MSc Financial Economics

The Spill Over Effects of the 2021 GameStop Short Squeeze on Shorting Activity in the European Equity Market: An Empirical Analysis

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Abstract

In 2021 the GameStop short squeeze occurred in the US markets. This paper explores the spill over effects that this squeeze had into European equity markets, specifically what effect it had on European shorting activity. This paper aims at providing a foundation for further research as short squeezes are unique occurrences and data on European shorts is relatively new. The short positions are aggregated and a short volume is calculated, which are subsequently tested for difference in means and medians. Results indicate significant decreases in aggregate short positions and short volume. Using Ahmad et al.'s (2022) quantity effect we find evidence for a shift in risk awareness among short sellers in European equity markets, triggered by the GameStop short squeeze. Further research can improve metrics, examine long-term effects as well as using additional and better complementary data.

Keywords: short squeeze, GameStop, European shorting activity, short volume, short interest, spill over effects

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1. Introduction

In January 2021 the financial world was enthralled by the developments regarding the stock of GameStop Corp. The stock was heavily shorted at the time and it led to a spectacular short squeeze at the end of January 2021, causing the price to rise from approximately $19.12 to a peak of $483 in less than 4 weeks[1]. A year earlier the price of the poor-performing company had been hovering around $4, being the target of many short sellers (Jakab, 2022). Short squeezes can occur when the short sellers want to exit their short position, but experience difficulty in obtaining the security, for example in a case of low supply of the floating shares which causes the price of the stock to rise radically (Allen et al., 2021).

GameStop Corp. (GME) is an American retail company mainly offering video games and consumer electronics. The fundamentals of GME were not of good quality caused by an increase in online sales and the 2020 Covid-19 pandemic, based on this hedge funds took short positions in the GME stock (Vasileiou et al., 2021). Vasileiou et al. further describe how a coordinated online effort between retail investors created a situation where, based upon the fundamentals of GME, irrational investing behaviour led to profits at the cost of the shorting hedge funds. Essentially, by taking long positions the retail investors wished to decrease the number of available shares that could be used to cover short positions and therefore drive up the price (Klein, 2022).

In early 2021 the short float (SF) of the stock of GME Corp exceeded 140% (Reuters Staff, 2021). SF is the number of shares that have been sold short as a percentage of the total float of shares, which is the number of shares that is in hands of public investors. A Goldman analyst reported that a SF above 100% only happened 15 times in the past ten years as of 2021 (Ponciano, 2021), suggesting that these situations are quite exceptional. To understand how more shares can be shorted than are in the current float, one can take a look at an illustrative example[2]: entity A borrows a share from entity B, after which entity A sells the share to entity C (A is taking a short position). Now theoretically, C can again lend the share to entity D who can, like entity A, take a short position. Through this, one share can be shorted multiple times and it is possible to achieve a SF exceeding 100% and more than the amount of outstanding stock. Even though this sounds potentially unlawful, it is a legal process and commonly known as 'rehypothecation' (Jakab, 2022, p. 80).

[1] Not adjusted for a stock split. Data retrieved from Yahoo Finance which adjusts for splits, dividends and/or capital gains distributions. GameStop performed a 4-to-1 stock split per 21st of July 2022, so the nominal price stated here is higher by a multitude of four compared to prices after 21st of July 2022.

[2] Derived from https://www.fool.com/investing/2021/01/28/yes-a-stock-can-have-short-interest-over-100-heres/

Another way to short more stocks than the amount outstanding is through so-called 'naked' short selling (Caplinger, 2021). The practice of naked short selling is different from the previous described rehypothecation, which is defined as 'covered' short selling. In covered short selling the shorter borrows the share (i.e., shorter is covered) and sells it to the market. In naked short selling the shorter does not borrow the share, nor an arrangement to borrow the share, but does sell this imaginary share to the market. The short seller will then later supply the share to the buyer, known as a delivery. In the US, there are rules regarding naked short selling but it is not necessarily against the law and actually can provide market liquidity (SEC, 2022). In the European Regulation No. 236/2012 chapter III article 12 (2012) (EU236 from hereon after) the practice of naked short selling, referred to as 'uncovered' short selling, is restricted. The restrictions outlined only allow for short selling whenever a share is borrowed (covered short selling) or an agreement/arrangement is present that offers a reasonable probability that the settlement can be realized. In other words, naked short selling is illegal under European regulation. Hence, if situations of (extremely) high short interest (SI), which is the amount of stock shorted as a portion of the amount of outstanding stock, occur in European stocks it is more likely it is a result of rehypothecation rather than naked short selling.

With retail investors uniting to buy the GME stock the price further rose and losses for short sellers became larger. The demand of GME shares by investors trying to close short positions, in order to stop further losses, further increased demand and price of the stock and therefore going into a vicious cycle, essentially squeezing the short sellers out of their position (Li, 2021). The GameStop short squeeze caused worldwide attention for the stock, short squeezes and retail investing. The online forum (also known as *subreddit*) r/wallstreetbets, which was the main online discussion platform of the squeeze, grew by more than 1.5 million users overnight on January 29th and had 75 million pageviews in 24 hours January 27th (Morse, 2021), which denotes the scale of the hype. The short squeeze caused a global ripple across equity markets, for example, Malaysian investors got inspired and attempted a similar short squeeze in the Malaysian listed stock Top Glove (Smith & Wigglesworth, 2021).

The event of the short squeeze in the GME stock is interesting for investigating the role of short positions in stock markets and how those positions develop around and after the event. While GME is listed on the US New York Stock Exchange (NYSE), a matter of interest is whether the event has had any significant effect on shorting behaviour in European equity markets. As of August 2022, when investing in US listed stocks one does not face the obligation to disclose a net short position (i.e. larger short than long position of the security in their portfolio) to the market. However, when investing in the EU (and UK) listed stocks investors do have to disclose those positions to respective

European authorities at certain thresholds since 2012. In a regulation, called Regulation No 236/2012 (EU236) of the European Parliament and of the Council of 14 March 2012, the definition of when the regulation applies is laid out as follows:

"*… financial instruments (…) that are admitted to trading on a trading venue in the [European] Union, including such instruments when traded outside a trading venue.*"

The relatively recent availability of data on (net) short positions above 0.5% of issued capital of companies listed on European trade venues combined with the 2021 US short squeeze allows for novel research on the spill over effects of the US event into shorting activity in the European equity markets. Besides this, short squeezes are uncommon in the financial world and the 2021 short squeeze allows for research in a recent context. Hence, the topic of this research is the spill over effects of the short squeeze of the GME stock in the US equity market into the European equity markets. This research is of academic relevance as European short data is relatively new and the event of the short squeeze of 2021 is unique. The main research question is formulated as follows:

What are the spill over effects of the 2021 GameStop short squeeze in the US market on shorting activity in European equity market?

In order to answer this research question this paper explores sub-questions. These sub-questions are designed in such a way that they will assist in finding an answer to the main research question. First of all, one wants to investigate how short positions above 0.5% developed during and after the short squeeze, specifically how they developed in European countries. Answering this examines the spill over effects of the US short squeeze into European short activity by looking at actual short positions. Therefore, the first sub-question is the following:

How did short positions above 0.5% in European stocks develop before, during and after the GameStop short squeeze?

A second field of interest is whether these are spill over effects are limited to stocks that are heavily shorted, like was the case with GME, and how this differed from stocks with lower SI. Answering this could provide answers to the assumption that short sellers feared stocks with more potential for a short squeeze and, therefore, that those high SI stocks saw a greater effect. Due to limitations in data availability, the metric for level of shorting will be proxied by the published amount of shorts above 0.5%. The second sub-question is formulated as follows:

What are the differences between stocks with higher pre-squeeze levels of shorts and stocks for which this was lower?

On the assumption and condition that a change in shorting activity is observed, a third sub-question explores underlying cause. That is, is this change due to a change in behaviour of short sellers or is it explained by increase in prices in (heavily) shorted stocks? The latter would cause shorting activity (in terms of € volume) to seemingly increase, while it is caused by underlying increasing prices. Hence, we formulate the third sub-question as:

Are any observed changes in European shorting activity after the GameStop short squeeze due to a change in shorting behaviour or rather due to a change in stock prices?

2. Theoretical Framework

The theoretical framework lays the foundation of this research by outlining the event and the subsequent problem. First, a definition of a short squeeze is given and we assess the event to provide a contextual basis for this research. After this, a literature review is provided to examine existing literature on the topic and formulate relevant hypotheses.

2.1 Short squeeze

When one speculates a stock will fall in value the investor can short the stock to capitalize on this belief. Shorting a stock is the practice of borrowing a share from a shareholder and selling this borrowed share at the current market price. Then, when the stock price falls according to belief, the shorter buys back the share at the lowered price and gives it back to the original shareholder whom the share was borrowed from. In numbers, a shorter can borrow share X and immediately sells it for €100. A week later, following bad performance of the stock, the share is bought back for €90 and given back to the loaner and shorter is left with €10. This practice of short selling plays a significant role in the equity markets and, as Rapach et al. (2016) describe, has become more prominent over the last four decades as observed by an increased aggregate short interest. Rapach et al. mention that this increase is likely to be attributed to a decrease in short selling constraints and an increase in the assets under management of hedge funds. Besides short selling being important size-wise, it also shows evidence of downward price discovery and efficient markets (Bris et al, 2007).

When a trade is crowded it means that a (much) larger number of investors are on one side of the trade (Rocker, 1999), thus we can say a trade is crowded on the long side when a vast majority of the investors believe in a long position for whatever reason. Hong et al. (2016) analyse the link between crowded short trades and potential liquidity problems, they find that there is a potential for destabilization if an exit occurs at the crowded side of the trade since the other side of the trade offers little liquidity. Filippou et al. (2022) provide a basic definition of a short squeeze in equities as occurring “when shares experience a large price increase that forces short sellers to close their position, which leads to further price increases.”. Combining Hong et al.’s (2016) description of potential crowded exit hazards and Filippou et al’s (2022) definition of a short squeeze, one gets to understand the underlying intentions of the retail masses in the GameStop case. In the case of GameStop, retail investors actively sought to buy much of the free float of the stock in order to make it even more difficult for the large number of short investors to exit their position (Klein, 2022). That is, there was an attempt at forcing such a squeeze/destabilization of short positions.

