

Power of 280: Measuring the Impact of Elon Musk's Tweets on the Stock Market

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Abstract

This research aims to measure the extent up to which Elon Musk's Twitter posts may influence stock prices of companies tagged, specifically the essential market metrics such as price, volume, and returns obtained from listed stocks. Intra-day data from well-recognized data providers have been utilized, for a period of 900 minutes, ranging from -600 minutes to +360 minutes, with the 0th minute being the time of his tweet ($t=0$). The study incorporates an event study and has adopted sentiment analysis and cumulative abnormal returns and found a significant impact of his tweets on five of the eight events.

Keywords: Twitter, Elon Musk, sentiment analysis, cumulative abnormal returns, event study, stock market, the stock price

1. Introduction

Over the past few years, herding behavior on Twitter has increased by leaps and bounds, owing to a large number of users who tend to share their opinions and views regarding companies and the stock market, with the authors often sharing their mood or sentiment regarding the same (Nofer & Hinz, 2015). Besides, the past few

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years have highlighted the role of this micro-blogging site as a tool for broadcasting financial news and sentiments, which inarguably have an impact on the investor behavior and stock market movements across the globe which has led to herding behavior as well (Valle-Cruz et al., 2020).

Various studies have flagged several vital issues surrounding the usage of Twitter for publicising one's opinions concerning the market. Well-known figures ranging from world leaders to big investors hold power to determine a stock market's direction, which may even lead to systemic risk (Ajjoub & Zhao, 2020). The vast majority of users of Twitter tend to quickly get influenced by such posts and base their investing decisions on them; users who otherwise would predominantly rely on trusted mediums of financial news like televisions and newspapers (Ranco et al., 2014). It indicates the phenomenon of random walk theory (Horne & Parker, 2018).

One such personality who enjoys an upward of 45-million followers as of March 2021 on Twitter is Elon Musk, the founder of various popular companies including SpaceX, Tesla, The Boring Company and Neuralink. Having a massive fan following both online and offline, Musk is a 21st-century entrepreneur and business magnate whose business ideas revolve around innovative and future-ready operations.

The popularity of Musk amongst investors and their regard for his thoughts and opinions have an impact on every aspect of the stock market and economy (Vance, 2015). His tweets have often led to a characteristic fluctuation, primarily in the trading of Tesla, the world's most valuable automobile manufacturer. His tweet in 2018 regarding making Tesla a private company (Musk, 2018), led to a 6% increase in the stock price and \$14 billion was wiped-off of the carmaker's value after he opined that he thinks the share price is too high.

Given the dearth of research on Elon Musk's tweets' financial impact on various companies, it has become ever-necessary to understand the financial implications caused by using just 280-characters and how his words carry a force powerful enough to

influence the sentiments and trading decisions of investors and the public alike.

2. Review of Literature

In the recent studies revolving around investment strategies and practices, researchers have found a growing phenomenon of 'random-walk theory' which implies that historical financial data may not be relevant in forecasting future price movements. It supports the idea that fluctuations in the stock market about a stock's intrinsic value is random (Horne & Parker, 2018). Since the theory alludes to fluctuations in a stock's value in a random sense, it may be noted that an event extraneous to the organisation may also be considered arbitrary, resulting in the phenomenon of herding behaviour.

An instinctual behaviour of a human being as a social animal to stick together and confirm one's action consistent with that of a group is called herding mentality. This mentality is noted in every place of group activities like the stock market. Liu et al. (2019) examined the herd effect and concluded that individual investors' incomplete information and speculative motive are its main factors. In their findings, the preference factor is often manifested as the apparent irrational herd mentality and behaviour, which financial experts have begun to take as a crucial investment decision making factor for reference. Herding mentality can be found predominantly in new and emerging markets due to a lack of market participants or experience. Dang et al. (2016) suggested the existence of herding behaviour in the stock market by exploring the return and return dispersion of the Ho Chi Minh Stock Exchange (HOSE) of Vietnam between 2007 and 2015 as the stock exchange itself started in 2000.

As the study presents the influence of essential personalities and figures on investor sentiments and the stock market, several studies have been conducted on Donald Trump's Twitter activity during his tenure as the President of the United States of America. A study revolving around media and non-media companies and their impact on the stock market was conducted by Ajjoub & Zhao (2020), which used an empirical analysis on his tweets posted for

two years and found that "positive tweets have a pronounced positive stock price impact, whereas negative and neutral tweets have little or no effect. The President's attitude towards the news appears to play a major role in this context." Frydendahl & Stenger (2019) hypothesised that the President's Twitter usage affects the price movements of stocks in the stock market. They use the event study methodology to determine how Trump's tweets' opinions on targeted companies affect their stock prices. The research documents that Trump's positive company-specific tweets, on average, have a positive effect on the stock prices of the targeted companies on the day the tweet was posted.

