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Analyzing the statistical significance and potential impact of abnormal returns caused by a short squeeze

Mémoire recherche réalisé par
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Master's Thesis in Business Engineering

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Abstract

The aim of this master's thesis is to study if a short squeeze event can have a significant long-term impact on the abnormal returns of companies. Due to the extremely short term but exponential price spike during a short squeeze we first establish that these short-term returns are significant. We then look at returns on a longer term to establish whether there are significant abnormal returns using the event case methodology and a generalized rank test developed by Kolari & Pynnonen (2011).

We identified a number of occasions when short squeezes had occurred as defined by IHS Markit[1] *and created an estimation window in each case in order to determine the normal expected returns with three different types of conditionings. Using the GRANK test we searched whether the cumulative abnormal returns during two different event windows (6 days, and 120 days after the event) were significantly different from those during the estimation window.*

It is found that although the initial price spikes are significant, the cumulative abnormal returns in both studies' event windows are not statistically significant. This implies that any short-term returns disappear as time progresses and that the price relationship between investors and affected securities does not change after a short squeeze.

Keywords: *Short squeeze, event case study, abnormal returns*

[1] IHS Markit definition: 3 standard deviation moves versus prior 60 trading days over a period varying between 1 and 3 days, followed by a decrease in shares on loan (over 5 consecutive days)

Abbreviations

CAPM……………………………………………………………Capital Asset Pricing Model

CAR…………………………………………………………..Cumulated Abnormal Returns

GSAR……………………….………….Generalized Standardized Abnormal Returns

GRANK………………………………………………………………Generalized Rank Test

HML…………………………………………………………………………High Minus Low

NYSE…………………………………...............................New York Stock Exchange

OLS…………………………………………………………………...Ordinary Least Squares

SAR………………………………………………………..Standardized Abnormal Returns

SCAR…………………………………....Standardized Cumulative Abnormal Returns

SMB…………………………………………………………………………..Small Minus Big

Contents

1.Introduction

Short selling has been a present and controversial fixture of the stock market since its inception. Legend has it that Napoleon once described short-sellers as “enemies of the state” (Osborne, 2012), American businessman Daniel Drew came up with the creative ditty: “He who sells what isn't his'n, must buy it back or go to pris'n” (Waggoner, 2005), and the Malaysian finance ministry proposed caning as a punishment for abusive shorting in 1995. The first shares ever reportedly sold short were those of the Dutch East India Company in 1609 which created so much havoc that the practice was banned from the Netherlands, but later reinstated within some years. Short selling has been blamed for the great depression crash of 1929 and the more recent crash in 2008.

Today short selling maintains its ambiguous public perception but is also progressively associated with professional, activist investors e.g. Bill Ackman with Herbalife (Cox, 2016), who maintain that short selling is not merely done in order to profit off the loss of others but is a means to correct over-pricing and bring securities closer to their fundamental value (Dechow, Hutton, Meulbroek, & Sloan, 2001) . They also claim that short selling improves the informational efficiency of the market (Saffi & Sigurdsson, 2011) and can expose corporate financial misconduct (Karpoff & Lou, 2010). Academic research has been done that has generally found that short-selling can be a force for good, helping in price-discovery and preventing overpricing. However, in times of crisis, regulators and markets, too often look for someone to blame and short sellers can bear the brunt of this search.

Short selling is a difficult strategy to pull off because in the long run, markets tend to rise (Economist, 2008) and the potential for loss is greater than the potential for success. The maximum a short seller can gain is capped at the price of the share at the moment of sale, however, if the price rises instead of falls there is no maximum level or cap to that rise. When a large number of short sellers attempt to cover their position on a stock, it can drive the price of that stock even higher in a very short period of time. This is a short squeeze.

Although short selling has been extensively researched, the relative rarity of the short squeezing phenomenon has meant that there is less research into the specific long-term consequences of such an event happening. It is our objective to provide additional insights, by identifying whether investors treat and invest differently in securities that have experienced such price shocks as a consequence of a short squeeze. We therefore wished to investigate the following research question: *Are abnormal returns of securities that have undergone a short squeeze significantly different from the returns prior to the happening of the short squeeze event?*

In order to better observe this phenomenon, we turned to event case studies. These types of studies have a long history in the domains of economics and finance. As far as we can ascertain we are the first to apply the case study methodology to the short squeeze phenomenon.

Previous studies have determined that stocks with a high short interest (exactly those most likely to experience short squeezes) show significant and long-term negative abnormal performance (Desai, Ramesh, Thiagarajan, & Balachandran, 2002). The inherent properties of a short squeeze make it so that short interest is drastically reduced, at least for a short period of time after the event. Our initial hypothesis is thus that after a short squeeze, securities show significantly different abnormal returns than prior to the event.

1.1. Limitations

Our study and sample of securities were limited only in scope due to the fact that there is no transparent database for short squeeze events available to the public at large. We contacted IHS Markit and Shortsqueeze.com, both financial services providers, for more information and date concerning securities that had experienced short squeezes. Although the information was available, the price asked for access was not within the means or the purpose of a master's thesis.

All data concerning price, returns, risk-free rates, market-premiums and other input was obtained from Bloomberg terminals in the BSPO library of the Université Catholique de Louvain. Daily data was downloaded alongside corresponding market rates for the concerned securities.

1.2 Outline

This thesis is structured as follows. Section 2 provides the theoretical framework and literature as pertaining to the event case study. Section 3 provides an overview of the current functioning of short squeezes and a review of our studied event. Section 4 applies the framework described in section 2 on the short squeeze event and section 5 concentrates on the findings of our research and the model. Section 6 is used for discussion and recommendations for future studies and section 7 encompasses our concluding remarks.

2.Theoretical Framework

A short squeeze is an event that is unexpected and extremely difficult to predict. IHS Markit recently created a short squeeze composite in order to attempt and predict the next short squeeze before it happens. They search for stocks where short sellers have no choice but to cover their positions by buying back the shares they have borrowed. This type of retreat can often lead to sharp stock price spikes. To observe these types of trades IHS Markit examines stock loan information, calculates at what price loans were made, and determines the in- and out-of-the-money percentage. Next the company looks for concentrations of short sellers near the break-even point, as it is likely these may be the next to cover their positions. Lastly the company searches for news announcements such as earnings announcements, headlines or possible market volatility which have the potential to start off a short squeeze. In order to determine the effects of such an event we turn to the event case study.

2.1 Event Case Study

2.1.1 Assumptions

On the basis of financial data, an economist can measure the impact of a specific event on the value and the returns of a firm. This is possible thanks to the efficient-market hypothesis that states that the effects of an event will be reflected immediately in the security's price (Fama E. F., 1970) . Event studies have been used in many different fields since their inception (the first published study using this technique was in 1933 by James Dolley; where he examines the price effects of stock splits), and can be found in varying domains such as accounting, finance, and law. Examples of events studied include mergers and acquisitions, earnings announcements, issues of new debt or equity, and announcements of macro-economic variables such as the trade deficit (MacKinlay, 1997). A second assumption made in a case event study is that the event is unforeseen. This is necessary so we may use abnormal stock returns as a measure of market reaction to the event. A third assumption for the use of the event case study method, besides the previous and the semi-strong capital market efficiency hypothesis is that there are no other confounding effects which may influence the stock price (Sitthipongpanich, 2011)

2.1.2 Event definition, window & selection

It is recommended to start the event case study by defining the event of interest and to identify the period over which the security prices of the firm(s) involved in this event will be examined; this is also called the event window. In practice the event window is generally defined as larger than the specific period of interest. This is done in order to examine the periods surrounding the event and to capture the price effects due to the event.

Having defined the event, it is subsequently necessary to provide criteria for the selection and subsequent inclusion of a given security in the event case study. Possible restrictions include those imposed by data availability or limitations within particular industries. Subsequent summarization of key characteristics of the studied firms is then generally provided for an overview of the study and to explain certain potential biases in the selection.

2.1.3 Abnormal Returns

It is important to separate the portion of the total returns that is a reaction to the event. A segment of the movement of a stocks' price is a reflection of the overall state of the stock market and needs to be separated in order to better understand the effects caused by the event (Schweitzer, 1989). This is why in the following step the abnormal returns are examined, which by definition are separate from general market movements.

Abnormal returns are observed in order to measure the impact of the studied event. These abnormal returns are defined as the ex post return of the security over the event window minus the normal return of that same window such as shown in the formula below. Where firm *i* and event date τ:

$$AR_{i\tau} = R_{i\tau} - E(R_{i\tau}|X_\tau) \tag{1}$$

$AR_{i\tau}$ is the Abnormal Return, $R_{i\tau}$ the actual return, and $E(R_{i\tau}|X_\tau)$ the normal returns for the period τ. X_τ represents the conditioning for the normal return model of the expected returns.

2.1.4 Expected Returns

The choice of conditioning for the normal return is a key element of the event case study. There are several different types of conditioning that can be used in terms of expected returns. In our paper, we have chosen to examine the 5 principal forms generally used but have opted to focus our calculation efforts on 3 of these forms. All five however are explained below: the mean-adjusted return, the market-adjusted return, the market-model-adjusted return, the CAPM-adjusted return, and the Fama-French three factor model.