2.2 The event

A significant rise in retail investor activity preceded the GameStop short squeeze event, facilitated by the new zero-commission trading apps such as Robinhood, being at home during the pandemic lockdown, having little to spend during these lockdowns and a stimulus check for many Americans (Jakab, 2022). Jakab (2022) provides an extensive timeline of the events leading up to and after the short squeeze of the GME stock. A major role was fulfilled by subreddit r/wallstreetbets on the website Reddit, where retail investors discuss risky 'all-or-nothing' investments. In a seek for profits they became aware of the immense SI of GME and learned of the short squeeze that they could potentially trigger, which would be profitable if covering shorts had to bid up to exit their short positions. Their attempts to trigger a short squeeze were not limited to GME, also other high SI stocks became targets such as Blackberry, Nokia and AMC Entertainment Holdings Inc. Jakab further describes a series of (relatively small) GME squeezes before the infamous squeeze in late January, triggered by short- and gamma[3] squeezes. Jakab analysed the page statistics for r/wallstreetbets and learned the subreddit had the most daily comments of the entirety of the website during January 24th and February 4th, 2021. This is in line with the major price increase of GME. Hence, this provides an appropriate event window for this research and will be used in the methodology of this research.

2.3 Literature review

While academic literature exists in numerable quantities on US short selling and squeezes, it remains meagre on European equity markets. Consequently, various papers on the US equity market are analysed. Short squeezes are not exceptional and academic research on them can add value in understanding market dynamics. In terms of examining its spill over effects into European shorting markets the research touches upon an unexplored frontier and lays a foundation for further research.

In the 2008 short squeeze of Volkswagen stock the SI decreased from 18% to 8.5% in 5 days, caused by short sellers covering as they were squeezed (Allen et al., 2021). Also GME experienced this expected decrease in SF, from 140% at the start of the month January 2021 to 50% at January 29th 2021 (Jakab, 2022, p. 213). This is inline with market research from S3 partners (Dusaniwsky, 2021a, 2021b) that report 71.79 million shares shorted (139.57% SF) per January 26th and on January 31st this number decreased to 27.13 million shares still being shorted (≈27.08% SF)[4], which means a large portion of GME short positions had been covered (Dusaniwsky, 2021b). 140% of the float being

[3] Jakab (2022) defines the gamma squeeze as when call contracts are bought and the seller(s) of those will have to cover their risk by buying the underlying stock, driving up the price.

[4] Float not readily available per article. Float of 26th of January 2021 (Dusaniwsky, 2021a) used to approximate SF of GME at 31st of January 2021.

shorted (i.e. short float (eq. 1)) is possible through, as earlier stated, rehypothecation or naked short selling and can even theorize more stocks being shorted than the outstanding stock in a legal manner in the case of rehypothecation (Jakab, 2022, p. 80). The decrease in the SF went hand in hand with the immense price increase of the stock, this is in line with Filippou et al.'s (2022) basic definition of a short squeeze that states large price increases force short sellers to cover their position, which further increases prices. This can be explained through Kyle's (1984) theory regarding how short squeezes can happen in the futures market, finding that covering shorts need to drive up the price in order to cover their position because of liquidity problems. To better understand the squeezes, and specifically the GameStop short squeeze, one can take a look at the mechanisms behind the process of the squeeze.

$$[Short\ Float]_{i,t} = \frac{[Amount\ of\ shares\ shorted]_{i,t}}{[Amount\ of\ shares\ in\ (public)\ float]_{i,t}} \quad (1)$$
$$i = stock\ i, t = time\ t$$

Kyle (1984) describes a simple futures market model to explain squeezes and this model consists of hedgers, speculators and squeezers. While the equity market is different this research assumes it can be applied to a certain extent to shorts in the equity market (Allen et al., 2021). Therefore, we assume a model in which we have shorters, speculators and squeezers. The short squeeze model describes how the probability of a short squeeze influences and is influenced by these 3 players. The shorter influences it through demand and covering; the speculator considers the probability of a squeeze and enters a position and the squeezer builds a sufficient large long position to decrease supply without alerting the shorter(s). Kyle further describes how such a squeeze only becomes apparent when covering is active and the squeezer holds onto his long position, which causes covering shorters to bid up in order to get out of their position, thus the squeezer profits at the cost of the covering party. Per Kyle, this model is comparable to the economic model of supply and demand but, instead of price and quantity, determines the equilibrium level of short covering and probability of a short squeeze.

Among holders of large short positions a higher probability of a short squeeze goes hand-in-hand with a fear of expensive liquidation (i.e., forced covering of short positions) through an increased share price and/or recall of the loaner (Brunnermeier & Pedersen, 2005). Ahmad et al. (2022) observe this alertness among holders of shorts in US stocks with a higher SF and subsequent decrease in SF in US stocks after the GameStop short squeeze. Consequently, this paper assumes stocks with a higher probability of a short squeeze proxied by a large amount of shorted stocks that causes a level of fear, as described by Brunnermeier & Pedersen (2005), that would trigger a decrease in short exposure among European stocks after the GameStop short squeeze. This

expectation is in line with the observation of Ahmad et al. (2022) but extends the spill over effect cross nations. In my research regarding spill over effects of the GameStop short squeeze in the European equity markets, Kyle's (1984) model of probability of a squeeze and short covering are essential in interpretation of this paper's findings the retail investors are considered squeezers and the position holders in European short positions are the shorters.

Taking into consideration that holders of short positions in European markets could have become fearful of potential short squeezes in their holdings, it is expected that they covered their positions in order to prevent potential (additional) losses. In US markets such a spill over effect in shorting activity was already observed in the case of GameStop where short sellers have been made more aware of the risks of their short positions and adjusted their strategy on a long-term basis (Ahmad et al., 2022). Their interpretation of their findings that other high SI stocks saw declines in SI are in line with Jakab's (2022, p. 169) observation that (retail) traders were seeking stocks with similar characteristics as GME in order to trigger short squeezes.

2.4 Hypotheses

Taking previous literature in account, we can formulate hypotheses regarding spill over effects of the GameStop short squeeze into European markets. In line with Brunnermeier's & Pedersen's (2005) description of fear of forced liquidation, we expect fear among shorters in European stocks that is induced by the GameStop short squeeze, with the underlying mechanism being the higher perceived probability of a short squeeze as described by Kyle's (1984) model. In order to test whether this observed spill over effect of the GameStop short squeeze followed in European equity markets, the following first hypothesis is formulated:

H1: *The GameStop short squeeze caused short activity in European equity markets to decrease on an aggregate level.*

Being able to examine the first hypothesis determines whether there is any difference on an aggregate level. However, using a Wilcoxon signed rank test, Ahmad et al. (2022) find that the observed spill over effect in shorting activity among US stocks differs between stocks with different levels of pre-event SF and is not monotone. More specifically, they observe that stocks with high pre-event SF (>20%) experience a decrease in SF and stocks with low pre-event SF (<5%) experience an increase in SF. Jakab (2022, p. 169) and Ahmad et al. (2022) describe that these (retail) investors were especially targeting SME companies with high SF and this research assumes targeting resulted in a higher perceived short squeeze probability in European stocks with high pre-event SF. While there is no data readily available for me on the float of shares of European stocks, there is data on large short positions and the amount of outstanding stock that can behave as a proxy for short

interest (SI; eq. 2) since we can assume it is the only publicly available dataset for the squeezers, speculators and shorters. Hence, we formulate a second hypothesis:

$$[Short\ Interest]_{i,t} = \frac{[Amount\ of\ shares\ shorted]_{i,t}}{[Amount\ of\ shares\ outstanding]_{i,t}} \quad (2)$$
$$i = stock\ i, t = time\ t$$

H2: *The GameStop short squeeze caused short positions in European equities with higher pre-event short interest to decrease in short interest, vice versa for equities with lower pre-event short interest.*

A further inspection of Ahmad et al.'s (2022) paper *Analyzing spill over effects of the GameStop squeeze on short interest* will clarify how they tested for a shift in risk awareness of short sellers. They find significant lower SF in GME after the squeeze and interpret this as a signal that short positions became thought of as riskier than before the squeeze. However, in the paper a problem is stated that formulates the decrease in SF can be caused by either a liquidity problem or an actual change in risk awaress of short sellers. In order to understand this, here is an example of why a decrease in SI might have few to do with a shift in strategy:

> Let's say GameStop Corp. has a market capitalization of $1 bln per 1 January 2021, with 100 mln outstanding shares at a share price of $10. About 50 mln shares are shorted, that is a short volume of $500 mln. Now during a month the share price increases to $40 and thus the short volume increased to $2 bln, quadrupling. This increase is called the *price effect* of change in short volume by Ahmad et al. (2022). However, the short sellers might not want their portfolio to be heavier weighted towards GameStop, so they decrease their number of shares shorted to 12.5 mln to get back at the original short volume. Even though the short interest decreased, their dollar value of the short did not change due to portfolio rebalancing. This decrease is called the *quantity effect* of change in short volume by Ahmad et al. (2022).

Now, to answer their hypothesis that the decrease is related to a shift in shorting strategy Ahmad et al. develop a formula that decomposes the change in short volume (SV) into the *price effect* (PE) and *quantity effect* (QE) which will be further analysed in the Methodology section. In short, the PE denotes the € value change in SV that is caused by changing stock prices and the QE denotes the € value change in SV that is caused by a change in short positions. Ahmad et al. interpret a decrease in QE as a shift towards more risk awareness. Using these effects, they find that, indeed, short sellers have become more aware of their risks in short positions in US stocks and altered strategies for this. Consequently, my paper will use the analysis of the change in SV as described in Ahmad et al. (2022) in order to dissect changes in SV in European short positions into the QE and PE. By doing so, the QE will provide as a proxy for a potential (and hypothesized) shift in risk awareness among shorters of European stocks.