Although studies revolving around Trump enabled researchers to highlight how his social media posts carried a force strong enough to influence the market, the media-driven sentiments also impact the pricing and returns of stocks. The same phenomenon was studied by Umar et al. (2021). The research examined the relationship between GameStop returns and its pricing, which is sentiment-driven, using a put-call ratio and short volume sale. The study concluded a positive relationship between GameStop returns and media-driven sentiments exists.

In the event above, the community's sentiment played an important role in contributing to the immense media coverage and drawing the attention of small traders and investors who aided in increasing GameStop Inc's valuation. It is imperative to understand the phenomenon of sentiment and how analysing the same becomes essential in forecasting stock market movements. To understand how inherent sentiments or emotions behind a text or a tweet may result in movements in financial markets, Yang et al. (2014) attempted to present empirical evidence of a presence of financial investment communities on Twitter, which found that the presence of like-minded users, within which influential Twitter users with a sizeable number of followers were present, provided a "proxy for the relationship between social sentiment and financial market movement." By expanding the scope of research into a similar subject, Affuso & Lahtinen (2018) additionally examined the impact of geography on stock market returns by measuring investor sentiment and the geographical location obtained from Twitter data. It was found that Twitter sentiment is indeed an essential

determinant to predicting and measuring stock returns and concluded that "negative tweets have a larger impact than positive tweets." Further, the relation between sentiment analysis and stock market returns was empirically studied by Tabari et al. (2018) with Granger Causality's help. The study noted evidence of trending financial news and stock market tips to be in line with the sentiment recorded for a particular stock.

Besides sentiment analysis, calculating and analysing abnormal returns attributable to a specific event may further broaden the scope of event study methodology and enable researchers to study an event's impact empirically. To decode and measure the impact of such events on the intra-day prices and associated returns of a stock, Ante (2020) calculated the cumulative abnormal returns (CAR) in lieu with Armitage (1995). The study suggests that with the help of CAR, researchers can evaluate the true extent of an extraneous event by dividing the stock market hours into several time intervals and gauging the abnormal returns derived for each window. The study revolved around Elon Musk's tweets and their impact on cryptocurrencies across the globe.

2.1. Research Gap

Though ideally expected to cause a certain level of impact on the stock market, the literature questions the extent of short-term implications of Elon Musk's tweets on the stocks of recognised companies among a diverse range of industries, combined with sentiment analysis and deriving cumulative abnormal returns. Besides, the understanding of the author's emotion in the tweets made by him and its relationship to the subsequent movements (negative or positive) in the stock prices and other critical metrics of such companies has not been previously established in the research papers reviewed.

2.2 Aim of the Study

Intending to understand the growing phenomenon of herd mentality amongst netizens who base their investment decisions on social media posts, this study is attempting to understand how Elon Musk has historically impacted the short-term value and trading of major companies, including Tesla Inc., Amazon US, Etsy

Corp., GameStop, Bitcoin, Shopify Inc., and Sandstorm, with his tweets made on the verified Twitter handle "@elonmusk". The study further tests whether the sentiment of his tweets and the resulting statistical outputs hold any relationship.

Thus, the objectives of the study have been broadly classified into two divisions:

- i. To study the sentiment of select tweets made by Elon Musk on his Twitter account (@elonmusk), using sentiment analysis
- ii. To study and measure the short-term trading impact of Elon Musk's selected tweets

2.3 Scope of the Study

The primary objective is to measure the short-term impact of Elon Musk's tweets on major companies' stock prices and critical metrics. The study focuses on seven companies mentioned by Musk in his tweets. The study incorporates eight tweets (events) where the listed companies have been tagged or said and Musk shares an accompanying statement. The duration of tweets has been confined to the 11 months preceding March 2021, which covers the months ranging from April 2020 and February 2021, a time marked by increased access to the internet and online data (De et al. 2020). The intra-day trading data of the selected companies were obtained from Alpha Vantage. The data has been confined to a period of 960 minutes - from 600 minutes before the tweet was made to 360 minutes after the tweet was made, only during the official market hours of the US stock markets (9:30 AM to 4 PM), to make the derived results robust (Armitage, 1995). After conducting a sentiment analysis of the tweets in question, cumulative abnormal returns for the period ranging from 0th minute ($t=0$ when the tweet was made) to 360 minutes have been calculated, using which our observations and inferences have been drawn. Since the study relies exclusively on online data, the geographical scope per se has been limited to the United States of America, and the companies' trading data has been derived as available from US stock markets.