The two most commonly chosen conditions are the mean-adjusted return and the market-adjusted return models (Campbell, Lo, & MacKinlay, 1997). The mean-adjusted return model states that the average return of the security over the examined period of time prior to the event should be used as a measure for expected return. It remains constant throughout the period. The second most used choice, the market-adjusted return makes the assumption that there is a stable linear relationship between the market return and the security return, and thus uses the expected market return as conditioning.

The three other forms of conditioning have been used intensively throughout event case study literature and are different by the fact that they incorporate more factors or require more calculation. The market-model-adjusted return for example builds on the actual returns of a reference market. As described in the formula below the market-model-adjusted return represents the normal return which is predicted based on two inputs. These are the typical relationship between a firm's stock and its reference index (α and β) and the actual returns of that market ($R_{m\tau}$). The two variables are estimated using the Ordinary Least Squared (OLS) regression over the estimation period.

$$E(R_{i\tau}) = \alpha_i + \beta_i * E(R_{m\tau}) \quad (2)$$

The CAPM-adjusted return uses the capital asset pricing model to predict the expected return of the stock. As the formula below indicates it uses the risk-free rate added to the market risk premium. The beta factor represents the risk of the stock (i) which implies that a higher risk requires a higher return.

$$E(R_{i\tau}) = R_{f,\tau} + \beta_i * (R_{m\tau} - R_{f,\tau}) \quad (3)$$

The final model we examine is the Fama-French three factor model. It is an extension of the previously explained CAPM-adjusted return, where it adds additional risk factors. These are a factor for size (SMB: Small-minus-Big) and a factor for book-to-market-equity ratio (HML: High-minus-Low) (Fama & French, 1993).

$$E(R_{i\tau}) = R_{f,\tau} + \beta_i * (R_{m\tau} - R_{f,\tau}) + S_i * SMB_\tau + H_i * HML_\tau \quad (4)$$

SMB describes the difference between the average returns of stocks with small market capitalisations and those with large capitalisations. The factor accounts for the spread in returns between small- and large-firms, which is due to the small firm effect as small firms tend to outperform larger ones. HML is also referred to as value premium and accounts for the spread in returns between value stocks (with a high book-to-market ratio) and growth stocks (with a low book-to-market ratio).

2.1.5 Estimation Window

The following step in the event case study process is the selection of an estimation window prior to the event, to provide the information necessary for a normal return. MacKinlay recommends that for an event study using daily data (daily and monthly returns are commonly found in previous literature, but daily is preferred for short-term event studies and monthly for more long-term studies) and the market model (X_τ is the market return), that the market-model parameters can be estimated 120 days prior to the event around which the case study is concentrated. There is however no distinct consensus as to the necessary length of this estimation period and different event case studies use different periods of time. The event period is not considered within this

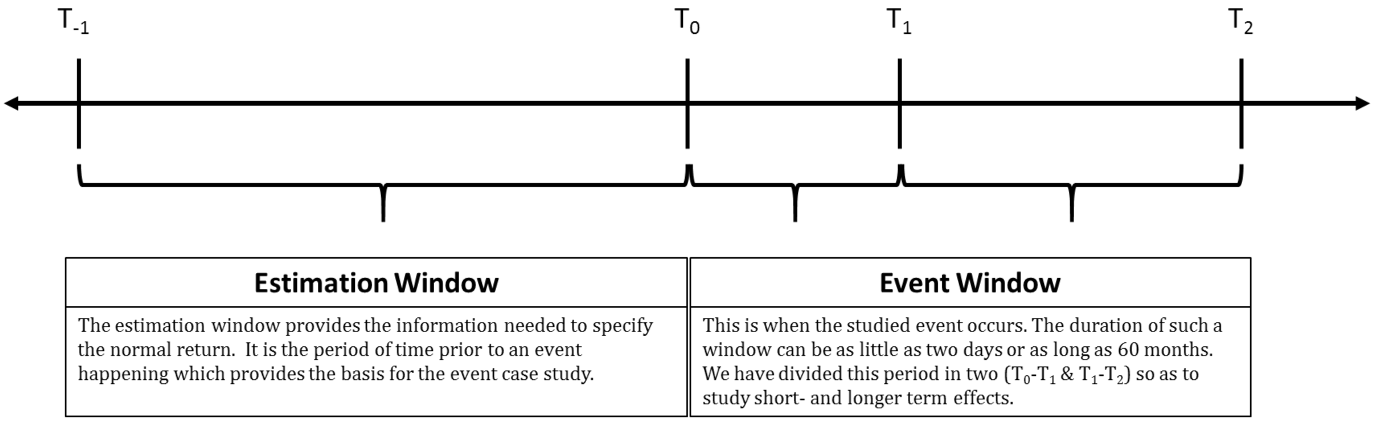


Figure 1: Studied Timeline

period to avoid the event from influencing the normal performance model parameter estimates. Literature has provided examples of event windows being as short as a two-day period (Lummer & McConnell, 1989) or as long as 60 months (Gregory, 1997).

2.1.6. Calculation

The normal performance model's conditioning having been established and an estimation window chosen, then the following step is to calculate the abnormal returns for the studied periods and firms by subtracting the actual returns from the different expected returns as determined by the chosen conditioning.

The hypothesis at this stage remains the null hypothesis. This means that there is no significant difference between the measured periods and that any observed difference is due to a sampling or experimental error (Shuttleworth, 2008). In order to deviate from the null-hypothesis and determine whether there is a statistically relevant change in the abnormal returns due to the event, a combination of parametric (such as a t-statistic test) and non-parametric tests (a sign-, or rank-test) are applied in order to substantiate the results.

A condition for the use and interpretation of t-test results is that the data on which the results are based are normally distributed (Mordkoff, 2016). Brown and Warner (1985) however, report that stocks are not normally distributed. This leads to parametric test potentially yielding misspecified results. However once standardized our data can become normally distributed and is to be used as a base for our non-parametric test.

Following Kolari and Pynnonen we let day t=0 indicate the event day, $t=T_{-1}+1, T_{-1}+2, \ldots, T_0$ are the estimation period before the event day. For all $t=T_0+1, T_0+2, \ldots, T_2$ are situated in the event window. We use $L_1=T_0-T_{-1}$ as the estimation period, $L_2=T_2-T_0$ as the total event window. We have further divided the event window to capture a short- and longer-term view. The combined length of both periods is defined as $L=L_1+L_2$.

Given that AR_{it} denotes the abnormal return of security i on day t, and after having determined the conditioning and factors for the expected return, then standardized abnormal returns are defined as being situated in $T_0 \leq t_1 \leq T_{2-} \tau$, and $1 \leq \tau \leq L_2$.

The t-test results were obtained with the formulas below. First, we found test statistics for single firms in each time point t and with a Null-hypothesis:

$$H_0: AR_{i,t} = 0 \tag{5}$$

$$SAR_{i,t} = \frac{AR_{i,t}}{S_{ARi}} \tag{6}$$

Where S_{ARt} is the standard deviation of the abnormal returns in the estimation window with a length of *n*, and SAR is the standardized abnormal returns.

$${S_{AR}}^2 = \frac{1}{n-2}\sum_{T_{-1}}^{T_0}(AR_{it})^2 \tag{7}$$

We then proceeded to provide the t statistic for the Cumulated Abnormal Returns of each firm. The t statistic and the Null hypothesis are defined as:

$$H_0: CAR_{i,t} = 0 \tag{8}$$

$$SCAR_{i,t} = \frac{CAR_i}{S_{CARi}} \tag{9}$$

Where S_{CARi}

$$S_{CAR}^2 = S_{ARi}^2 * (T_2 - T_1) \tag{10}$$

Following the example of Boehmer et al. (1991) the result of the previous t-test (9) which represents the standardised cumulative abnormal return (SCAR) is re-standardised with the cross-sectional standardised deviation. This is done in order to account for possible event-induced volatility.

$$SCAR_i^* = \frac{SCAR_{i\tau}}{S_{SCAR,\tau}} \tag{11}$$

Where

$$S_{SCAR,\tau} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(SCAR_{i\tau} - \overline{SCAR_\tau})^2} \tag{12}$$

Is the cross-sectional deviation of $SCAR_i$, n is the number of securities in our sample, and:

$$\overline{SCAR_\tau} = \frac{1}{n}\sum_{i=1}^{n} SCAR_{i\tau} \tag{13}$$

Having determined the re-standardized the SCAR, we can now use it in our definition of generalised standardized abnormal returns. The reason we can do this is because the *SCAR** is now a zero mean – and a unit variance random variable. The generalised standardized abnormal return *(GSAR)* is defined as follows:

$$GSAR_{it} = \begin{cases} SCAR_i^*, for\ t_1 + 1 < t < t_1 + \tau \\ SAR_{it,} for\ t = T_0 + 1, \dots, t_1, t_1 + 1 + \tau, \dots, T_2 \end{cases} \quad (14)$$

With *SCAR** and SAR_{it} defined in equations (11 & 6) respectively.

During our event window τ is thus the only time when the abnormal return is equal to the re-standardised SCAR. At all other times the abnormal return is equal to the standardized abnormal return.

We do this because the GSAR during the event window and attributed to the studied event, behaves like any other standardized return under the null-hypothesis, but begins to deviate under the alternative hypothesis. The rank test developed by Kolari and Pynnonen takes advantage this possible deviation under the alternative hypothesis.