In case H1 and/or H2 cannot be rejected another question becomes relevant: did these changes occurs because of a shift in strategy or merely caused by a change in stock prices? Assuming

a scenario where short positions changed significantly in the wake of the GameStop short squeeze, we expect this to be related to a shift in shorting risk awareness as concluded by Ahmad et al. (2022) for the spill over effect of the event into US stocks. We can use Ahmad et al.'s quantity effect to assess this and examine the following hypothesis:

H3: *The GameStop short squeeze caused short sellers in European stocks to decrease their exposure to short positions as they became aware of tail risks of short selling.*

3. Data

This section lays out the sources of data that will be used in this research. First, an outline is given of the regulation surrounding reporting and publishing of short positions in European countries. Then, the relevant databases are mentioned with a brief assessment of their data and a subsequent section how the data was prepared. Finally, the data is portrayed in a descriptive manner.

3.1 Availability of European data

Reports on European short positions are done according to Article 9 of Regulation (EU) No 236/2012 (EU236) that determines a threshold of 0.2% of the issued share capital and every ten basis points above that. It is noteworthy that this is regarding the *reporting* requirement, the *publication* threshold is 0.5% of issued share capital and every 10 basis points above that. When the publication threshold is exceeded, the position will be publicized through the websites of national authorities. As the law came into place in 2012, one can expect most data from this year onwards. Additionally, because of the publication threshold we can expect to miss data of short positions below the threshold for most countries and therefore do not know the total amount of shares shorted per stock. This is a limitation in interpreting our results.

A limit in data availability in this research is caused by the earlier-stated fact that EU236 does not facilitate a complete view of short positions for stocks, but rather enables research on 'large' short position holders. In other words, while we have data on large net short positions, generally we do not know the number of short positions that are below the 0.5% threshold**.** Thus, research regarding European short activity will be limited to the behavior of large short position holders (i.e. exceeding the publication threshold). This limit is noteworthy as it inhibits utilizing the total number of shares shorted, which is used in previous academic research on US shorting activity. Another limit of the European short data, lies in the availability of data on the float of European stocks which is used to calculate short float (SF). The difference with short interest (SI) lies in the differing denominator, where SF uses the shares in the (public) float and SI uses the total amount of shares outstanding. The float of shares is the amount of shares that are publicly held and the amount outstanding adds the locked-in shares to this. Since the amount of publicly held shares cannot be higher than the total amount of outstanding shares, the SF will always be equal to or higher than the SI since the nominator (amount of stock shorted) is the same. SF and SI are often used interchangeably, hence it is important to have established a difference between the two. In the

European large financial centres[5], which account for about 70% of the observations in the WRDS short dataset, the average float of shares over the period August 2015 until November 2019 was estimated to be 63% of the outstanding shares (Oxera Consulting LLP, 2020). Oxera Consulting LLP (2020) investigated these European equity markets for the European Commission and state that the float can be important to provide enough stocks at a given time when required, where smaller firms often have lower free float available for trade. Per Kyle's (1984) model, this implies a low float can play a role in a higher probability of a short squeeze, hence it is relevant for the interpretation of our results.

3.2 Databases

Using WRDS one can obtain a cleaned-up aggregate of European short positions above 0.5% of the outstanding stock that are publicized under EU236 (WRDS Research Team, 2022). In table A1 in Appendix A the dataset is given a brief description regarding the variables as well as some noteworthy comments regarding these variables. Note that data is excluding EU countries Bulgaria, Croatia, Cyprus, Estonia, Latvia, Lithuania, Malta, Portugal, Romania, Slovakia and Slovenia. Another observation from table A1 is that the dataset includes data on stocks issued in the UK market, while the UK exited the EU per 31st of January 2020. As, per the manual of this dataset, the UK has most observations under EU236 (WRDS Research Team, 2022) and the research question is not limited to spill over effects into EU countries, it will be included in this research. On a legislative note, upon the exit of the European Union the UK adopted the amended EU236 legislation, where there were no changes regarding the publication threshold and calculation of the net short positions (HM Government, 2023). Hence, the calculation and publication requirement are identical to that expressed in EU236 and we can keep using UK data in the WRDS European short data.

Per recommendation of the WRDS Research Team (2022) CompuStat Global will be used to supply for missing ISINs, GME stock data, as well as providing complementary stock data. More specifically, it will be used to retrieve the daily closing price and total amount of outstanding shares for each shorted stock.

3.3 Event window

While Ahmad et al. (2022) do not mention a specific event window, they do use data ranging from the 1st of November 2020 up to and including 31st of March 2021 without a supporting argument or explanation for using this range. This range is to a certain extent in line with Jakab (2022) who describes popularity of the subreddit starting in 2020 and the 'heart of [the] meme-stock

[5] Large financial centres include France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden and the UK. Based on Oxera Consulting LLP (2020).

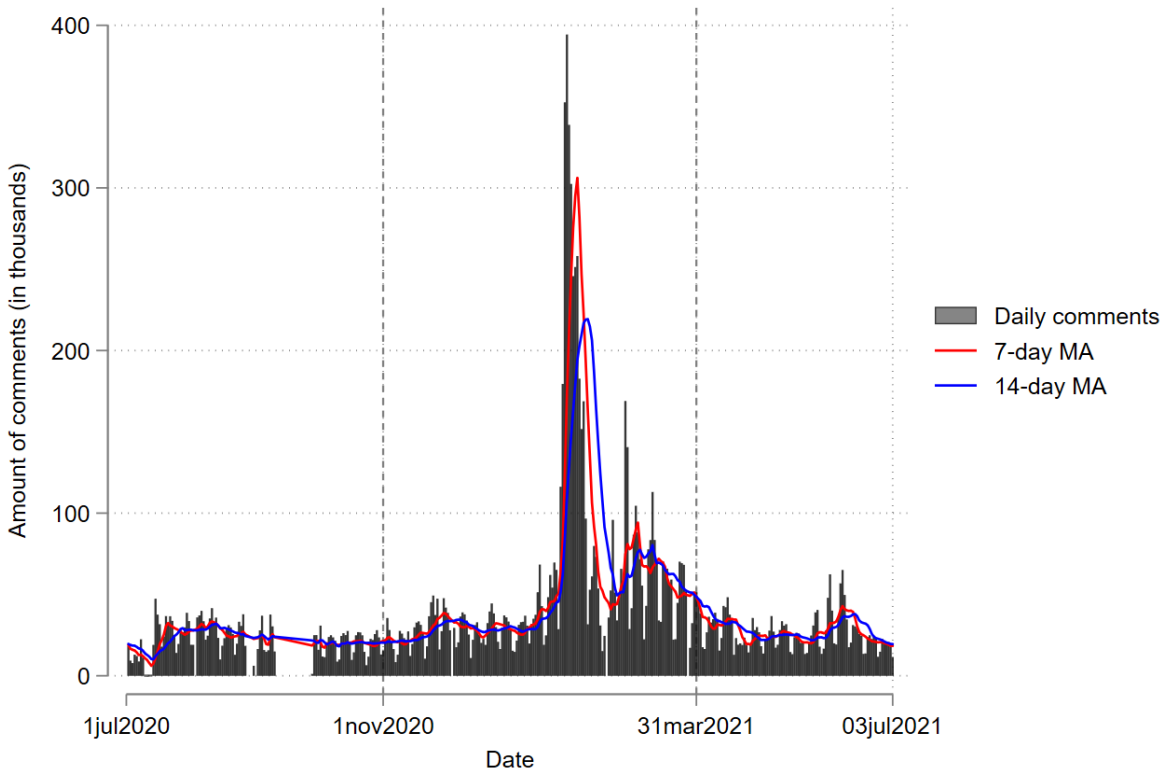
mania' ending in the beginning of February, specifically lasting from January 24th 2021 until February 4th 2021. The website *subredditstats.*com (2023) provides public access to data of these subreddits of Reddit, although it should be noted the reliability of this website is debatable and should merely provide as guidance/indicative data. Through this website we obtain the number of comments per day on the r/wallstreetbets subreddit and, as seen in figure 1, this date range and event window seem appropriate. Combining this information, the established date range to inspect will be 1st of November 2020 – 31st of March 2021 with the event window January 24th 2021 until February 4th 2021. However, we will perform data cleaning and adjustments on the entire dataset.

3.4 Cleaning the data

According to the WRDS Research Team (2022) the dataset already accounts for some errors but other researchers should be aware of some other imperfections that exist in the available dataset, which are caused by the facts that they aggregate all European dataset into one. The WRDS Research Team mentions the following data inconsistencies: missing ISINs, positions reported as number of shares, stricter thresholds and extreme values. In Appendix B an extensive step-by-step overview is given of how the final dataset is composed and how data was cleaned/filtered.

Figure 1.

Number of daily comments (in thousands) on the r/wallstreetbets subreddit. MA = Moving average. Data obtained per 19th of February 2023 from https://subredditstats.com/r/wallstreetbets.



The first and most noticeable imperfection is due to missing ISINs (i.e. International Securities Identification Numbers) which will highly affect the quality and consistency of the dataset if not addressed before the complementary stock data is added, since the ISIN is a unique identifier. Per advise of the WRDS Research Team the CompuStat Global dataset is used to link these missing ISINs through fuzzy company name matching, also known as approximate string matching. There are various techniques in fuzzy matching but we stick to two: matching strings based on character limits and the *matchit* STATA command that uses the *bigram* technique for fuzzy matching. In short, this *matchit* technique provides a similarity score between the string variables of the issuer of the stock (e.g. 'SAAB AB') between the two datasets. It does this by splitting the strings into 2-character strings (e.g. 'SA', 'AA', 'AB', etc.), compares these between datasets and gives a score between 0 and 1, where 0 is not similar at all and 1 is exactly similar. Unfortunately, the WRDS European Short data dataset contains issuers like 'SSP GROUP PLC' and 'WSP GROUP PLC', which will have a similarity score of 0.93 but are not the same. Therefore, it is unreliable even when the reported similarity is high and similarities above 0.95 are few. Therefore, we first move towards identical strings based on character limits. The method used is to limit characters of the *issuer* variable that contains the name of the company in the short data dataset whenever no ISIN is present. We start with 20 characters (e.g. '*International Business Company*' becomes '*International Busine*') and compare it to the CompuStat Global issuer name. When the ISIN is still missing we check 15 characters, then 10 characters and finally 7 characters. Before any of this, we start with 10,769 observations of missing ISINs. After *matchit* and the matching using character limit this went down to 302. When merging stock data using CompuStat Global a large portion of information is missing, almost 12.62%. This is largely due to ISINs of issuers of the shorted stocks not being found in the CompuStat Global dataset, whereas only 1% of found ISINs have missing values in the CompuStat Global dataset itself. A full overview of this process is given in table A2 in Appendix B.