3. Research Methodology

The study incorporates event study methodology and encapsulates quasi-experimental research. Our study seeks to establish a relationship between Elon Musk's tweets and the changes in the stock prices of Tesla Inc., Amazon US, Etsy Corp., GameStop, Bitcoin, Shopify Inc., and Sandstorm. With the help of derived data, the objective of attempting to find a relationship between the sentiment of Elon Musk's tweets mentioning the listed companies and their stocks is aided, which also helps understand the relationship between the two variables. The sources of data for this study are described below.

For capturing the tweets made by Elon Musk, we have used the Twitter API, which enables anyone to access and read historical Twitter data. With our focus on Musk's official handle @elonmusk, his tweets on select dates between April 2020 and February 2021 have been sourced. For our research, we have identified eight specific tweets. We intend to test if the events had a profound impact on well-established firms' stock prices across the globe, where the tweets also garnered immense media scrutiny for the same reason.

Table 1: Eight activities or/and tweets on recognised entities, on Elon Musk's Twitter feed.

Event	Date	Entity Mentioned	Activity or Tweet
1	01.05.2020	Tesla Inc.	Tweeted: Tesla stock price is too high IMO (Musk, 2020)
2	04.06.2020	Amazon.com, Inc.	Tweeted: Time to break up Amazon. Monopolies are wrong! (Musk, 2020)
3	25.01.2021	Etsy	Tweeted: I kinda love Etsy (Musk, 2021)
4	27.01.2021	GameStop	Tweeted: Gamestonk!! (Musk, 2021)
5	29.01.2021	Bitcoin	Activity: Added #bitcoin to Twitter bio. (Musk,

			2021) Tweeted: In retrospect, it was inevitable (Musk, 2021)
6	29.01.2021	Shopify	Tweeted: Shopify is great too. SpaceX used them. (Musk, 2021)
7	04.02.2021	Sandstorm	Tweeted: Sandstorm is a masterpiece (Musk, 2021)
8	19.02.2021	Bitcoin	Tweeted: That data, like all data, is subject to latency & error. The system will evolve to that which minimises both. (Musk, 2021)

Source: Twitter API

The study has incorporated data from Alpha Vantage to access the targeted companies' per-minute, intra-day trading information. This software captures trading data from notable data providers and helps users monitor and analyse the same. Our study's 0th minute (t=0) is the exact minute in the trading hours at which the event occurred, i.e., if the tweets were posted during the official trading hours. Specific tweets were made outside the official trading hours, necessitating assigning the preceding minute of the official trading hours as the 0th minute (t=0).

3.1 Sentiment Analysis

The qualitative tool used in this study is sentiment analysis. It enables interested parties to understand the author's emotion from their text and assign, one among the three emotions - positive, neutral or negative. The statistical tools used in this study are predominantly graphical representations indicating movement in Price, returns and trading volume of targeted companies, and cumulative abnormal returns.

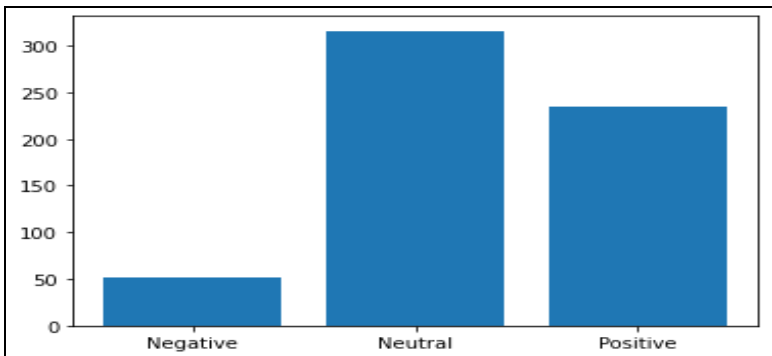
In this research, we have incorporated sentiment analysis on Elon Musk's tweets to understand the polarisation of his tweets and their effect on the stock market. We use Python Analytics and specific documentation called "Tweepy" to analyse the said tweets.

To use Tweepy, one needs developer access from Twitter to extract tweets from the Twitter API. Some tweets do not contain words but emojis, images or links, which may clutter the sentiment analysis algorithm. Hence, such tweets are removed from the analysis input. After the data collection is done, we use "TEXT BLOB" documentation of sentiment analysis.