The following step is then to proceed with the non-parametric test. We have decided to concentrate our efforts on a generalised rank (GRANK) testing procedure as developed by Kolari & Pynnonen in 2011. Their results with this test outperformed previous rank tests of CARs and was robust to abnormal return serial correlation and event-induced volatility (Kolari & Pynnonen, 2011). Additionally, the GRANK procedure exhibits superior empirical power relative to popular parametric tests.

There are generally two approaches used to test the CAR with ranked abnormal returns. The first includes defining multi-day returns based on the number of days used to calculate the CAR and subsequently testing ranked multi day returns (Corrado, 1989). The second and more common method is to cumulate daily ranks of abnormal returns within the CAR-period (Cowan, 1992) into a single cumulative event day. It is this second method that Kolari and Pynnonen chose to work with.

A negative aspect of the first method is that it immediately limits the number of observations. Taking a (-5,+5) CAR period limits the number of observations to one eleventh when compared to the observations in the original one-day period sample. Due to a reduction of samples, the result of such a test is also significantly weakened. The second method is also not without negative aspects. Its results are significantly weakened if the abnormal return caused by the studied event occurs on a random single day in the event window. When using cumulated ranks, the cumulation may result in no longer being able to detect the abnormal returns. This is because returns are transformed into rank numbers and no longer reflect the absolute size of the returns but their relative rank to others in the sample. The GRANK test proposed by Kolari & Pynnonen sought to establish a new method to test significance without falling in the same pitfalls as the methods mentioned above.

At the start of the non-parametric test we must redefine our event window where the CAR period, length of τ, is made into a single observation with *t=0* which is from now on referred to as the *cumulative event day*. This implies that we are now dealing with L1+1 observations. L1 being the days in the estimation period and the additional observation being the cumulative event day.

We start by defining the *demeaned standardized abnormal ranks* of the GSAR which is:

$$U_{it} = \frac{Rank(GSAR_{it})}{T+1} - 1/2 \tag{15}$$

Again, we follow the methodology established by Kolari and Pynnonen in order to move forward with our calculations. For i=1,…,n and t∈T = $\{T_{-1}+1,\ldots,T_0,0\}$ which incorporates all of our observations. Broken down this means that the estimation period is $\{T_{-1}+1,\ldots,T_0\}$ and the cumulative event day is situated at t=0. The number of observations will thus always be one plus the number of observations in the estimation period. What Rank($GSAR_{it}$) does, is replace standardised returns with their respective rank numbers going from 1 to T. T being equal to L_1+1 or T_0-T_{-1}+1 which is equal to the number of observations. Given that U_{it} denotes the demeaned standardized abnormal rank of the cumulative abnormal return the expected value under the null-hypothesis should be zero for all i=1,…,n (Kolari & Pynnonen, 2011).

Kolari & Pynnonen then defined the formula for the t-ratio which can test for significance of our abnormal returns. With the null hypothesis being:

$$H_0\colon \mu_\tau = 0 \tag{16}$$

With $\mu_\tau = E[CAR_\tau]$, or the expected cumulative abnormal returns over the period τ, our GRANK-T is defined as:

$$t_{GRANK} = Z\left(\frac{T-2}{T-1-Z^2}\right)^{1/2} \qquad (17)$$

Where

$$Z = \frac{\bar{U}_0}{S_{\bar{U}}} \qquad (18)$$

With

$$S_{\bar{U}} = \sqrt{\frac{1}{T}\sum_{t\in T}\frac{n_t}{n}\overline{U_t^2}} \qquad (19)$$

$$\bar{U}_t = \frac{1}{n_t}\sum_{i=1}^{n_t} U_{it} \qquad (20)$$

n_t is the number of valid $GSAR_{it}$ observations available at time t; T is the number of observations and $\bar{U}_0$ is the mean $\bar{U}_t$ at t=0, and n is the number of securities in our observed portfolio.

When studying the asymptotic distribution of the t_{GRANK}, Kolari and Pynnonen denoted a convergence towards the Student t-distribution with T-2 degrees of freedom. When analysing the results from our calculations it is thus the student distribution table (Appendix 1) which we will use as a testing stone to search for statistical significance.

2.2. Event studies with daily or monthly returns

Past literature shows that many different measurement intervals have been used in event case studies in order to compute returns. The most used are monthly-, weekly-, and daily intervals. However, as demonstrated by MacKinlay (2007), there is a significant decrease in power going from a daily data interval to a monthly interval. He uses a sample of fifty securities to demonstrate that the power to reject the null-hypothesis of a 5% t-test went from 0.94 to 0.35 and 0.12 when using weekly and monthly data respectively.

A number of concerns may however arise due to particularities related to the characteristics of daily stock return data which may affect event study methodologies (Brown & Warner, 1985). Daily data departs from more from normality than do monthly data, however as we concentrate our efforts on non-parametric tests, this should not hinder our efforts.

A second aspect concerns the variance of the data samples. This variance is extremely important for tests of statistical significance. The first issue is related to the time-series properties of daily data. Because of non-synchronous trading it is possible that daily excess returns show serial dependence, which may bias the results. A second issue is the stationarity of daily variances. Evidence in earlier literature (Patell & Wolfson, 1979) demonstrates that the variance in stock returns increases for the days immediately around announcements of major events, such as earnings announcements that could potentially trigger a short squeeze.

Nevertheless, considering both the positive and negative aspects of both daily- and monthly data observations, we decided to continue with daily observations in our study due to added robustness and in order to better study the short-term effects possibly linked to the suddenness and short-term aspects of short squeezes.

2.3 Ordinary Least Square

OLS is a generalised linear modelling technique used to model a single response variable all the while minimizing the sum of the squares of the differences between the observed responses. This technique is used in order to determine the α and β variables of the market-model-adjusted return. The differences between the observed responses are also called the error terms, by using ordinary least squares we minimise the quantity of errors in our estimation of the expected return and also link the returns closer to a general market return. For each studied security, the corresponding market index of the country where the firm is established is used.

2.4 Parametric & Non-Parametric tests

Both types of tests are used to measure the significance of obtained results. The major difference between the two are conditions when they can- or cannot be used. Literally, parametric tests are those that make assumptions about the “parameters” of the population distributions from which the data is drawn. A non-parametric, unsurprisingly makes no such assumptions. For example, a parametric test such as a Student t-test and its results rest on the assumptions that there is a normal distribution of variables without which its results would not represent accurate findings. A non-parametric makes no assumptions about such distribution. This is especially relevant in our study as stock prices are not normally distributed.

However due to the structure of the event case study test developed by Kolari and Pynnonen (2011) there are certain elements which can be analyzed using parametric techniques. For example, conditional on the market return over the event window, the abnormal returns will be normally distributed with a zero-conditional mean. This property of event window sampled abnormal returns is used and built on in the further development of the non-parametric test which leads to the aggregation of abnormal returns as seen in equation (8).

Another significant difference of the rank test used in this event case study is that it does not focus its efforts on median values. Classic non-parametric tests, in contrast to parametric-tests perform their calculations using medians instead of averages. In the context of an event case study examining abnormal returns, medians would be of little use to us. If we were to use medians, then the elevated abnormal returns cause by the event would be outliers and would not be correctly taken into consideration. More specifically our non-parametric test analyses the differences in the population mean rank of the studied observations.

3.Event Review

Short squeezes are seen as an object of controversy, and are sometimes treated as an even more dangerous aspect of the already risky trading practice of shorting stocks. In this review, we will go over the functioning of the short mechanism, the indicators that express the risk that an investor is exposed to during the short, and the potential factors leading to a short squeeze.

3.1 Shorting a stock

When investors believe that a security will rise in price they can buy the security now and wait for the price to rise, then sell it for a profit. In this circumstance, they would be "long" on a certain security. However, if they believe a security will do badly it is also possible to make a profit off that circumstance. This is what short sellers do.

There are several variations of short selling but the core principle is that a market actor proceeds to sell an asset they do not currently own at the time of sale. The security is on loan from a third party. The borrower will look to re-purchase an identical asset at a later date so as to return the borrowed assets and close their position (Schol, McNulty, & Jacobs, 2010).

This practice is a well-established market activity making up 24% of New York Stock Exchange and 31% of Nasdaq volume in 2005 (Diether, Lee, & Werner, 2009). Looking back to 1984, only 9% of the total trading volume on the NYSE came from short selling, of which 80% of the positions were taken by specialists (Brent, Morse, & Stice, 1990). It is clear short selling has experienced significant growth over those 20 years.

It is true that some literature supports the concerns of regulatory instances that short selling contributes to market instability and may veer securities too far away from their true value (Henry & Koski, 2010) but there are a host of others that argue the opposite view. There are several recognized positive effects of short selling. Firstly, they provide market liquidity by shorting into up markets and reducing short positions in down markets (Woolridge & Dickinson, 1994) Secondly short sellers can also act as a reality check on investors' unrealistic expectations by selling securities and sharing their opinions in the midst of otherwise over-enthusiastic responses. It has been shown that restrictions on short selling also harm the process of price discovery. Restrictions constrain short sellers but also buyers who do not share the bearish views of short sellers (Brenner & Subrahmanyam, 2008) and simultaneously wish to limit their risk by buying put options from these now-constrained short sellers. Restrictions on short selling therefore reduce transactions and potentially increase liquidity risk due to an uncertain future volume of transactions.