The next shortcoming in the dataset manual is caused by position holders reporting their position in the amount of shares shorted. However, there is no trace of this in the used dataset for this research.

Another inconsistency is the difference in reporting/publishing thresholds among countries. An example is Belgium requiring reporting every 0.01 percentage point increase instead of the general 0.1 percentage point, therefore having more observations in the dataset than any other country and about 25% of the entire dataset. The WRDS Research Team (2022) leaves it up to researches to filter Belgian observations of necessary. In this research we will not adjust Belgian observations since it should not affect the interpretation of our performed methods, in fact, it could provide more datapoints to determine changes since we have a more detailed view of change in

shorting behavior. Only when interpreting the results between countries, this should be accounted for.

The next imperfection is the existence of extreme values that can be observed through really high net short position values. It is not a straightforward operation of removing certain high positions since values do not exceed 100 or obvious outliers, rather some high values seem to be in line with previous reported positions. Only 5 running positions of a total of 16,617 position account for values above 30%, therefore a manual check is viable. We drop one position that enters with a 100% short position and fully exits two days later. We observe two positions where one can safely assume an entry error since position hover around 0.5% and 1% with one observation moving above 70% and immediately going decreasing back to below 1%. For these two observations we divide the outlier by a factor 100. The remaining two are less obvious errors since previous positions are also tens of percentage points. Because of this insecurity of an error, these two remain in the dataset.

About 87.24% of the short positions can be complemented with accompanying stock data of price and amount of outstanding shares, while we only had to drop about 1% of the total observations due to no matchable ISIN or company name. This means that the bottleneck is that about 12% of the ISINs are not found in the CompuStat Global dataset. The stock price data from CompuStat Global was not uniform in terms of currency. In order to be able to compare them the currencies were all converted to EUR (€) using GFD data on exchange rates.

3.5 Descriptive statistics

Once the data has been cleaned and prepared for analysis a descriptive overview can be generated. In table 1 a descriptive summary is given for relevant variables during the data range 1st of November 2020 – 31st of March 2021, since this is the relevant date range. Two metrics are displayed per date and per ISIN per date: aggregate short positions and short volume (SV). The aggregate short positions sums the running short positions per date (per ISIN per date) in percentage points (pp). That is, if on the 1st of January 2020 there are 10 short positions of 1% of various ISINs the aggregate short position at the date will be 10pp. The aggregate short positions per ISIN per date is the sum of active short positions per ISIN per date the ISIN shows in the dataset. From table 1 we can conclude that the mean of aggregate short positions per date was 2112.057pp during the period 1st of November 2020 until 31st of March 2021. For the short volume this would be €82.395 bln. If one looks at the aggregates per ISIN per date the mean short position is 5.038pp and an average SV of €167.967 mln. For the 108 data entries (for 108 different dates) the standard deviations (SDs) are relatively low compared to the SDs for the metrics per ISIN per date, which

indicates that there is variation in the metrics among the different ISINs. Where the mean SV per ISIN per date is €167.967 mln, with a maximum of €4,698.627 mln.

Table 1

Descriptive data for short positions and short volume. Split up into aggregate, per date and per ISIN.

	N (# of obs.)	Mean	SD	Median	Min	Max
Short position (pp)	8,404	0.876	0.598	0.680	0	6.210
Aggregate short positions per date (pp)	108	2,112.057	54.240	2,132.242	2,038.955	2,211.134
Short volume per date (€ bln)	108	82.395	1.001	82.485	80.721	84.380
Aggregate short positions per ISIN per date (pp)	6,808	5.038	4.190	3.860	0	28.610
Short volume per ISIN per date (€ mln)	6,808	167.967	274.338	77.541	0	4,698.627

Another variable of interest is the distribution of observations among position holders. In figure 2 the five position holders with most observations are laid out, earning the title most active short sellers in the European equity markets. The short sellers are analyzed as displayed in the WRDS European Short data dataset, hence similar investment firms for different countries may appear (e.g. Citadel Advisors LLC (US) and Citadel Europe LLP (UK) are both linked to Citadel Group). The largest holders of short positions are large (alternative) investment management firms, which can be expected. The positions seem to be spread out across various short sellers to reasonably assume there is a wide variety of position holders and no major influences of single (or few) position holders.

In figure 3 one can observe the two aggregate variables for net short positions and short volume per date with the date range (red dashed lines) and event window (grey dashed lines) tagged by the lines.

Figure 2.

Five most active short sellers in the European equity market as appearing in the WRDS Euorpean Short Data dataset based on data from 1st of November 2020 up to and including 31st of March 2021.

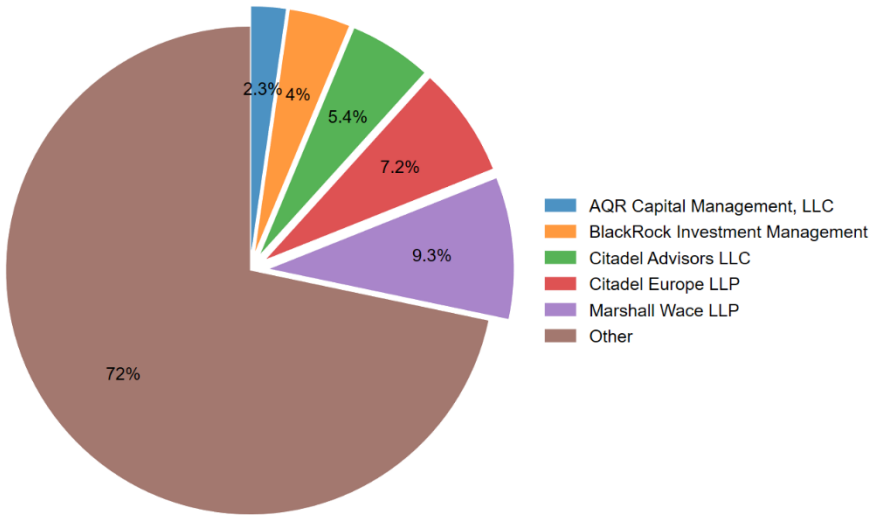
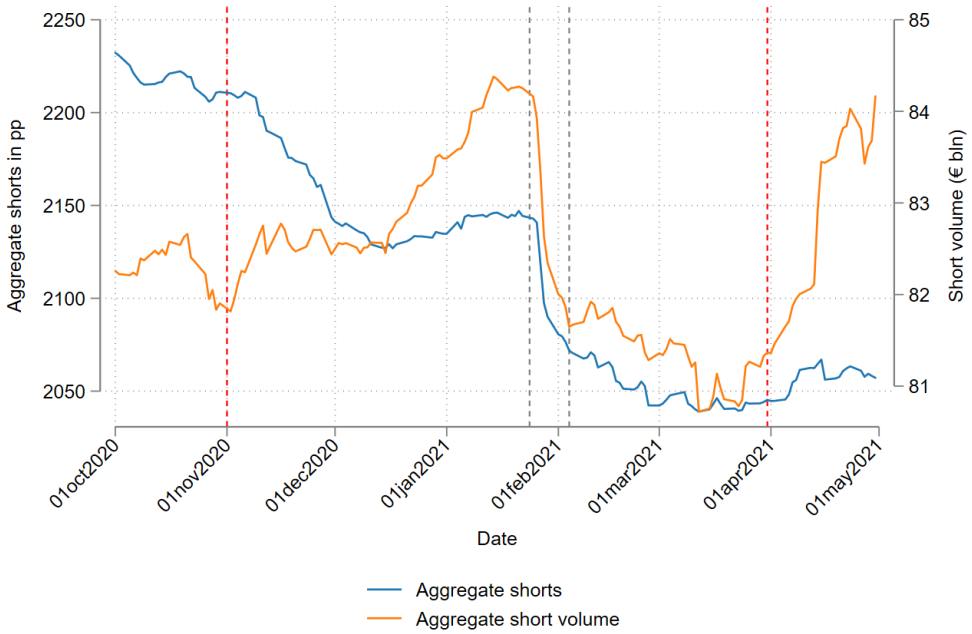


Figure 3.

Aggregate short positions and short volume against time. Dashed red lines show range of 1st of November 2020 up to and including 31st of March 2021. Grey dashed line is event window of the GameStop short squeeze.



4. Methodology

In order to be able to test the three hypotheses the methods for this need to be addressed. This will be done in this section. First, the problems are stated again and a brief description of *what* needs to be tested. Then, the method(s) will be described.

4.1 Difference on aggregate and stock level

The first hypothesis states that the GameStop short squeeze caused short positions in the European equity markets to decrease on an aggregate level. In other words, we need to test whether these short activities were different post-event compared to pre-event. Two accompanying null hypotheses $H1.1_0$ and $H1.2_0$ are formulated that state there is no difference in the short positions and short volume before and after the GameStop short squeeze. To test these null hypotheses a before and after period is established, based on the earlier argued date range and event window. Therefore, short positions between the 1st of November 2020 and the 23rd of January 2021 are considered *pre-event*, while positions between the 5th of February 2021 and 31st of March 2021 are considered *post-event*.