Sentiment analysis measures the subjectivity and polarity of each tweet. Subjectivity refers to the individual bias on a concept opposite to objectivity. Polarity scores decide the sentiment of the tweet. If the score is greater than zero, then the statement is positive, whereas if the score is zero, it is neutral, and if the score is below zero, it is negative.

The first step entails 'cleansing' tweets, removing hyperlinks and Twitter mentions that do not contribute much to the analysis. After cleansing the data, the second step involves using a "TEXT BLOB" documentation to perform the following process -

- i. Tokenisation process breaks up all the sentences in a tweet into individual words. The algorithm measures the data's polarity by breaking up the sentences into individual sentences but not as a sentence as a whole. However, it is to be noted that due to tokenisation, the algorithms are often unable to detect the sentences' real intent as it breaks up the sentence word by word for analysing process.
- ii. Lemmatisation finds the base or dictionary form of words in data.
- iii. After the previous step, the data's polarity is generated by comparing it to the pre-existing parameters encoded in the "TEXT BLOB" documentation.



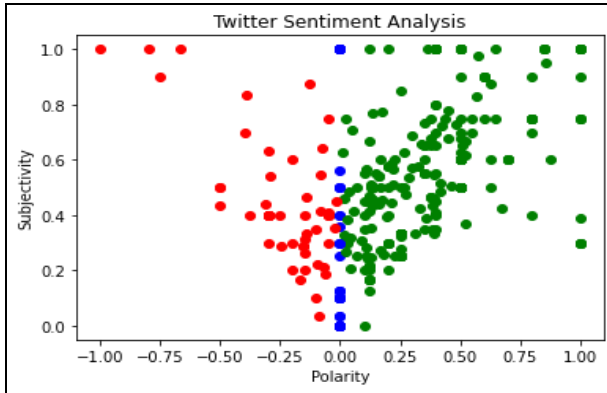


Exhibit: Graphical Representation of the Sentiment Analysis of Musk's 630-latest tweets (up to March 19, 2021, at 4 PM IST)

To further explain this concept, we have taken a sample of the latest 630 tweets made by Elon Musk (up to March 19, 2021, at 4 PM IST), from which we find that only 8.6% of the tweets made by him are negative, while 38.9% of tweets made by him are positive while the rest of the tweets stand neutral. This indicates that tweets made in public, in general, contain an inherent sentiment or an emotion, which may impact the way viewers of the tweet react to it.

3.2 Cumulative Abnormal Returns

This event study is broadly divided into eight tweets (hereafter referred to as events), in which Elon Musk either mentioned or tagged the seven companies in question. The trading data derived using Alpha Vantage is utilised for 960 minutes (600 minutes before and 360 minutes after the tweet) to assess and graphically represent the difference in trading price, volume and returns, and quantify the cumulative abnormal returns for the period between $t=0$ minutes and $t=360$ minutes (Armitage, 1995).

We calculate the cumulative abnormal returns (CAR) for each event during estimation windows starting $t=0$, i.e., recording the Twitter activities for different time intervals. CAR for each event has been calculated in conformity with Ante (2021), using the following steps:

- i. Identifying and listing the closing price for each stock per minute, 600 minutes before the tweet (event, $t=0$), and 360 minutes after.
- ii. Calculating the returns for each period by subtracting the closing price from the opening price, dividing the resultant figure by the opening price, and multiplying it with 100
$$\text{Returns} = (\text{Closing Price} - \text{Opening Price}) / \text{Opening Price} * 100$$
- iii. Calculating the average of obtained returns before the occurrence of the event, i.e., between $t= (-)600$ minutes to $t= (-)1$ minute
$$\text{Average Returns} = \Sigma \text{Returns (between (-) 600 minutes to (-) 1 minute)} / \text{Number of Observations (600)}$$
- iv. Subtracting the average returns obtained from all returns obtained in step (ii), to generate abnormal returns per minute
$$\text{Abnormal Returns} = \text{Individual Returns} - \text{Average Returns}$$
- v. Calculating the summation of abnormal returns for each time window after the occurrence of the event - 0 to 5 minutes; 0 to 10 minutes, 0 to 30 minutes, 0 to 60 minutes, 0 to 120 minutes, 0 to 240 minutes, 0 to 300 minutes and 0 to 360 minutes.
- vi. Each time interval sums up the values obtained in preceding intervals to obtain a cumulative of total abnormal returns of each stock

As per *Ante (2021)*, the calculation of abnormal returns enables a researcher to generate returns that would not have been derived if a said event had not occurred or taken place. With the occurrence of eight events considered in this study, we calculate the abnormal returns attributable to Musk's tweets and calculate the cumulative of such abnormal returns to quantify the extent of abnormality in returns for each period of the time window.