It has been demonstrated in the past that short sellers are not simply vultures praying off the losses of others, and are in general valued by the markets. This does not however mean it is easy for short sellers to make money. A short seller only makes money when closing their position. By selling in the first place they may depress stock prices, but profit only follows by buying high and closing low. If the buying and selling of securities have a symmetric impact on prices, then prices will rise to their original levels as the short seller closes their position. Instead of a profit, there will be losses due to trading and borrowing costs.

3.1.1. Stock lending & naked short selling

In order for a short seller to sell something they do not own in the first place, they must first borrow a security from a third party. If they sell a security without borrowing, or arranging to borrow the underlying asset, this is called "naked short-selling" and is increasingly restricted across the global financial markets.

Thus, even if, in the past, many governments and markets have imposed restrictions on short-selling and were considering lifting these restrictions, such activity could not take place if securities borrowing and lending were not facilitated. Currently, when borrowing a security, short sellers must post collateral and pay a loan fee until they close their position. On top of the normal risks a trader faces (such as margin calls and regulatory changes), short sellers also face the risk of loan recalls and the risk of changing loan fees. Extant literature has come to the conclusion that as short selling grow costlier, the less short sellers are likely to trade and as a result prices could be biased and tend to be less efficient (Lamont & Thaler, 2003).

Typically, in order to borrow a stock, an institutional investor would request such a procedure from their broker who locates the security in its own inventory or in the accounts of customers who allow their securities to be lent out for a fee. Companies that lend out stocks are typically large insurance companies, pension funds or index funds, who have long-term visions on their holdings and generate small risk free returns by doing this (Duffie, Gârleanu, & Heje Pedersen, 2002). Once located, and via the broker, the borrower would typically put up 102% of the market value as cash collateral (105% for international securities). Occasionally other securities can be used as collateral instead of cash but this represents a significant minority of such loans. Previous analysis suggests only 1% of the stocks on loan worked in such a fashion (Geczy, Musto, & Reed, 2002).

Lending agreements are typically on an open or continuing basis which means that they are renewed each day with an adjustment in the collateral depending on the change in market value of the borrowed security. The lender may choose to opt out of the lending agreement by issuing a recall notice which implies that the borrower must return the stock or face SEC (in the United States,) sanctions and severe reputational loss. The borrower will typically then return the stock or borrow the security from another lender. If the borrower or broker cannot locate another security to borrow they may be forced to buy the security outright. This is when a short squeeze may potentially occur. If the borrower fails to return the security in standard settlement time, the lender may use the collateral to buy the security themselves at the going market prices. The borrower however, remains responsible for any additional costs the lender faces when repurchasing the security.

3.2. Short interest

Short interest is a ratio for shares sold short in relation to the total number of shares outstanding. Over the past decades, researchers have not reached a consensus as to the precise relationship between short interest and stock performance. This has given rise to three different views on the matter supported by contrasting empirical findings (Schindler, 2015).

3.2.1 Original view: No Relationship

The oldest empirical studies and opinion surrounding short interest and stock performance hold that there is no significant relationship between the two studied factors. Using multiple regression analyses in 1968, Mayor was the first to come to this conclusion (Mayor, 1968). He found that short sellers that traded using short interest information could perform no better than a simple chance model. Any potential abnormal results could then be attributed to the random walk properties of the market which states that a markets' past performance gives no indication of future price movements and returns and that events cannot be predicted so any abnormal returns are pure chance.

Building on this previous analysis it was then found that short interest could not serve as a predictor of future stock performance and could not be linked to future stock performance (Hurtado-Sanchez, 1978). Other followers of this school of thought found no significant relationship between changes in the levels of short interest and monthly stock returns using a simple linear regression model (Woolridge & Dickinson, 1994). These last researchers also reported that short interest rises along with market price and short sellers are unable to make abnormal profits at the expense of less informed traders.

3.2.2 Contrarian view: The Bulls

The second opinion on the relationship between short interest and stock returns states that short interest predicts future demand due to necessary future position closing. This would mean that a high level of short interest is a bullish signal. This opinion is often referred to as "wall street wisdom" (Epstein, 1995). All opened short positions must be closed at a certain point in the future. This may at a certain point lead to a short squeeze and create sudden price spikes. These spikes create additional pressure on short sellers to cover their positions and thus to purchase even more shares. By analyzing short interest ratios (a ratio comparing the short interest to the average volume of shares traded in a single day, thus indicating how long it would take to cover all the short positions) and market prices, researchers found a significantly positive relationship (Hanna, 1976). Their results showed that a model that interpreted high short interest ratios as bullish signals would outperform-, and generate more returns than- a chance model.

3.2.3 Third view: The Bears

The third viewpoint on the relationship between short interest and stock returns starts from the assumption that a high short interest is a strong bearish signal, and thus indicating a pessimistic viewpoint from investors surrounding the concerned security (Aksu & Gunay, 1995). This last view is currently the dominant one and has been significantly developed over the past twenty years. The reasoning behind this last view goes as follows: because short sellers bear high amounts of risk for capped possible returns (when compared to buying stocks outright), Woolridge & Dickinson (1994) say, that we can conclude that most of the short sellers are professional investors. These types of investors are assumed to possess better knowledge than a random individual. A high level of short interest would therefore imply that not all negative information has been brought into the stock price which is seemingly overvalued (Irvine & Venkataraman, 2006). Therefore, these investors are able to identify securities which may underperform in the future. Irvine & Venkataraman developed a model which showed that highly-shorted portfolios were uniquely subject to short-squeeze risk. Their model however, also showed that the level of short interest is significantly related to the probability of a high subsequent positive return, a proxy for short squeeze risk.

Many academics have researched the relationship of our two variables and come to the "bears'" conclusion of a negative relationship between the two. In the past, a negative relationship was found between short interest and the returns of the S&P 500 (Kerrigan, 1974). Other academics analyzed the abnormal returns of stocks between January 1973 until June 1979 and were able to reciprocate that negative relationship (Figlewski, 1981). A third study, also comparing stocks with high short interest and S&P 500, found that the highly-shorted stocks strongly underperformed over a one month period (Choie & Hwang, 1994).

More recently researchers have focused their efforts on finding additional variables which may impact the relationship between short interest and abnormal returns. It was for example found that short sellers have a tendency to sell companies short with low fundamental to market values (Dechow, Hutton, Meulbroek, & Sloan, 2001). Once these ratios veer the opposite way, the same short sellers typically close their short positions. The authors' paper also demonstrated a negative relationship between stock returns and short interest. Others added a time component to their research and analysis of negative returns. It was found there that the relationship between short interest and negative stock returns persists up to 12 months after the release of the short interest data (Desai, Ramesh, Thiagarajan, & Balachandran, 2002).

Of particular note in our research into short squeezes is recent work using daily short interest data (previously unavailable in a daily format, being only release bi-mensually by various stock exchanges) that value-weighted portfolios of highly shorted stocks do not significantly underperform the market, using intercepts from three-factor time series regressions (Asquith, Pathak, & Ritter, 2005) It should be mentioned that the intercepts from this particular regression were positive, but also statistically not significant. Their magnitude however, decreased as short selling intensified. Further research argues that such positive abnormal returns may be caused by short squeezes (Au, Doukas, & Onayev, 2008). This same research indicates that small and less liquid securities with high levels of short interest are more likely to experience large positive abnormal returns in the short term, makes the attribution of such abnormal returns to short squeezes more plausible.

3.2.4 Overview

Our literature review surrounding short interest provided many different views on the matter as is evident from the sections above. We wanted to add to this breadth of research with our current investigation. All the securities we examine had by definition high short interests. An event such as short squeeze which (at least for a short time) impacts the short interest could further strengthen or diminish one of the three views.

3.3 Short Squeeze

Thus far, we have examined the ecosystem in which short squeezes can potentially occur. To illustrate the rarity of the phenomenon we use the IHS Markit short squeeze composite system. The financial services provider analyses over 30,000 listed stocks spanning the Americas, Europe, and Asia. They then analyze different decile groups, with the first category (D1) being the most likely to experience a short squeeze and the last (D10) showing the least likelihood to experience such a phenomenon. Within their first decile, over a three-year period, only 1.67% of this highly prone category shorted. In absolute numbers this means that only this phenomenon. Over the whole universe of observed securities, 0.94% on average showed signs of a short squeeze.

As previously stated, stocks with a high short interest are those most at risk to experience a short squeeze. It is evident that if no shares are sold short then it is not possible for short sellers to feel the necessary pressure to cover their positions if prices start to rise. Both the bearish and bullish views on short interest provide explanations for why a highly-shorted security may all of a sudden rise in price. Given that the bulls believe short interest demonstrates future demand, there is theoretically a certain level, or breaking point where all these short sellers rush to cover their short positions (for fear that others do this before them) and in their haste, create the event they incidentally fear: a short squeeze.

The reasoning behind the bears' thinking is somewhat less straightforward as they see an inverse relationship between short interest and stock prices. Short squeezes would only occur in this scenario if investors are wrong-footed and proceed to rush to cover their potential losses. An investor with a bearish view on short interest believes that a company is underperforming but that this underperformance is not fully reflected in the security's price. If, however news comes out about a company that indicates the situation is not as bad as previously thought these short investors could theoretically face unlimited losses as there is no cap on the heights to which a stock price may rise.