Before applying a method to test for significance in differences, an appropriate test needs to be established. First, a Shapiro-Wilk test for normality is performed on the percentage change per date for both metrics (aggregate shorts per date & SV per date) during the date range which concludes the rejection of the assumption (H_0) of normal distribution for those metrics during the date range (Prob>z = 0.000000 for $\Delta_{\text{aggregate shorts}}$; Prob>z = 0.00000 for $\Delta_{\text{aggregate SV}}$). The Central Limit Theorem (CLT) states that a random, independent and large enough sample size will always show a normally distributed sampling distribution of a mean, while our metrics for change in aggregate shorts per date and SV per date do not satisfy this. This violation of normality has impact on the accuracy of statistical test results even though the CLT still applies because of the law of large numbers that states the sample mean will approach the true mean the larger the sample size.

Since normality is rejected for aggregate shorts per date as well as SV per date, the appropriate tests are nonparametric tests. We can test $H1.1_0$ and $H1.2_0$ by using the nonparametric two-sample test on the equality of medians which tests the null hypothesis that the two samples (pre- and post-squeeze) are from the population with the same median. Specifically, the tests takes the two samples and its median and then compares all observations in the two samples to this median. Observations are categorized based on whether they are above, below or equal to the median and the results are tested using a Pearson's $\chi 2$ test. Rejecting the null hypotheses accompanying this test would suggest significant different means in the two metrics (aggregate

shorts per date & SV per date) before and after the GameStop short squeeze. The test will be performed for the aggregate short positions per date in percentage points ($H1.1_0$) as well as short volume per date in EUR ($H1.2_0$), where for both metrics sample size N equals the amount of data entries (days) in the dataset.

H1: *The GameStop short squeeze caused short activity in European equity markets to decrease on an aggregate level.*

$H1.1_0$: *There was no significant difference in the median aggregate short positions after the GameStop short squeeze relative to pre-event short positions.* $M_{Shorts\ before} = M_{Shorts\ after}$.

$H1.2_0$: *There was no significant difference in the median aggregate short volume after the GameStop short squeeze relative to pre-event short positions.* $M_{SV\ before} = M_{SV\ after}$.

4.2 Difference between different levels of shorted stocks

The second hypothesis proposes that stocks with a higher pre-event short interest (SI) saw a stronger decline in the amount of shorted stock post-event. For stocks with a lower pre-event number of shorted stocks a positive difference is expected post-event. This research will also look at the short volume (eq. 3) to assess for differences in SV. This method is based on Ahmad et al.'s (2022) process to find spill over effects of the GameStop short squeeze into US stocks. A testable null hypothesis $H2_0$ is formulated for both metrics which expects there to be no difference in short squeeze effect among stocks with different levels of SI pre-event. In other words, if any effect is observed this effect is uniform across categories instead of a differences in effects between categories. The one sample t-test will be performed to test for significant differences for both hypotheses.

$$SV_{i,t} = SI_{i,t} * F_{i,t} * S_{i,t} \quad (3)$$

$where\ i = stock, t = time, SI_{i,t} = Short\ Interest, F_{i,t} = Oustanding\ shares, S_{i,t} = Stock\ price$

H2: *The GameStop short squeeze caused short positions in European equities with higher pre-event short interest to decrease in short interest, vice versa for equities with lower pre-event short interest.*

$H2.1_0$: *There is no difference between the various levels of pre-event shorted stock and their respective event effect using SI.* $\Delta SI_i = \Delta SI_j, where\ i\ and\ j\ are\ different\ pre-event\ SI\ categories.$

$H2.2_0$: *There is no difference between the various levels of pre-event shorted stock and their respective event effect using SV.* $\Delta SV_i = \Delta SV_j, where\ i\ and\ j\ are\ different\ pre-event\ SI\ categories.$

While Ahmad et al. (2022) use short *float* (SF), there is no exact match in terms of data since the float of stock is not provided by CompuStat Global. Hence, we will use the amount of outstanding stock to analyse the short *interest* (SI). Although, as stated earlier, this is merely a difference in terminology, it should be mentioned this research will use the number of outstanding shares. First, the stocks are split into categories based on the different levels of pre-event SI. Descriptive data regarding the SI of these categories are compared with the same descriptive data post-event. When a stock is in the 'low SI' category pre-event its values will be accounted for in the post-event 'low SI' category even though its SI became high enough post-event for another category. This allows for testing whether, as in line with the described squeeze model by Kyle (1984), stocks with a higher probability (as measured by SI) of a squeeze observe higher levels of covering. This expected effect as described in H2 could be further supported by Jakab's (2022) observation that retail investors sought stocks with high SI to squeeze.

$$[Short\ Interest]_{i,t} = \frac{[Amount\ of\ shares\ shorted]_{i,t}}{[Amount\ of\ shares\ outstanding]_{i,t}} \quad (2)$$
$$i = stock\ i, t = time\ t$$

4.3 Detecting a shift in risk awareness

As stated earlier, if found that there is a significant difference in post-event short positions it would be up to interpretation whether this is actually due to a shift in risk awareness as observed by Ahmad et al. (2022) in the case of US shorting behaviour. In equation 4 the price effect and quantity effect are described using the formula for Short Volume (SV) as originally described by Ahmad et al.

$$\Delta SV_{t1,t2} = \underbrace{(SF_{t2} * F_{t2} - SF_{t1} * F_{t1}) * S_{t1}}_{Quantity\ effect} + \underbrace{(S_{t2} - S_{t1}) * SF_{t2} * F_{t2}}_{Price\ effect} \quad (4)$$
$$where\ \ t = time, SF_t = Short\ Float\ F_t = Float\ of\ stock, S_t = Price\ of\ stock$$

In the context of European stocks there is no data available to me on total SI of stocks and only data on large short positions. Besides this, Ahmad et al. (2022) use the SF rather than the SI, hence it is correct to call it the SF of stocks that they analysed. Using the publicly available data of short positions on European stocks one can calculate the SV as well and, thus, also dissect it into the QE and PE if one obtains the relevant variables. Hence, we adjust equation 4 and formulate a new equation 5:

$$\Delta SV_{i,t1,t2} = \underbrace{(SI_{t2} * F_{t2} - SI_{t1} * F_{t1}) * S_{t1}}_{Quantity\ effect} + \underbrace{(S_{t2} - S_{t1}) * SI_{t2} * F_{t2}}_{Price\ effect} \quad (5)$$
$$where\ i = \ stock, t = time, SI_t = Short\ Interest, F_t = Oustanding\ shares, S_t = Stock\ price$$

Using equation 4 we can dissect the difference in SV (post-event compared with pre-event SV) into the quantity effect (QE) and price effect (PE) per stock. Then the effects can be inspected on

an aggregate level and a stock level based on levels of pre-event short interest. Especially QE during the squeeze ($QE_{squeeze}$) is of interest since it provides as an indication whether a decrease in SV is due to a shift in risk awareness caused by the squeeze (Ahmad et al., 2022). The PE will indicate what part of the change in aggregate SV per date is due to a change in prices of stocks. Using this, a testable null hypothesis $H3_0$ can be established that states the quantity effect is zero.

H3: *The GameStop short squeeze caused short sellers in European stocks to adjust their strategy as they became aware of tail risks of short selling.*

$H3_0$: *The quantity effect (QE) during the GameStop short squeeze, part of the change in aggregate SV, did not differ significantly from the observed mean/median before the squeeze.* $QE_{squeeze} = 0$

Finally, the second and third hypotheses will be combined to assess whether the QE during the GameStop short squeeze was different among the various categories of pre-event SI. This is of interest since it provides another insight into differences in spill over effects among those categories. To test for this, a one sample t-test is performed to assess whether the mean QE per category during the squeeze was different from a hypothesized mean of 0. Then, the significant result(s) can be compared to assess differences.

5. Results

The first null-hypothesis addresses the difference of the aggregate shorting behaviour in the European markets after the GameStop short squeeze. The methodology to test this requires us to prepare the data as described in the Data section and Appendix A2.

First, $H1.1_0$ and $H1.2_0$ are tested using the nonparametric two-sample test on the equality of medians since the Shapiro Wilk test rejects normality for both changes in aggregate shorts and changes in aggregate SV per date. The two-sample tests on the equality of medians can be seen in table 2. This table shows the probabilities that the medians of pre-event aggregate shorts and short volume were equal to the post-event medians. As seen in table 2 we reject the null-hypotheses $H1.1_0$ and $H1.2_0$ and, thus, it suggests different medians of aggregate short positions and short volume for European stocks in the immediate period after the GameStop short squeeze. Moreover, the alternative hypotheses (H_α) of the two-sample tests on the equality of medians indicates the medians post-event aggregate short positions and SV are drawn from a population with a different median than the pre-event median. To assess whether this difference in shorting position is attributable to the squeeze period (*During event* in table 2) we can analyse the differences using the same methodology. Table 2 shows the differences of these variables during the squeeze as compared to the pre-event period. We reject the null-hypotheses at a 1% confidence level that state the medians of the differences of the variables during the squeeze were similar to the pre-event differences. We observe a significant decrease in the medians of aggregate shorts and SV after the short squeeze of 98.583pp (-4.60%) and €1.342bln respectively (-1.62%).

The results for the date range (as seen in table 2) only allow for interpretation on the short-term spill over effects of the GameStop short squeeze onto European shorting activity. If we extend figure 3 (displayed in figure 4) one can observe the levels of aggregate short positions and SV beyond the selected date range (as indicated by the red dashed lines). On this scale, the decrease in SV due to the GME short squeeze (as indicated by the grey dashed lines) is observable but not as strong as during the start of the COVID-19 pandemic in 2020. Besides that, soon after the 31st of March 2021 the aggregate SV recovered to pre-squeeze levels. This is less apparent for the amount of aggregate short positions.