4. Data Analysis and Results

4.1 Sentiment Analysis

Table 2: Sentiment Analysis of the eight identified tweets and activities

Event	Activity or Tweet	Subjectivity	Polarity	Score
1	Tweeted: Tesla stock price is too high IMO (Musk, 2020)	0.539	0.16	Positive
2	Tweeted: Time to break up Amazon. Monopolies are wrong! (Musk, 2020)	0.9	-0.625	Negative
3	Tweeted: I kinda love Etsy (Musk, 2021)	0.6	0.5	Positive
4	Tweeted: Gamestonk!! (Musk, 2021)	0.0	0.0	Neutral
5	Activity: Added #bitcoin to Twitter bio. (Musk, 2021) Tweeted: In retrospect, it was inevitable (Musk, 2021)	1.0	0.0	Neutral
6	Tweeted: Shopify is great too. SpaceX used them. (Musk, 2021)	0.75	0.8	Positive
7	Tweeted: Sandstorm is a masterpiece (Musk, 2021)	0.0	0.0	Neutral
8	Tweeted: That data, like all data, is subject to latency & error. The system will evolve to that which minimises both. (Musk, 2021)	0.333	-0.166	Negative

Source: Authors own

1. **Tweeted:** "Tesla stock price is too high IMO" (Musk, 2020)

In this tweet, Elon Musk hints that Tesla stock prices are inflated. He tweets this with a hidden message which conveys a negative emotion in the tweet. However, the algorithm recognises this tweet positively upon performing sentiment analysis. The reason is due to an absence of negative words in the statement, and the word "high" is considered as positive in the encoded "TEXT BLOB" documentation.

2. **Tweeted:** "Time to break up Amazon. Monopolies are wrong!" (Musk, 2020)

Musk criticises Amazon Inc. over its monopolistic action in the above tweet, which carries a negative emotion, and the algorithm detects the same.

3. **Tweeted:** "I kinda love Etsy" (Musk, 2021)

This tweet shows that Musk appreciates or promotes Etsy, primarily focusing on handmade/vintage items. It carries a positive emotion which the algorithm rightly detects.

4. **Tweeted:** "Gamestonk!!!" (Musk, 2021)

This tweet indicates Musk's acknowledgement of the increasing GameStop stock price; it is written colloquially, which the algorithm detects as neutral as there are neither negative nor positive words.

5. **Tweeted:** "In retrospect, it was inevitable" (Musk, 2021)

This tweet shows Musk's point of view towards Bitcoin, which is positive in emotion, but due to the lack of positive words, the algorithm detects it as neutral.

6. **Tweeted:** "Shopify is great too. SpaceX used them." (Musk, 2021)

This tweet shows Musk's support towards Shopify's e-commerce business, which is positive in emotion, and the algorithm detects the same due to positive words.

7. **Tweeted:** "Sandstorm is a masterpiece" (Musk, 2021)

This tweet of Musk indicates a positive emotion, but the algorithm could not recognise this as there was a lack of positive words; hence the same is classified as neutral.

8. **Tweeted:** "... That data, like all data, is subject to latency & error. The system will evolve to that which minimises both." (Musk, 2021)

Musk discussed Bitcoin technology's shortcomings in this tweet and its way of rectifying it, but the tweet indicates a negative emotion in general. The algorithm detects the same as there are more negative words than positive comments.

4.2 Descriptive Statistics

Figures 1 through 8 show the price level changes, returns, and trade volume per minute of each event, starting from -600 minutes before the Twitter activity was initiated ($t=0$) to 360 minutes after.

Figure 1 depicts, as soon as the tweet was made, alluding to Event 1, the price of Tesla shares took an immediate dip from \$747.93 at $t=0$ to \$686.68 within 1.5 hours. The corresponding returns fell by nearly 10.4% within the first 40 minutes of posting the tweet. However, the trading volume indicates to have risen considerably, owing to the plunge in prices of Tesla shares and investors lining up to purchase it at discounted prices. Figure 3 depicts a similar impact of Event 3 over the prices and returns of Etsy, an American e-commerce firm. The returns increased to 7.2% within one minute of posting the tweet and the price per share rose to \$225 at $t=10$, from about \$208 a minute before the tweet was made. Due to unexpected events, the company's value increased by nearly \$2 billion (Gambrell, 2021).

Figure 2 indicates that there is no significant long-term impact of Event 2 over the trading volume of Amazon. However, the impact of the tweet "*Time to break up Amazon. Monopolies are wrong!*" may not be substantial, owing to the rise of share price to \$2473.8 from \$2464.46 within 40 minutes of the time of the event.