It is therefore not unsurprising to see short sellers rush to close their positions before the damage is done, unknowingly pushing the price of the concerned securities even higher. Had short sellers not all closed their positions the damage could have been limited but we are here faced with a type of prisoner's dilemma applied on a macro-economic scale.

There are several kinds of announcements that could trigger a rush to cover short positions. Typically, announcements, or even rumors of merger or acquisition activity can make short sellers twitchy. Better than expected earnings announcements or earnings sentiment articles which capture the expectations of future performance could also trigger a rush to sell. Reports about trading activity, such as large incoming orders, index rebalances or stock buybacks can create a perilous situation for short sellers. Operational news such as approval of important patents or a successful debt restructuring can set off a rush to cover positions, hopefully before anyone else…

Much rarer nowadays, is a short squeeze triggered by a market corner. This implies that one strategic buyer exerts enough control over the supply of a certain security or commodity determine how much is available. If the supply were suddenly constrained, all short sellers who need to close their positions in the future would rush to cover rather than risk having to buy later at a much higher price. This has happened in the past with the silver and copper markets and more recently in 2008 with Volkswagen shares. This type of short squeeze is extremely rare nowadays as obtaining such a control over a certain market is legally impossible or in a grey area.

4. Short Squeeze Event Case Study

Having covered the theoretical framework of an event case study and the extant literature surrounding a short squeeze event, the next step in this paper is the application of the theory to a set of real-world examples.

4.1 Event definition, window & selection

We have used the definition of financial services & information provider IHS Markit to define the presence of a short squeeze event. The conditions they require for a squeeze include a sudden spike in price (3 standard deviation move versus prior 60 trading days over a period varying between 1 and 3 days), followed by a decrease in shares on loan (over 5 consecutive days) (IHS Markit, 2015). As a proxy for shares on loan it is technically possible to use the short interest ratio which is defined as the number of shares sold short to the total number of shares in the market. If this ratio were to reach a peak and subsequently diminish, this could also indicate that a short squeeze was occurring (Beneish, Lee, & Nichols, 2014).

Difficulties arise in obtaining pertinent data for the historical quantity of shares on loan as this information stems from brokers and is often proprietary or available only upon paying fees to financial services providers such as IHS Markit or Euroclear. Information on short interest is also subject to restrictions. Most of international stock exchanges do not provide this information, and American stock exchanges such as the NASDAQ and the NYSE report this information twice a month as required by the Financial Industry Regulatory Authority (FINRA, 2017).

Therefore, we focused on the price aspect of the IHS Markit definition and relied on a number of financial reporting sources to identify a host of short squeeze events. By scouring reports of financial services providers and news reporting sources we were able to identify eleven sample instances of securities that had undergone a short squeeze in the past 10 years.

As recommended by event case study literature we chose to make our event window start (T_0) one day prior to the start of the sudden price increase that characterizes our short squeeze event. In order to better understand and distinguish the possible abnormal returns, we then further divided the event window in two. A short - term window going from T_0 to T_1 lasting 6 trading days and a second window going from

T_0 to T_2 lasting 120 days. The reason for the length of this second period is to mirror the estimation period about which more is discussed further in this paper.

An overview of the studied firms that experienced a short squeeze and of which the returns were examined in depth is provided in below table:

Security Name	Date of Short Squeeze	Sector	Current Market Cap. (B EUR)
BankAtlantic Corp.	01/11/2011	Consumer Services	0.735
Chesapeake Energy Corp	07/03/2016	Energy	5.914
Cliffs Natural Resources Inc	07/03/2016	Materials	1.853
EnteroMedics Inc	(04-08)/01/2017	Health Care Equipment	0.032
EP Energy Corp	07/03/2016	Energy	1.135
JC Penney	(24-27)/02/2014	Retailing	1.633
Nokia OYJ	03/09/2013	Technology	32.915
Quidel Corp	26/10/2011	Health Care Equipment	0.826
Rexx Energy Corp	07/03/2016	Energy	40.600
Tesla Motors Inc.	08/05/2013	Automobiles	53.072
Volkswagen AG	(26-28)/10/2008	Automobiles	73.162

Table 1 : Overview of studied securities that have experienced a short squeeze. The returns of these studies were analysed in our tests.

Once we had identified a potential short squeeze from a news outlet or financial report we tested IHS Markit's price criterium to confirm that a short squeeze had happened and for the concerned security to be added to our consideration. The chosen securities are for 81% based in the united states. The two European securities (Nokia and Volkswagen) also have equity floating in the United States but we chose to concentrate our efforts on their main equity. Since markets are efficient any effects on one listing will also impact the other. The companies come from a multitude of industries as our theory indicates that a short squeeze can happen to any company and is not restricted to certain sectors.

4.2 Actual & Expected returns

In order to calculate abnormal returns, we obtained the actual returns of each of the concerned securities from Bloomberg. In our theoretical explication of the event case study we went over the 5 main different types of conditioning for the expected returns *E(R).* We have decided to concentrate our efforts on 3 different types (the mean-adjusted return, the market-adjusted return, and the CAPM-adjusted return).

Despite extensive case study literature, one of the recurring feature throughout all research is the use of a number of alternative techniques to estimate expected returns (Cable & Holland, 1999). Efforts have been made to propose an objective framework for the testing and selection of the appropriate conditioning used to determine the "normal" return. Cable & Holland researched the different methods of normal return estimations and came to the conclusion that simpler, non-regression models (market- and mean-adjusted return models) were more accurate than more complicated models.

They did note however, that no single model was correct all the time. It is therefore still useful to use a number of these types of models in order to cover several possibilities of results. They concluded that most models currently available are at best, crude instruments with low explanatory (which also implies predictive-) power of equations. However, given that for now these are the most efficient and straightforward tools at our disposal for the event study, and those closest to reality, we will maintain their use.

4.3 Estimation Window

As suggested by MacKinlay we decided to use an estimation period of 120 days prior to the event window. This length of 120 days is mirrored to the end of the event window and is a key element of properly analysing the statistical significance of the returns after the event.

5. Data & Results

5.1 Standardized Abnormal Returns

Because our abnormal returns within the event window are normally distributed as stated by MacKinlay et al. (2007), the first thing we examined were the standardized abnormal returns on the event day(s) of the short squeeze. Using formula (6) we found the following values for our standardized abnormal returns:

Security	BankAtlantic Corp.	Chesapeake Energy Corp	Cliffs Natural Resources Inc
SAR (Mean Adjusted Returns)	23.662	3.387	2.755
SAR (Market Adjusted Returns)	23.525	3.333	2.738
SAR (CAPM Adjusted Returns)	23.529	3.332	2.738

Security	EnteroMedics Inc	EP Energy Corp	JC Penney
SAR (Mean Adjusted Returns)	10.011	9.661	5.853
SAR (Market Adjusted Returns)	9.866	9.571	5.648
SAR (CAPM Adjusted Returns)	9.866	9.569	5.647

Security	Nokia OYJ	Quidel Corp	Rexx Energy Corp
SAR (Mean Adjusted Returns)	14.523	5.245	4.987
SAR (Market Adjusted Returns)	14.559	5.303	4.944
SAR (CAPM Adjusted Returns)	14.561	5.304	4.944

Security	Tesla Motors Inc.	Volkswagen AG
SAR (Mean Adjusted Returns)	7.982	25.574
SAR (Market Adjusted Returns)	8.045	25.599
SAR (CAPM Adjusted Returns)	8.050	25.601

Table 2: SAR results. If the short squeeze event occurred over several days we used the highest SAR-value over the effect days in this table. The effects over the full days is studied later on using cumulated abnormal returns over longer periods of time.

Because these abnormal returns are distributed normally we can use the t student distribution table in order to determine the significance of our t-test results (appendix 1). Considering the following null-hypothesis as defined in equation (5)

$$H_0: AR_{i,t} = 0$$

For a confidence level of 95%, and thus with a P-value<0.05 we see that the standardized abnormal returns show that the short squeeze has a significant effect on value of the securities on the day of the short squeeze event itself (our values are all larger than the required 1.96). We can safely reject H_0 at the hand of these results. There is also, as expected very little difference between the value of our results when applying different forms of conditioning for the expected return.