Table 2

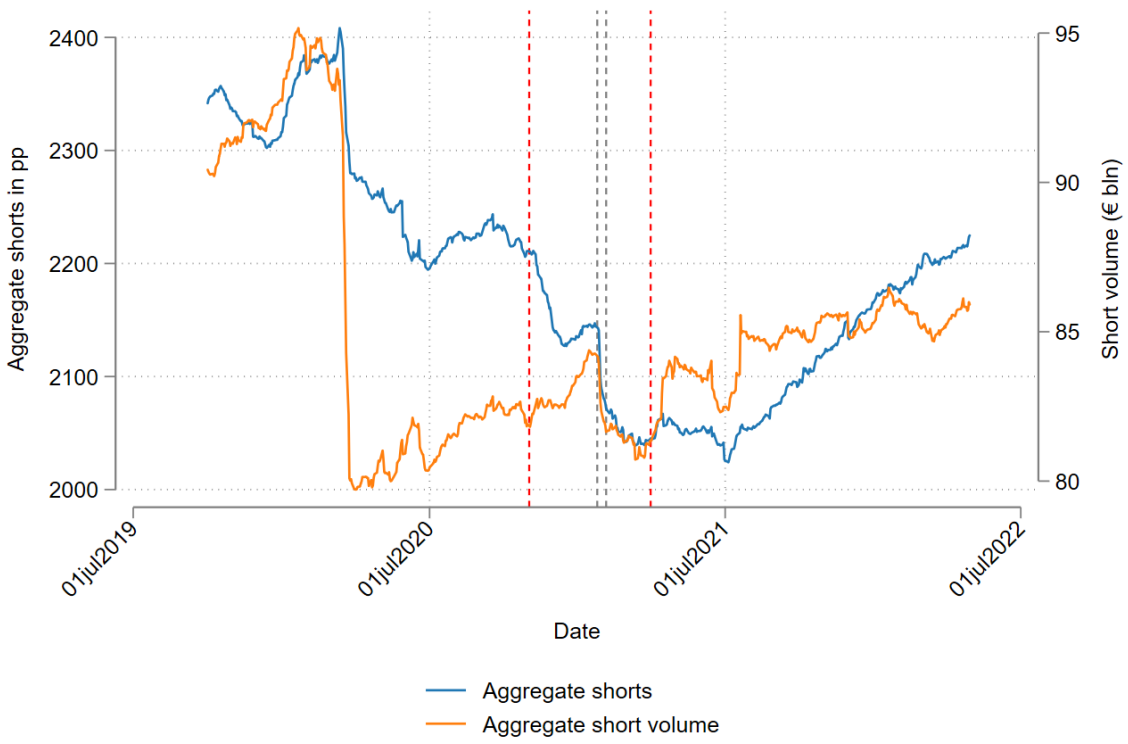
Results of the two-sample test on the equality of medians tests for four different variables. N (days) equals to amount of observations which equals amount of days (with data).

			# of observations		H_0
	N (days)	**Median**	**≤ Median**	**> Median**	**Prob([Median]$_{t1}$ = [Median]$_{t2}$)**
Aggregate shorts	99	2133.338 pp	51	48	
Pre-event	60	2143.990 pp	12	48	0.000***
Post-event	39	2045.407 pp	39	0	
Aggregate short volume	99	€82.500 bln	50	49	
Pre-event	60	€82.708 bln	11	49	0.000***
Post-event	39	€81.366 bln	39	0	
Δ Aggregate shorts	69	-0.048%	35	34	
Pre-event	60	-0.033%	26	34	0.000***
During event	9	-0.224%	9	0	
Δ Aggregate short volume	69	0.015%	35	34	
Pre-event	60	0.062%	26	34	0.002***
During event	9	-0.283%	9	0	

Note: */**/*** indicate significance at 10%/5%/1% significance levels respectively.

Figure 4.

Aggregate short positions and short volume against time. Dashed red lines show range of 1st of November 2020 up to and including 31st of March 2021. Grey dashed line is event window of the GameStop short squeeze. Extended version of fig. 3.



The second sub-question examines whether these observed effects are different among different levels of pre-event short interest, the null hypothesis $H2_0$ stating that there is none. These levels of SI are measured in the date range pre-event and split into various levels. First, they are split into eight categories based on the level of SI pre-event, as seen in table 3. Then, in the post-event period the change in SI per category is observed. In figure 5 one can see the boxplots of the differences in SI per level of pre-event SI where the increasingly negative change in SI can be observed among various categories. In contrast with Ahmad et al. (2022) our results are not significant, only observing significant differences for SI at pre-event SI categories between 1% and 2% and categories between 3% and 20%. While we reject $H2.1_0$ that states there is no difference between categories, the differences are not as explicit as observed in US stocks (Ahmad et al., 2022). We observe a stronger relative negative effect among stocks with pre-event SI between 10% and 20% compared to the categories with lower pre-event SI.

Table 3

Splitting pre-event SI into various categories and analysing their mean difference in SI over the pre-event (01 November 2020 – 23 January 2021) and post-event (24 January 2021 – 4 February 2021) periods. N = unique ISINs recorded in category. Rounded to three decimals.

SHORT INTEREST		Pre-event		Post-event		Mean difference	Testing	
SI Category	**N (# of ISINs)**	**μ_{SI}**	**SD**	**μ_{SI}**	**SD**	**Δ μ_{SI} (%)**	**T**	**P-value**
Overall	**443**	**3.530**	**3.727**	**3.235**	**3.454**	-0.295 (-8.36)	-1.222	0.222
0 ≤ SI < 0.5%	31	0.355	0.214	0.505	0.547	0.150 (42.39)	1.426	0.164
0.5 ≤ SI < 1%	63	0.750	0.169	0.733	0.303	-0.016 (-2.19)	-0.375	0.709
1 ≤ SI < 2%	96	1.387	0.290	1.296	0.437	-0.091 (-6.57) *	-1.701	0.092
2 ≤ SI < 3%	85	2.513	0.293	2.429	0.658	-0.084 (-3.36)	-1.081	0.283
3% ≤ SI < 5%	74	4.077	0.625	3.735	1.002	-0.342 (--8.40) **	-2.494	0.015
5% ≤ SI < 10%	66	6.994	1.463	6.294	1.569	-0.700 (-10.00)***	-2.649	0.010
10% ≤ SI < 20%	25	12.595	2.183	10.878	3.697	-1.717 (-13.63) **	-2.000	0.057
SI ≥ 20%	3	26.851	2.402	25.525	2.557	-1.326 (-4.94)	-0.655	0.559

Note: */**/*** indicate significance at 10%/5%/1% significance levels respectively.

Now, while the change in SI is not significant for all categories one can also look at the change in SV per category of pre-event SV. In table 4 the change in SV is displayed per category and we observe no significant results. That is, there is little evidence to support a significant difference in change in SV among various categories of pre-event SI.

Figure 5.

Difference in short interest (pp) after the short squeeze as compared to pre-event short interest levels split into categories as seen in table 3.

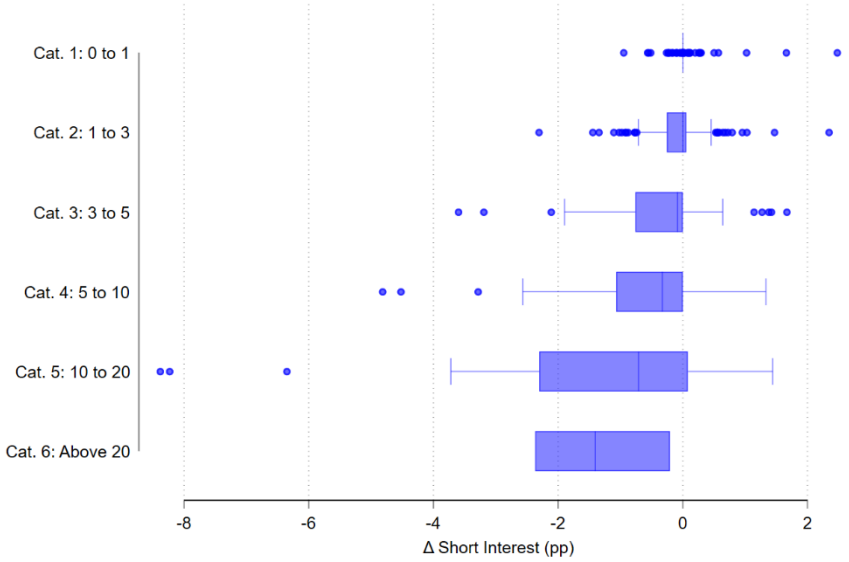


Table 4

Splitting pre-event SI into various categories and analysing their mean difference in SV over the pre-event (01 November 2020 – 23 January 2021) and post-event (24 January 2021 – 4 February 2021) periods. N = unique ISINs recorded in category. μ and SD are in €mln.