Figure 4 depicts the price of GameStop, an American gaming retailer, which touched \$350 within a minute, from \$145 at the time of the event. Elon Musk joined the bandwagon of a Reddit-led group of users who, using a coordinated approach, wanted to

increase GameStop's price in a bid to target leading hedge-funds in the USA. The company's share price ended up rising by more than 92% within a day. The returns also witnessed a massive spike of nearly 141% within a minute of the event. Day-traders jumped in to purchase the shares and short-sell them, thereby leading to an enormous spike in the trading volume of the same.

Figures 5 and 8 are two sides of the same coin, Bitcoin. During Event 5, Elon Musk added "#bitcoin" to his Twitter bio and tweeted in support of its widescale adoption. This activity led to a surge of nearly 18%, leading to the price of 1 Bitcoin rising to a high of \$37,682.29 from \$32,054.62 a minute before the said activity. This led to the associated returns to jump by nearly 17% in the estimation window of 1 minute, helping the trading volume increase correspondingly. Figure 8, however, depicts the plunge in Bitcoin's price due to negative remarks made by Elon Musk on Bitcoin's stability and alleged high price, by 8.6% in the first minute since the comments were made public. The price per Bitcoin fell from an all-time high of \$53,800 to \$45,050 within 1.5 hours.

Figure 6 alludes to Shopify, an e-commerce entity whose Price rose by 3.5% at the end of the trading day. The associated returns and trading volume indicate a transient increase, but the same can be attributed to external market factors and not alone Elon Musk's tweet. Perhaps the irony in Event 7 lies in the fact that the tweet was a reference to Sandstorm, a song composed by Darude, but netizens of Twitter misidentified it as Sandstorm Inc., a gold-mining company. His tweet led to a nearly 55% surge in the pre-trading hours of the company, which is not accounted for in this study. The figures indicate a 2% surge in the price of Sandstorm at the opening minute of the trade, which is short-lived and momentary.

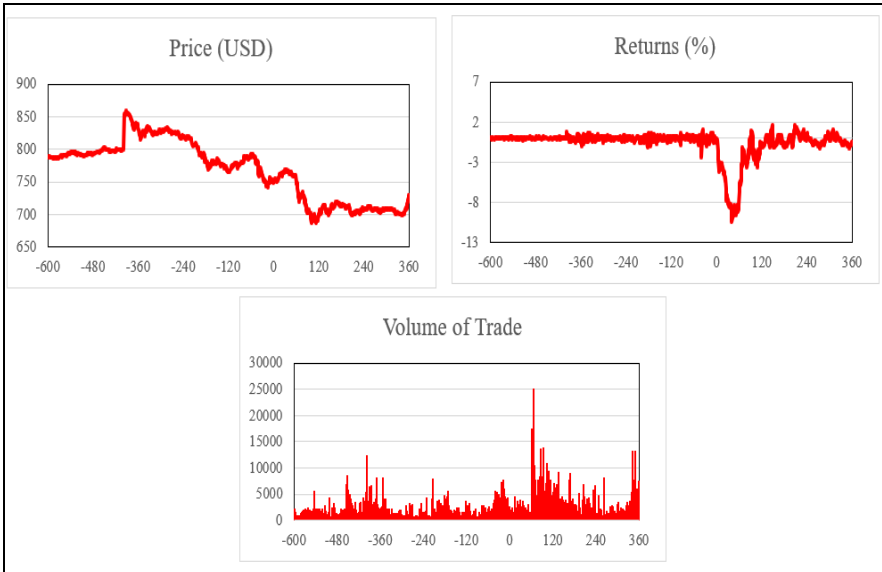


Figure 1. Price, returns and volume of trade per minute of Event 1 (Tesla stock price is too high IMO)