5.2 Standardized Cumulative Abnormal Returns

Following the methodology explained in the case event study of Kolari and Pynnonen we proceeded to determine the standalone value of standardized cumulative abnormal returns. We did this for both T_0-T_1 (as indicated by the 1 in the results) and T_0-T_2 (as indicated by the 2 in the results) in order to better understand and differentiate the short term and long term effects. Using formula (9) we found the following values for our SCAR values:

Security	BankAtlantic Corp.	Chesapeake Energy Corp	Cliffs Natural Resources Inc
SCAR 1 (Mean Adjusted Returns)	8.917	2.089	-0.561
SCAR 2 (Mean Adjusted Returns)	3.638	1.598	1.778
SCAR 1 (Market Adjusted Returns)	8.715	1.958	-0.609
SCAR 2 (Market Adjusted Returns)	2.827	1.027	1.559
SCAR 1 (CAPM Adjusted Returns)	8.711	1.950	-0.613
SCAR 2 (CAPM Adjusted Returns)	2.821	0.989	1.542

Security	EnteroMedics Inc	EP Energy Corp	JC Penney
SCAR 1 (Mean Adjusted Returns)	11.801	6.076	4.929
SCAR 2 (Mean Adjusted Returns)	2.832	2.587	2.936
SCAR 1 (Market Adjusted Returns)	11.505	5.891	4.517
SCAR 2 (Market Adjusted Returns)	1.888	1.815	1.310
SCAR 1 (CAPM Adjusted Returns)	11.501	5.880	4.511
SCAR 2 (CAPM Adjusted Returns)	1.879	1.775	1.293

Security	Nokia OYJ	Quidel Corp	Rexx Energy Corp
SCAR 1 (Mean Adjusted Returns)	7.066	0.745	2.754
SCAR 2 (Mean Adjusted Returns)	2.315	-0.302	0.670
SCAR 1 (Market Adjusted Returns)	7.143	0.881	2.650
SCAR 2 (Market Adjusted Returns)	2.673	0.319	0.216
SCAR 1 (CAPM Adjusted Returns)	7.126	0.877	2.642
SCAR 2 (CAPM Adjusted Returns)	2.579	0.302	0.185

Security	Tesla Motors Inc.	Volkswagen AG
SCAR 1 (Mean Adjusted Returns)	5.931	13.542
SCAR 2 (Mean Adjusted Returns)	1.726	1.491
SCAR 1 (Market Adjusted Returns)	6.254	13.643
SCAR 2 (Market Adjusted Returns)	3.520	2.007
SCAR 1 (CAPM Adjusted Returns)	6.248	13.644
SCAR 2 (CAPM Adjusted Returns)	3.484	2.009

Table 3: SCAR results

Because these abnormal returns are distributed normally we can use the t student distribution table in order to determine the significance of our t-test results (appendix 1). Considering the following null-hypothesis as defined in equation (8)

$$H_0: CAR_{i,t} = 0$$

We observe the first cracks in our initial hypothesis as the results indicate that we can reject the null-hypothesis in some cases, but certainly not all. We also note differences in the results of our different event windows. The SCARs in our T_0-T_2 interval are all lower than in the first interval indicating that the initial price spike resulting in strong abnormal returns as seen in section 5.1 are being relegated to obscurity as time progresses.

5.3 Cross-Sectional Re-Standardization

Having established a measure for the standardized cumulative abnormal returns, Kolari & Pynnonen proceed to re-standardize this measure to account for possible event-induced volatility. They do this by standardizing the SCARs using formula (11) with the cross-sectional standard deviation as seen in (12) (Kolari & Pynnonen, 2011).

Event Windows	$T_0 - T_1$	$T_0 - T_2$
Mean Adjusted Return		
$\overline{SCAR_\tau}$	5.7536	1.9334
$S_{SCAR,\tau}$	4.4403	1.1073
Market Adjusted Return		
$\overline{SCAR_\tau}$	5.6861	1.7419
$S_{SCAR,\tau}$	4.4275	1.0193
CAPM Adjusted Return		
$\overline{SCAR_\tau}$	5.6798	1.7144
$S_{SCAR,\tau}$	4.4287	1.0142

Table 4: Cross-standardized values. The results of these calculations take into account the effects from all 11 securities that have experienced a short squeeze

Using data found in the above table were able to determine the appropriate re-standardized SCAR* for each security in both event windows. The results of these calculations, in both event windows, are to be found in appendix 2.

5.4 Generalized Rank Test

Having determined all previous figures, we were able to determine the generalized standardized abnormal returns (GSAR) for the appropriate time windows. Outside of the event window we used SAR, inside the event window the value for SCAR* as described in formula (14). The values for GSAR were then ranked relatively to the other values in the observed period (1 being the highest rank, and the total number of observations T, being the lowest rank).

Security	BankAtlantic Corp.	Chesapeake Energy Corp	Cliffs Natural Resources Inc
tGRANK 1 (Mean Adjusted Returns)	-0.009732458881	0.000000000000	-0.001269260354
tGRANK 2 (Mean Adjusted Returns)	-0.009732020591	0.000000000000	-0.001263470963
tGRANK 1 (Market Adjusted Returns)	0.000000000000	0.000000000000	-0.000744072904
tGRANK 2 (Market Adjusted Returns)	0.000000000000	0.000000000000	-0.000707194251
tGRANK 1 (CAPM Adjusted Returns)	-0.009732458881	0.000000000000	-0.000744072904
tGRANK 2 (CAPM Adjusted Returns)	-0.009732020591	0.000000000000	-0.000707194251

Security	EnteroMedics Inc	EP Energy Corp	JC Penney
tGRANK 1 (Mean Adjusted Returns)	0.000000000000	-0.005289128537	0.000000000000
tGRANK 2 (Mean Adjusted Returns)	0.000000000000	-0.005310788695	0.000000000000
tGRANK 1 (Market Adjusted Returns)	0.000000000000	-0.005289128537	0.000000000000
tGRANK 2 (Market Adjusted Returns)	0.000000000000	-0.005300286648	0.000000000000
tGRANK 1 (CAPM Adjusted Returns)	0.000000000000	-0.005289128537	0.000000000000
tGRANK 2 (CAPM Adjusted Returns)	0.000000000000	-0.005300286648	0.000000000000

Security	Nokia OYJ	Quidel Corp	Rexx Energy Corp
tGRANK 1 (Mean Adjusted Returns)	-0.007885369225	-0.002135643418	-0.003614131911
tGRANK 2 (Mean Adjusted Returns)	-0.007885369225	-0.002075976366	-0.003614131911
tGRANK 1 (Market Adjusted Returns)	-0.010473374798	-0.002125750525	-0.016295681272
tGRANK 2 (Market Adjusted Returns)	-0.010618463799	-0.002135581225	-0.016669252488
tGRANK 1 (CAPM Adjusted Returns)	-0.010444854059	-0.002125750525	-0.016295681272
tGRANK 2 (CAPM Adjusted Returns)	-0.010618463799	-0.002138259760	-0.016696537591

Security	Tesla Motors Inc.	Volkswagen AG
tGRANK 1 (Mean Adjusted Returns)	0.000000000000	0.000000000000
tGRANK 2 (Mean Adjusted Returns)	0.000000000000	0.000000000000
tGRANK 1 (Market Adjusted Returns)	0.000000000000	0.047980581202
tGRANK 2 (Market Adjusted Returns)	0.000000000000	0.047981561584
tGRANK 1 (CAPM Adjusted Returns)	0.000000000000	0.000000000000
tGRANK 2 (CAPM Adjusted Returns)	0.000000000000	0.000000000000

Table 5: t_{GRANK} test results. In order to for these to be significant, the absolute value of the results need to be larger than 1.96 when following the t Student distribution. This is clearly not the case.

Using formula (15) we were able to calculate the demeaned standardized abnormal ranks which forms the basis of our t_{GRANK} formula. Given the null hypothesis as previously defined in equation (16)

$$H_0: \mu_\tau = 0$$

Upon seeing the results, it became overwhelmingly clear that we would not be rejecting the null hypothesis. The generalized rank test therefore gives evidence towards the thought that a short squeeze does not fundamentally change the price relationship between investor and affected securities. Although the abnormal returns on the event days on their own were significant, it is apparent that over a longer period of time the cumulated abnormal returns are not significantly different after a short squeeze than they were prior to one.

Of note is the consistency of the results whether in period T_0-T_1 or T_0-T_2. Any difference in the results in these two periods can be traced back to the differing SCAR* values. If the re-standardized cumulative abnormal returns in the two periods differed enough to be attributed non-identical ranks, then the make-up and standard deviation of the demeaned standardized abnormal ranks would be affected. This is subsequently shown in different results for the t_{GRANK}. However, event with very different ranks attributed the results do not differ by much. This is further evidence to the strength of the t_{GRANK} test and the fact that it is not affected or deterred by longer event windows.

6. Discussion and further recommendations

Our initial hypothesis was that the short squeeze event would fundamentally change the way investors look at a security and how they invest in companies that have known such events. Our results however, indicate that the null hypothesis was not rejected and we must thus conclude that a short squeeze seems not to have long-term effects on the affected securities. While researching extant literature we found differing views on securities that were most prone to a short squeeze event, and their subsequent reactions. The most recent and prevalent research argues that securities with a high short interest (and thus at risk of a short squeeze) demonstrated negative abnormal returns for significant periods of time. With a short squeeze the short interest would by definition be significantly be reduced as short sellers covered their positions. It was therefore our hypothesis that having experienced a short squeeze, subsequent abnormal returns would be different from those prior to the event.

Our tests have concluded that this is not the case, as demonstrated by the generalized rank test developed by Kolari & Pynnonen (2011) and executed above. It could be argued that this "reset" of short interest cause by a short squeeze does not fundamentally change the circumstances of a business. As stated earlier in our paper investors short a company because they believe it will do badly. Short sale constraints hinder the price reflection of these investors' belief. The sudden spike in price caused by a short squeeze may scare away investors, who will not be willing to be exposed to the short squeeze risk, but it does not change the fundamental abnormal returns delivered by the affected company.