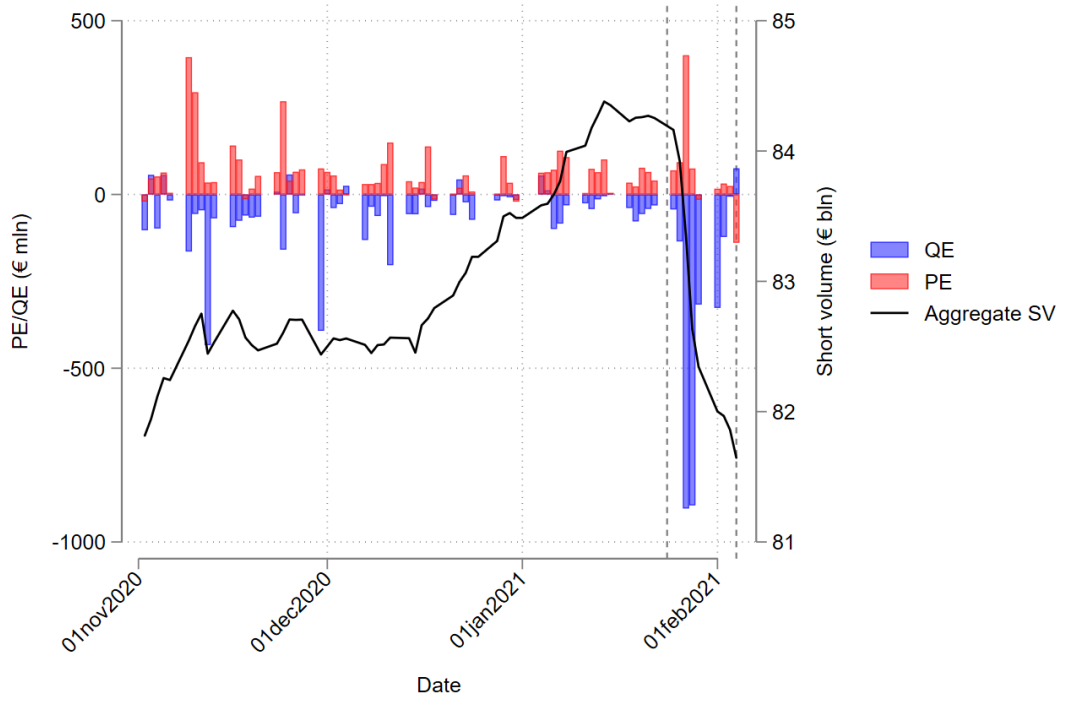
SHORT VOLUME (€ mln)		Pre-event		Post-event		Mean difference	Testing	
Short interest level	**N (# of ISINs)**	**μ_{SV}**	**SD**	**μ_{SV}**	**SD**	**Δ μ_{SV} (%)**	**T**	**P-value**
Overall	**443**	**130.158**	**274.338**	**129.473**	**273.230**	-0.685 (-0.53%)	-0.037	0.970
0 ≤ SI < 0.5%	**31**	11.438	25.873	16.041	29.839	4.603 (40.24%)	0.649	0.521
0.5 ≤ SI < 1%	**63**	17.443	24.704	16.556	25.270	-0.887 (-5.09%)	-0.199	0.843
1 ≤ SI < 2%	**96**	57.096	66.552	57.529	72.483	0.433 (0.76%)	0.043	0.966
2 ≤ SI < 3%	**85**	109.567	150.051	117.725	168.535	8.158 (7.45%)	0.333	0.740
3% ≤ SI < 5%	**74**	170.005	237.516	161.723	216.983	-8.282 (-4.87%)	-0.221	0.825
5% ≤ SI < 10%	**66**	211.525	257.066	217.514	290.048	5.989 (2.83%)	0.126	0.900
10% ≤ SI < 20%	**25**	540.993	802.676	500.253	787.654	-40.740 (-7.53%)	-0.181	0.858
SI ≥ 20%	3	448.797	277.934	485.677	259.118	36.880 (8.22%)	0.168	0.877

Note: */**/*** indicate significance at 10%/5%/1% significance levels respectively.

The third hypothesis has accompanying $H3_0$ that states the quantity effect of the difference in short volume is zero, expecting no shift in risk awareness. In figure 6 the development of the aggregate short volume is plotted against the price and quantity effect (eq. 5; PE and QE respectively). As visible, the decrease in the median aggregate short volume, which was found to be significant, is mainly attributable to the QE. The QE accounts for the negative effect during the squeeze, whereas PE shows a positive effect during the GameStop short squeeze.

Figure 6.

QE and PE plotted against the aggregate SV during 1st of November 2020 up to and including 4st of February 2021. Grey dashed lines indicate start and end of GameStop short squeeze.



Using a more formal way to test whether this supposedly negative QE is significant we can perform tests for similar means of QE in the period before the squeeze and during the squeeze. First, we assess normality using the Shapiro-Wilk test for the average quantity effect per date during the period 1 November 2020 – 4 February 2021 and reject normality at a 1% confidence level. Hence, we use the nonparametric two-sample test on the equality of medians which tests the null hypothesis that the two samples (pre- and during the squeeze) are from the population with the same median and the results are displayed in table 5. As visible, we can reject $H3_0$ at a 10% confidence level but we compare 9 observations to 60 observations which can cause inaccuracy in findings, but are suggestive of a lower median quantity effect during the GameStop short squeeze. Additionally, a Welch's t-test (since variances are not equal) is performed to test for mean difference and its results are visible in table 6. The results of the Welch's t-test indicate that $H3_0$ can be rejected at a 10% confidence level as well as a strong indication (at a 5% confidence level) of a lower QE during the squeeze (i.e., more negative in the squeeze period). Thus, $H3_0$ is rejected and the Welch's t-test provides significant suggestive statistics of the alternative hypothesis of a more negative QE during the squeeze compared to before the squeeze.

Table 5

Results of the two-sample test on the equality of medians tests for the quantity effect (QE). N (days) equals to amount of observations which equals amount of days (with data).

		in €mln	# of observations		H_0
	N (days)	**Median**	**≤ Median**	**> Median**	**Prob([Median]$_{t1}$ = [Median]$_{t2}$)**
Quantity effect (QE)	69	-41.747	51	48	
Pre-event	60	-37.492	28	32	0.082*
During event	9	-135.200	7	2	

Note: */**/*** indicate significance at 10%/5%/1% significance levels respectively.

Table 6

Welch t-test for the quantity effect (QE) Comparing the before (01 November 2020 – 23 January 2021) and squeeze (24 January 2021 – 4 February 2021) periods. N (days) equals to amount of observations which equals amount of days (with data).

QE (in € mln)	**N (days)**	**μ**	**SD**
Combined	69	-82.666	20.553
Before	60	-50.500	11.092
Squeeze	9	-297.108	121.934
Difference (= μ_{before} - $\mu_{squeeze}$)		246.608	
Alternative hypotheses	**P-value**	**T**	**Welch's DF**
μ_{before} != $\mu_{squeeze}$	0.078*	2.014	8.166
μ_{before} > $\mu_{squeeze}$	0.039**		
μ_{before} < $\mu_{squeeze}$	0.961		

Note: */**/*** indicate significance at 10%/5%/1% significance levels respectively.

In table 7 the ten position holders that occurred the most significant QE during the squeeze period are displayed. Just two of the most active short sellers of the entire dataset appear (Marshall Wace LLP and Blackrock Investment Management (UK) Limited; see fig.2). D1 Capital Partners LP lost about 20% of its capital during January 2021 and was one of the biggest victims of the squeeze losing about $4 bln, as well as Maplelane Capital LLC being a victim of the short squeeze (Karsh et al., 2021). Melvin Capital Management LP was the biggest victim of the GameStop short squeeze, losing more than $1 bln per day at the height of the squeeze, and also became the main target of the retail investors on r/wallstreetbets (Jakab, 2022). As seen in table 5, these investment firms saw the highest covering of short positions in European listed stocks.

Table 7

Ten position holders with strongest Quantity Effect (QE) during the GameStop short squeeze (24th of January 2021 – 4th of February 2021).

Position holder	Δ_{SV} (€ mln)	QE (€ mln)
D1 Capital Partners LP	-493.633	-429.373
Melvin Capital Management LP	-208.983	-413.745
Lone Pine Capital LLC	-177.246	-204.778
Marshall Wace LLP	-317.125	-160.640
AKO Capital LLP	-142.161	-151.849
BlackRock Investment Management (UK) Limited	-94.706	-90.584
Immersion Capital LLP	-69.354	-79.944
Maplelane Capital, LLC	-4.250	-72.866
Viking Global Investors LP	-78.159	-58.019
Meritage Group LP	-37.017	-52.275

Combining the second and third hypotheses one can also question whether this QE is variable among different levels of pre-event SI. Hence, a one sample t-test is performed to assess whether the mean QE during the squeeze were significantly different from zero. In this case, we are not testing whether the mean is different from the pre-event mean QE, but rather whether the QE during the squeeze was significantly different from zero. The results are displayed in table 8 and for multiple categories a significant negative QE is observed during the GameStop short squeeze. The QE seems to get more important the higher pre-event SI level. This signals, per Ahmad et al. (2022), an adjustment of risk perception of the probability of short squeezes. When looking at the QE as a percentage of mean SV (per pre-event SI category), there is an indication that this is related to a larger mean SV per category. If one looks at the categories 1% to 2% and 10% to 20% one will find the QE as a percentage of SV was higher for the lower SI category (-3.40%) than the category containing higher pre-event SI stocks (-0.75%). This is of interest since one can reasonably expect, per Kyle's (1984) model, the covering to be stronger for stocks with higher probabilities of a short squeeze, which can be proxied by higher pre-event SI. More covering would cause a stronger decrease in SV due to decreasing short positions, which is the QE of the change in SV.

Table 8

Assessing, per pre-event SI category, QE of change in SV during the GME short squeeze. T-test tests whether μ_{QE} is equal to zero. N = unique ISINs recorded in category. Rounded to three decimals. Values in € mln.

Short interest level	**N (# of ISINs)**	**μ_{SV}**	**μ_{QE}**	**μ_{QE} as % of μ_{SV}**	**SD**	**T**	**P-value**
Overall	219	130.158	-2.192	-1.68%	11.343	-2.859	0.005***
0 ≤ SI < 0.5%	3	11.438	-1.473	-12.88%	2.256	-1.131	0.340
0.5 ≤ SI < 1%	14	17.443	0.164	0.94%	1.470	0.417	0.683
1 ≤ SI < 2%	40	57.096	-1.940	-3.40%	4.072	-3.012	0.004***
2 ≤ SI < 3%	42	109.567	-0.065	-0.06%	23.105	-0.018	0.985
3% ≤ SI < 5%	45	170.005	-2.633	-1.55%	4.580	-3.857	0.000***
5% ≤ SI < 10%	50	211.525	-3.602	-1.70%	7.561	-3.369	0.001***
10% ≤ SI < 20%	22	540.993	-4.035	-0.75%	7.803	-2.425	0.024**
SI ≥ 20%	3	448.797	-3.383	-0.75%	2.801	-2.092	0.127

Note: */**/*** indicate significance at 10%/5%/1% significance levels respectively.