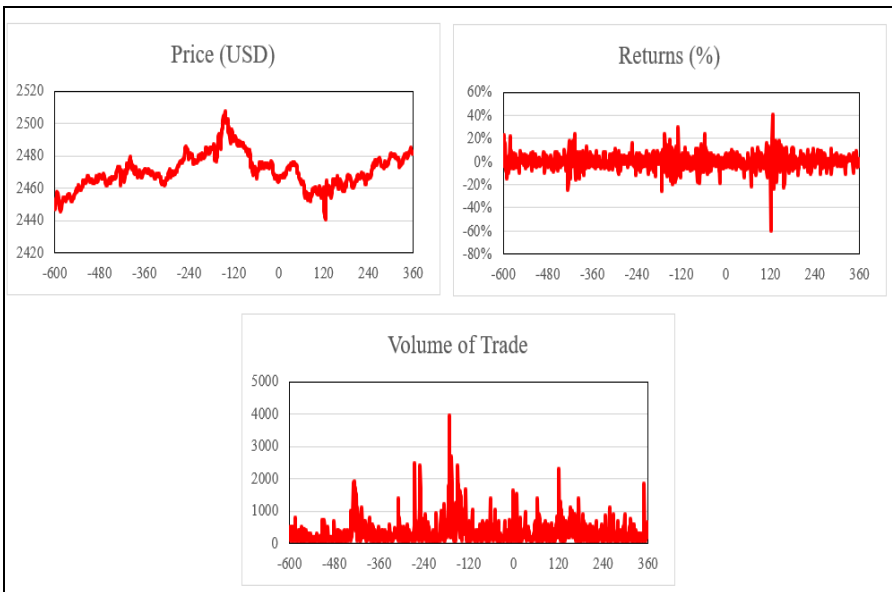


Figure 2. Price returns and trade volume per minute of Event 2 (Time to break up Amazon. Monopolies are wrong!)



Figure 3. Price, returns and volume of trade per minute of Event 3 (*I kinda love Etsy*)

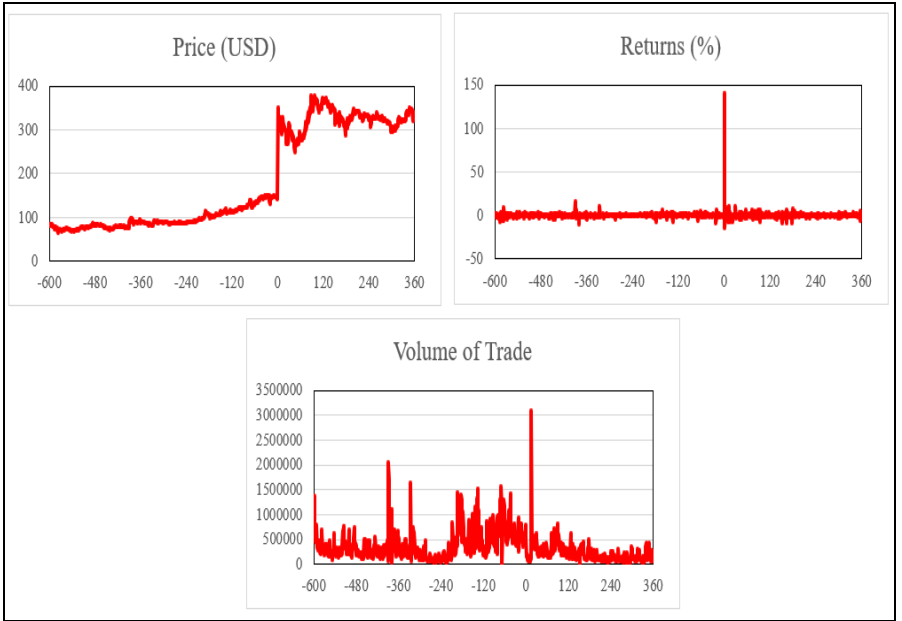


Figure 4. Price, returns, and trade volume per minute of Event 4 (*Gamestonk!!*)

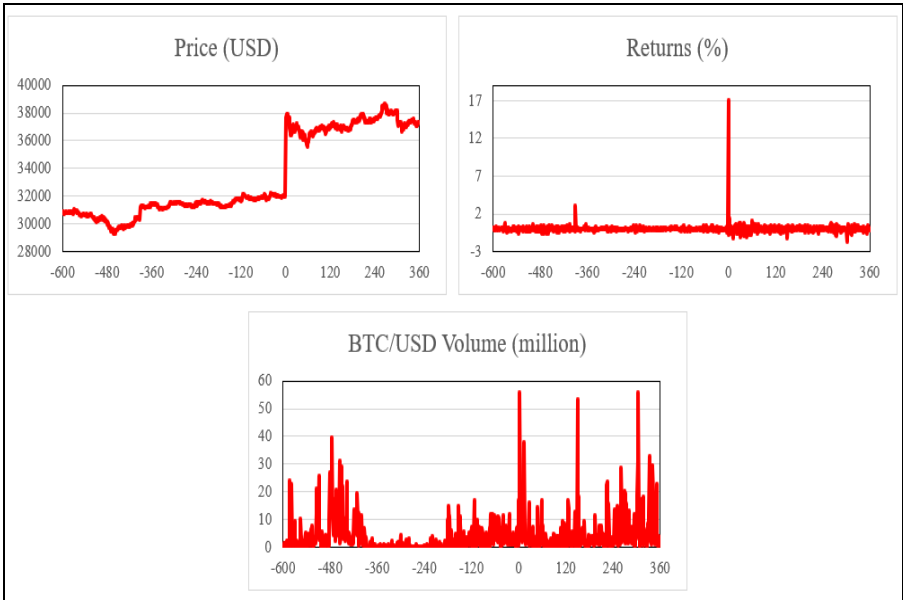


Figure 5. Price, returns and volume of trade per minute of Event 5 (*#bitcoin in Twitter bio*)