In practice this means that any short-term gains realized due to the initial price spike at the onset of a short squeeze are quickly dissipated. The market corrects itself, as it were. The short squeeze remains an artificial price increase caused by an imbalance in supply and demand and an unexpected release of information. Unfortunately for those caught on the wrong end of this movement, it can have severe short-term consequences. Due to the current functioning of the loan- and short selling market mechanism, many are forced out of their short positions and suffer severe losses. They are, as it were, punished for jumping on the boat at the wrong time.; and the market is unforgiving.

Literature and past media coverage remain ambivalent over the role of short selling in the modern financial markets. In general, it is thought to be a valid trading technique, but one fraught with high risk, and better left to professional investors. It can however also be anti-productive and not beneficial to the market as a whole, as is the case with naked-short selling, where investors are of a more speculative nature. In general terms, it is argued that short selling serves a positive role in the market providing liquidity and bringing prices of securities close to their actual value. A short squeeze is then perhaps an accidental byproduct of this positive market-aspect.

Taking into account our results that show that a short squeeze has no meaningful long-term impact on the returns of a company, the question then arises whether regulators can, or should do anything about short squeezes. Although in the long-term there is no significant impact, it is certain that in the short term, due to the current structure of short selling, there are winners- (owners of the shares) and most certainly losers (short sellers) in the marketplace.

To answer the first question whether regulators can do anything, it is important to note that short squeezes are a consequence of the current set-up of short selling. If there were a mechanism to limit the number of short sellers covering their positions at a point in time, we could eliminate short squeeze all together. But to act in such heavy-handed manner in the supply of certain shares would certainly set a bad precedent in free and liberal economic markets. It is therefore not a straightforward task to simply put a stop to such an engrained market mechanism.

The second question, as to whether they should implement measures, is of a more ethical nature. Many would say that short sellers who are ready to profit when things go badly, and who are aware of the uncapped risks, should then also face consequences when they are wrongfooted, and have bet badly. The main losers of a short squeeze, due to the risky nature of the preceding situation, tend to be powerful and informed hedge funds or speculative investment firms for which the public at large generally has little sympathy.

It is thus our opinion that, since there are no long-term significant effects, a short squeeze be treated as an important risk, but one of which short-sellers are aware, and is inherent to the functioning of short selling.

7.Closing Remarks

The author's interest in short squeeze were peaked after reading articles about the now infamous 2008 Volkswagen-Porsche short squeeze. The cause of this short squeeze was the sudden announcement by Porsche, that they held approximately 75% of Volkswagen shares. The German state held 20% which they would not sell, leaving 5% currently floating. The automobile industry was at that time suffering along with the general economy, and many investors felt that Volkswagen was overvalued, leading to a 15% short interest of Volkswagen shares.

Amidst growing panic to cover short positions, the share price shot up from just under €200 to a stratospheric €1,005, making it the world's most valuable company for a brief moment. Nothing had changed about the cars the company produced, or the management in charge. But somehow, over 2 days, billions of euros of value appeared and just as quickly disappeared. Porsche subsequently released 5% of shares held, to relieve the pressure on short sellers, but many of these had already suffered billions in losses. This thesis demonstrates that any abnormal returns made during the short squeeze long term even window are not significantly different from those made before the event. Thus, further demonstrating the efficiency of markets and that artificial value creation does not last.

Market mechanisms such as short squeezes, are often unintended by-blows of purposely created aspects of markets (in casu: short selling). They can create value just as quickly as they can make it disappear. Before examining such a concept, one needs to understand the circumstances that make such an event possible. This makes explaining and clarifying results obtained all the more challenging but also all the more interesting. As investors seek for increasing returns in an age where information and data are ever more important, investigating such quirks in the market which may or may not be beneficial, become all the more possible and all the more essential.

Bibliography

Aksu, C., & Gunay, E. (1995). An empirical analysis of the causal relationship between short interest and stock prices. *Journal of businss finance & accounting*, 733-749.

Asquith, P., Pathak, P. A., & Ritter, J. R. (2005). Short interest, institutional ownership and stock returns. *Journal of financial economics*, 243-276.

Au, A. S., Doukas, J. A., & Onayev, Z. (2008). Daily short interest, idiosyncratik risk, and stock returns. *Journal of financial markets*.

Beneish, M., Lee, C., & Nichols, D. (2014, October 05). In Short Supply: Short-Sellers and Stock Returns. United States of America.

Boehmer, E. (1991). Event-study methodology under conditions of event-induced variance. *Journal of financial economics*, 253-272.

Brenner, M., & Subrahmanyam, M. (2008). *Chapter 12: Executive Summary , Short selling.* Retrieved from Stern Business School NYU: http://whitepapers.stern.nyu.edu/summaries/ch12.html

Brent, A., Morse, D., & Stice, E. K. (1990). Short Interest: Explanations and Tests. *The journal of financial and quantitative analysis*, 273-289.

Brown, S. J., & Warner, J. B. (1985). Using daily stock returns: The case of event studies. *Journal of Financial Economics*, 3-31.

Cable, J., & Holland, K. (1999). Modelling normal returns in event studies: a model-selection approach and pilot study. *European Journal of finance*, 331-341.

Campbell, J. Y., Lo, A. W., & MacKinlay, A. C. (1997). *The Econometrics of Financial Markets.* Princeton, New Jersey: Princeton University Press.

Choie, K. S., & Hwang, S. J. (1994). Profitability of short selling and exploitability of short information. *The Journal of portfolio management*, 33-38.

Corrado, C. J. (1989). A nonparametric test for abnormal security-price performance in event studies. *Journal of Financial Economics*, 385-395.

Cowan, A. R. (1992). Non-parametric event study tests. *Review of quantitative finance and accounting*, 343-358.

Cox, J. (2016, 07 19). *Herbalife is back in the cross hairs of short sellers*. Retrieved from CNBC: http://www.cnbc.com/2016/07/19/herbalife-is-back-in-the-cross-hairs-of-short-sellers.html

Dechow, P. M., Hutton, A. P., Meulbroek, L., & Sloan, R. G. (2001). Short-sellers, fundamental analysis, and stock returns. *Journal of financial economics*, 77-106.

Desai, H., Ramesh, K., Thiagarajan, S. R., & Balachandran, B. V. (2002). An investigation of the informational role of short interest in the Nasdaq market. *The journal of finance*, 2263-2287.

Diether, K. B., Lee, K.-H., & Werner, I. (2009). Short-Sale Strategies and Return Predictability. *Review of financial studies*, 575-607.

Duffie, D., Gârleanu, N., & Heje Pedersen, L. (2002). Securities lending, shorting, and pricing. *Journal of financial economics*, 307-339.

Economist, T. (2008, 06 19). Nasty, brutish and short. *The Economist*. Retrieved from http://www.economist.com/node/11591349

Epstein, G. (1995). *Short can be sweet.* Barron's national business and financial weekly.

Fama, E. F. (1970). Efficient capital markets: a review of theory and empirical work. *Journal of Finance*, 383-417.

Fama, E. F., & French, K. R. (1993). Common risk factors in the returns on stocks and bonds. *Journal of financial economics*, 3-56.

Figlewski, S. (1981). The Informational effects of restrictions on short sales: some empirical evidence. *The journal of financial and quantitative analysis*, 463-476.

FINRA. (2017). Short Interest Reporting Due Dates. United States of America. Retrieved from http://www.finra.org/industry/short-interest/short-interest-reporting-due-dates

Geczy, C. C., Musto, D. K., & Reed, A. V. (2002). Stocks are special too: an analysis of the equity lending market. *Journal of financial economics*, 241-269.

Gregory, A. (1997). An examination of the long run performance of UK acquiring firms. *Journal of Business Finance & Accounting*, 971-1002.

Hanna, M. (1976). A stock price predicitve model based on changes in ratios of short interest to trading volume. *The journal of financial and quantitative analysis*, 857-872.

Henry, T. R., & Koski, J. L. (2010). Short selling around seasoned equity offerings. *The review of financial studies*, 4389-4418.

Hurtado-Sanchez, L. (1978). Short Interest: Its Influence as a Stabilizer of Stock Returns. *The journal of financial and quantitative analysis*, 965-985.

IHS Markit. (2015). *Short Squeeze Model.* London: IHS Markit Research Signals.

Irvine, P. J., & Venkataraman, K. (2006, August). Liquidity and asset prices: The case of the short squeeze and the returns to the short position.

Karpoff, J. M., & Lou, X. (2010). Short sellers and financial misconduct. *The journal of finance*, 1879-1913.

Kerrigan, T. J. (1974). The short interest ratio and its component parts. *Financial analysts journal*, 45-49.

Kolari, J. W., & Pynnonen, S. (2011). Nonparametric rank tests for event studies. *Journal of empirical finance*, 953-971.

Lamont, O. A. (2005). *Short Sale Constraints and Overpricing*. Retrieved from The National Bureau of Economic Research: http://www.nber.org/reporter/winter05/lamont.html

Lamont, O. A., & Thaler, R. H. (2003). The law of one price in financial markets. *Journal of economic perspectives*, 191-202.

Lummer, S. L., & McConnell, J. J. (1989). Further evidence on the bank lending process and the capital-market response to bank loan agreements. *Journal of financial economics*, 99-122.

MacKinlay, A. C. (1997). Event studies in Economics and Finance. *Journal of Economic Literature*, 13-39.

Mayor, T. H. (1968). Short trading activities and the price of equities: some simulation and regression results. *The journal of financial and quantitative analysis*, 283-298.