6. Interpretation & Discussion

In the previous section the results were laid out and results indicated a rejection of most null hypotheses, except for $H2.2_0$. In the following section we will discuss the results on a deeper level as well as discussing limitations, potential improvements and implications.

Regarding our first hypothesis that there would be significant difference in aggregate short positions and short volume, one can conclude that European stocks observed a difference in short positions and short volume on an aggregate level. More specifically, the post-event median aggregate short positions and short volume were significantly lower than the pre-event aggregates as seen in table 2, suggesting the GameStop short squeeze, between the *before* and *after* periods, caused those metrics to decrease. Supporting evidence for this was found in rejecting the null-hypotheses that the differences (for aggregate short positions and SV) are similar to the pre-event period and for the difference in SV there is significant evidence that the before periods endured higher differences. In other words, it suggests that the GameStop short squeeze triggered a decrease in SV during the squeeze itself as well as rejecting the idea that the level of aggregate shorts was the same as pre-event. In numbers, the median aggregate shorts decreased by 4.60% and the median SV decreased by -1.62%. Hence, we interpret our findings as significant indication of a change in shorting metrics (i.e., aggregate short interest & SV) triggered by the 2021 GameStop short squeeze. This would be in line with Kyle's (1984) model of short squeezes and the expectation of a reassessment of squeeze probabilities among shorted stocks, as perceived by the shorters. This results, through the supply and demand mechanism as described by Kyle, in this observed decrease in shorting metrics.

The second hypothesis expected, similar to findings of Ahmad et al. (2022) in US stocks, that the change in SI would be distinct among stocks with different levels of SI pre-event. While one can observe a significant decrease among stocks with pre-event SI levels between 3% and 20% (split in three categories), no effects are observed for low (<1%) and high (>20%) levels. Although it should be noted that the latter category shows few observations and, hence, we are limited in interpreting our findings. While these results make it hard to conclude we observe similar effects to Ahmad et al. (2022), the decrease in SI become more noticeable among positions with higher pre-event SI, at least up to 20%.Using Kyle's (1984) model of the squeezer, shorter and speculator we can interpret our findings as indicative of shorters covering more of their positions for stocks with higher pre-event SI. This suggests Kyle's description of the supply and demand like effect of short covering and probability of a squeeze holds for the categories that observe significant change. It is also indicative of the assumed relation of SI and probability of a short squeeze in European stocks since Kyle's

model predicts a higher probability of a short squeeze would see higher levels of covering. Hence, it is indicative of the GameStop short squeeze triggering the covering of short positions in European stocks of which the effects seem to have been stronger for highly shorted stocks.

The third stated hypothesis, which states that the QE of the change in SV is equal to zero, is a test to assess a potential change in risk awareness of short sellers triggered by the GameStop short squeeze. As laid out in the results section, the mean and median QE during the squeeze is significantly lower from the mean and median QE in the pre-event date range. Hence, it suggests the GameStop short squeeze triggered a shift in risk awareness among short sellers in European stocks. This shift can be interpret as a reassessment of the probability of a short squeeze where probabilities were deemed higher than the earlier assumed probabilities. This was theorized through the assumption of the relevancy of Kyle's (1984) model and these findings are in line with the predictions of this model.

An additional explored area of shorting activity is combining the second sub-question with the third sub-question. More specifically, this paper analysed whether there has been a significant difference in QE of difference in SV among various levels of pre-event SI. In table 7 the results were outlined and significant negative mean QE levels were found for multiple categories, as well as on the overall level. While no difference in sign was observed (i.e. positive vs. negative QE) the size of mean QE varies among categories. In the higher pre-event SI categories the QE becomes more negative (i.e. a stronger QE effect) when the pre-event SI category is larger. This means that while the QE shows a change in risk awareness among short sellers it is contrary to the expectation of the change in risk awareness being more severe among stocks with large pre-event SI. Hence, it remains up to further research to determine whether the QE is an appropriate measure for a change in risk awareness. Additionally, Ahmad et al. (2022) do not examine whether QE differs among the various categories of pre-event SI levels and, thus, it is difficult to establish a conclusion whether our results regarding QE differs from the spill over effects of the GME short squeeze into US stocks.

Rejecting all null hypotheses allows for a reasonable assessment of spillover effects. In short, this research found significant differences among European short positions on an aggregate level and different pre-event SI levels during and after the GameStop short squeeze. Thus, it suggests the GameStop short squeeze did have significant impact on the development of those European short positions as well as the behavior of short sellers. The observed decrease in aggregate short positions and SV can, however, be argued to be the consequence of early warnings of a changing market environment rather than a change in behavior due to a shift in risk awareness triggered by the GameStop short squeeze (Garleanu et al., 2022). This suggests another potential cause for

decreasing positions, however the QE was significantly lower (mean and median) compared to the pre-event period which is to some extent contradictive to Garleanu et al.'s explanation for decreasing SI/SV. Besides that, a shift due to early signs of a changing market environment does not necessarily exclude spill over effects triggered by the GameStop short squeeze. Although our research observed significant changes in shorting activity in the immediate period following the GameStop short squeeze, it remains up for research whether this has any impact in the long-run activity by analysing a broader date range.

The stated interpretation of significant spill over effects should be considered to be limited due to limitations in the data. The available data on short positions mostly shows net short positions above 0.5%, meaning there is lack of knowledge of smaller short positions and, thus, a lack of information on actual levels of SI. This means that probabilities of short squeezes in European stocks are more difficult to estimate for short sellers and adds a layer of uncertainty. Besides this, using the amount of stock outstanding (short float), rather than the float (short float), might give an incorrect indication of actual probabilities of short squeezes since the float is usually lower (Oxera Consulting LLP, 2020). Improvement in future research on similar topics could be sourced from better datasets if available. Improved data does not have to be limited to the short positions itself, but also additional metrics that proxy probability of short squeezes, days to cover, using float instead of outstanding stock, etc. Another limitation in this research is the overlap of complementary data using CompuStat Global since about 12.63% of the reported ISINs could not be found in the CompuStat Global (entire) database and having to drop those observations. Hence, it is advised to use datasets with better overlapping data and/or use improved fuzzy matching techniques. As earlier stated, the publicly available short data is different from US data and, hence, there is potential for more suitable metrics. Besides this, the dissection of the change in SV (Ahmad et al., 2022) as seen in equation 4 is questionable in how we can interpret results since Ahmad et al. provide meager evidence to support that the QE of the change in SV is associated with a change in risk awareness.

7. Conclusion

In conclusion, this research provides evidence of spill over effects of the 2021 GameStop short squeeze on European short positions reported under EU236 and shorting activity. The results indicate a change in shorting activity during and the immediate period following the GameStop short squeeze. That means that, in line with expectations, the European markets observed significant spill over effects from the US GameStop short squeeze in various aspects. Medians of aggregate short positions and short volume significantly decreased (by -4.60% and -1.62% respectively) as compared to the pre-event period; differences in differences among various categories of pre-event SI stocks and significantly lower quantity effects (also different among categories). Besides that, the decrease in short volume is mainly contributable to the quantity effect of the difference in short volume, indicating a shift in risk awareness of short squeezes in European stocks, per Ahmad et al. (2022). While the findings suggest these spill over effects occurred its significance in terms of economic effects remains up for debate, since the long-run impact is unknown.

These findings are in line with expectations as established through the short squeeze model as described by Kyle (1984) and suggest a shift in risk awareness among short sellers triggered by the GameStop short squeeze. However, the interpretation of spill over effects is limited by the available data, which mostly shows net short positions above 0.5%. These findings add value in the field of researching European shorting activity and how overseas events affect this. Current research in this area is meager and this research provides a foundation for further examination of shorting activity or short squeezes. Future research in this area could benefit from improved datasets and additional metrics that proxy the probability of short squeezes. Overall, this research provides a foundation for further examination of shorting activity and short squeezes in the European market as well as analysing how European shorting positions developed during and after the GameStop short squeeze in 2021.

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Appendix A. WRDS European Short Data

Table A1. Descriptive data of the entire WRDS European Short Data dataset. (Source: WRDS)

Variable	Description	Type of data	Notes
country	Country of issuer	String	Includes United Kingdom
position_holder	Holder of (short) position	String	
issuer	Issuer of shorted stock	String	
isin	International Securities Identification Number of issuer	String	
position_date	Position date	Date	Starts at 26/03/2003
reporting_date	Reporting date	Date	Only 1,618 observations
net_short_position	Net short position	Numeric	
orig_short_position	Originally reported short position	Numeric	Never different than net_short_position or value is missing
NumPositions	Number of shares shorted in this position	Numeric	Only for Norway
Total observations:	305,375 (from March 2003 to January 2022)		

Appendix B. Preparing the WRDS European Short Data

Table A2

Preparation of the WRDS European Short Data dataset. This includes data cleaning and adding complementary data.

#	Action	Obs. with data	Obs. with data (%)
1.	Import WRDS Short data	313,037	100
2.	Use matchit to fill missing ISINs. Similarity score of atleast 0.85 is used.	313,037	100
3.	Merge complementary data from Compustat dataset based on ISIN (variable)	266,601	85.17%
4.	Use matching on character limits to obtain more ISINs. Using CompuStat dataset. Starting with 20 characters, then 15, then 10 and finally 7	266,601	85.17%
5.	Merge complementary data from Compustat dataset based on ISIN (like step 3)	273,438	87.35%
6.	Merge complementary data from Compustat dataset based on issuer (variable)	273,521	87.38%
7.	Drop position if any observation has missing ISIN	273,136	87.25%
8.	Remove duplicates	250,382	79.98%
9.	Drop positions with only one observation	250,032	79.87%
10.	Drop position with extreme outlier (1 position)	250,032	79.87%
11.	Merge FTSE and GME data	250,032	79.87%
12.	Convert currencies of short positions to EUR	250,032	79.87%
13.	Drop all data where one observation of position has no value for price or outstanding stock.	249,442	79.68%

Note: Observations with data is determined by the number of observations that contain the following data: net_short_position, stock price, outstanding shares and volume of the stock. Therefore, the number only changes after complementary data is added.