategy a majority of the time. This finding suggests that forecasting errors can be a problem when applying leverage in actual trading and motivates further research into improving forecasting techniques for optimal leverage rules.

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