Mordkoff, J. T. (2016). The assumption(s) of normality. Retrieved from http://www2.psychology.uiowa.edu/faculty/mordkoff/GradStats/part%201/I.07%20normal.pdf

Osborne, T. (2012). A kind broker, circa 1901: buying on margin. In T. Osborne, *Greed is good and other fables: office life in popular culture* (pp. 143-144). Santa Barbara, California: Praeger.

Patell, J. M., & Wolfson, M. A. (1979). Anticipated information releases reflected in call option prices. *Journal of Accounting and Economics*, 117-140.

Saffi, P. A., & Sigurdsson, K. (2011). Price efficiency and short selling. *Review of finance studies*, 821-852.

Schindler, D. (2015). *The effect of short interest on the subsequent stock performance in Nasdaq-100 companies.* Enschede: University of Twente: The faculty of behavioral, management, and social sciences.

Schol, S., McNulty, K., & Jacobs, A. (2010). *Short Selling, A comprehensive review of regulatory proposals.* Association for Financial Markets in Europe, International Securities Lending Association, International Swaps and Derivatives Association.

Schweitzer, R. (1989). *How Do Stock Returns React to Special Events.* Federal Reserve Bank of Philadelphia.

Shuttleworth, M. (2008, February 3). *Null Hypothesis*. Retrieved from Explorable: https://explorable.com/null-hypothesis

Sitthipongpanich, T. (2011). Understanding the Event Study. *Journal of Business Administration*, 60-68.

Waggoner, J. (2005, 11 24). Betting against shorts isn't wise. *USA Today*. Retrieved from https://usatoday30.usatoday.com/money/perfi/columnist/waggon/2005-11-24-short_x.htm

Woolridge, J. R., & Dickinson, A. (1994). Short Selling and Common Stock Prices. *Financial Analysts Journal*, 20-28.

Appendix

Appendix 1

t Table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	**0.50**	**0.25**	**0.20**	**0.15**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**	**0.001**	**0.0005**
two-tails	**1.00**	**0.50**	**0.40**	**0.30**	**0.20**	**0.10**	**0.05**	**0.02**	**0.01**	**0.002**	**0.001**
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										

Appendix 2

Security	BankAtlantic Corp.	Chesapeake Energy Corp	Cliffs Natural Resources Inc
SCAR* 1 (Mean Adjusted Returns)	2.008	0.470	-0.126
SCAR* 1 (Market Adjusted Returns)	1.968	0.442	-0.138
SCAR* 1 (CAPM Adjusted Returns)	1.967	0.440	-0.138

Security	EnteroMedics Inc	EP Energy Corp	JC Penney
SCAR* 1 (Mean Adjusted Returns)	2.658	1.368	1.110
SCAR* 1 (Market Adjusted Returns)	2.599	1.331	1.020
SCAR* 1 (CAPM Adjusted Returns)	2.597	1.328	1.019

Security	Nokia OYJ	Quidel Corp	Rexx Energy Corp
SCAR* 1 (Mean Adjusted Returns)	1.591	0.168	0.620
SCAR* 1 (Market Adjusted Returns)	1.613	0.199	0.599
SCAR* 1 (CAPM Adjusted Returns)	1.609	0.198	0.597

Security	Tesla Motors Inc.	Volkswagen AG	
SCAR* 1 (Mean Adjusted Returns)	1.336	3.050	
SCAR* 1 (Market Adjusted Returns)	1.412	3.081	
SCAR* 1 (CAPM Adjusted Returns)	1.411	3.081	

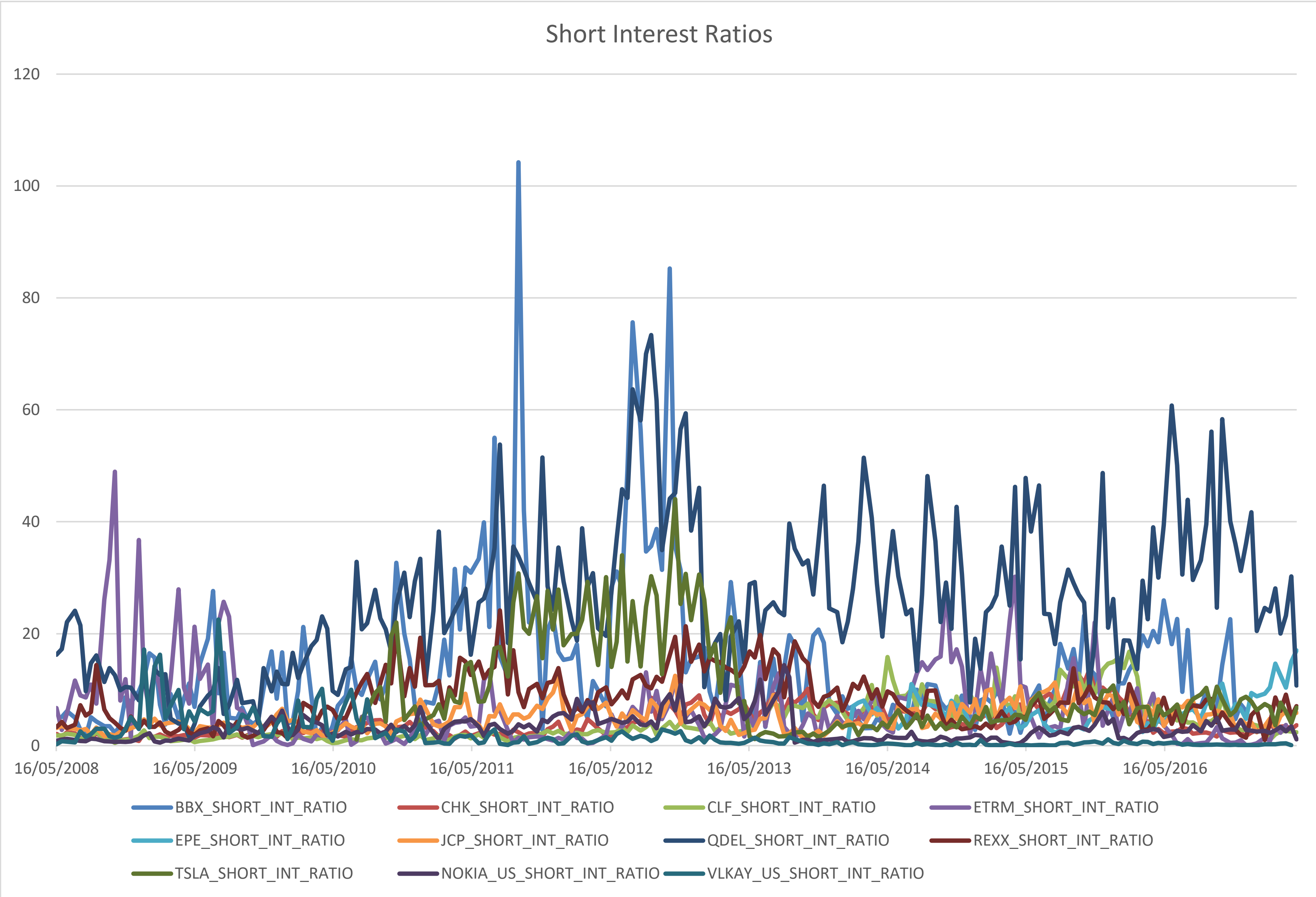
Security	BankAtlantic Corp.	Chesapeake Energy Corp	Cliffs Natural Resources Inc
SCAR* 2 (Mean Adjusted Returns)	3.285	1.443	1.606
SCAR* 2 (Market Adjusted Returns)	2.774	1.008	1.529
SCAR* 2 (CAPM Adjusted Returns)	2.781	0.975	1.520

Security	EnteroMedics Inc	EP Energy Corp	JC Penney
SCAR* 2 (Mean Adjusted Returns)	2.557	2.337	2.651
SCAR* 2 (Market Adjusted Returns)	1.852	1.781	1.285
SCAR* 2 (CAPM Adjusted Returns)	1.853	1.751	1.275

Security	Nokia OYJ	Quidel Corp	Rexx Energy Corp
SCAR* 2 (Mean Adjusted Returns)	2.091	-0.273	0.605
SCAR* 2 (Market Adjusted Returns)	2.622	0.313	0.212
SCAR* 2 (CAPM Adjusted Returns)	2.543	0.298	0.182

Security	Tesla Motors Inc.	Volkswagen AG
SCAR* 2 (Mean Adjusted Returns)	1.559	1.346
SCAR* 2 (Market Adjusted Returns)	3.454	1.969
SCAR* 2 (CAPM Adjusted Returns)	3.435	1.981

Appendix 3


Short Interest Ratios
120
100
80
60
40
20
0
16/05/2008
16/05/2009
16/05/2010
16/05/2011
16/05/2012
16/05/2013
16/05/2014
16/05/2015
16/05/2016
BBX_SHORT_INT_RATIO
CHK_SHORT_INT_RATIO
CLF_SHORT_INT_RATIO
ETRM_SHORT_INT_RATIO
EPE_SHORT_INT_RATIO
JCP_SHORT_INT_RATIO
QDEL_SHORT_INT_RATIO
REXX_SHORT_INT_RATIO
TSLA_SHORT_INT_RATIO
NOKIA_US_SHORT_INT_RATIO
VLKAY_US_SHORT_INT_RATIO

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