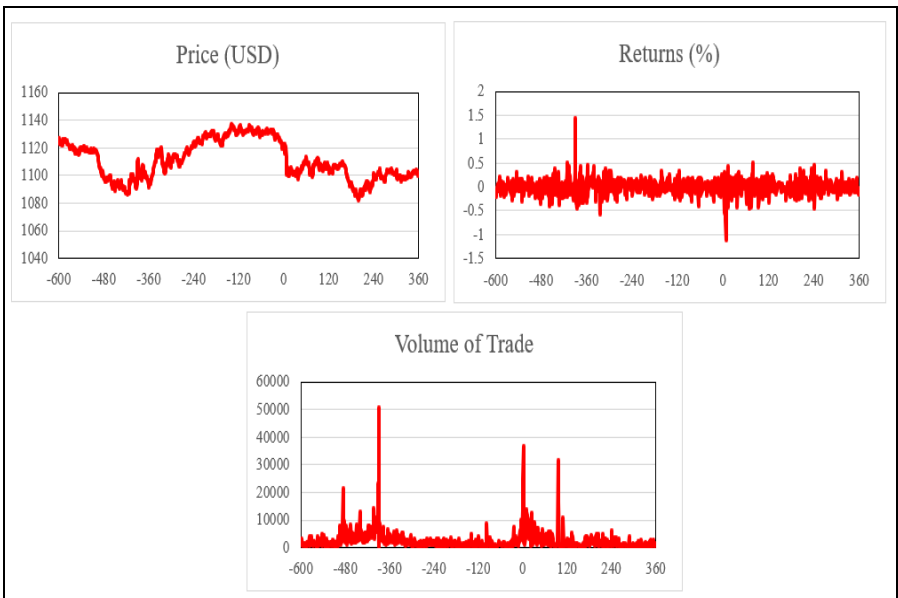


Figure 6. Price returns and trade volume per minute of Event 6 (*Shopify is great too. SpaceX used them.*)



Figure 7. Price, returns and volume of trade per minute of Event 7 (Sandstorm is a masterpiece)

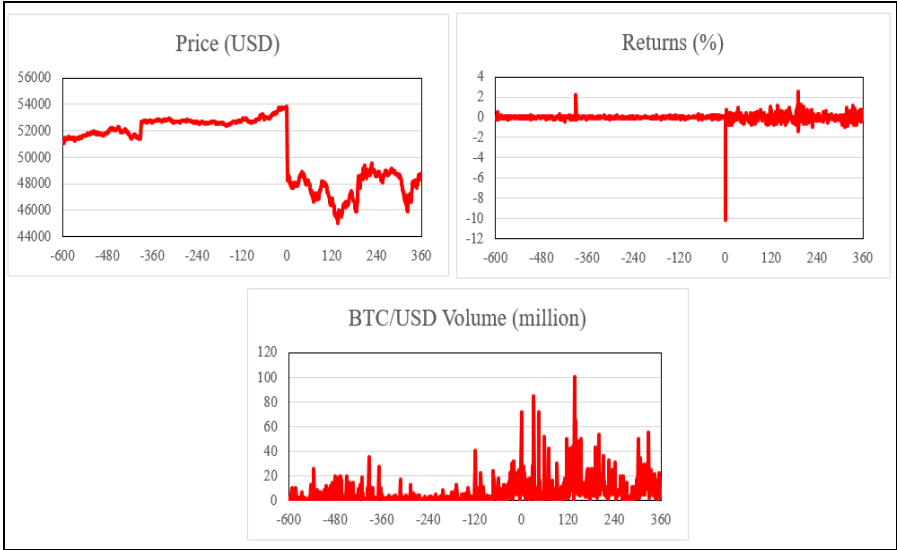


Figure 8. Price, returns and volume of trade per minute of Event 8 ("... That data, like all data, is subject to latency & error. The system will evolve to that which minimises both")

4.3 Event Study Results

The event study results are depicted in Table 3.

Table 3 Cumulative Abnormal Returns (CAR, in %) around Elon Musk's Twitter activity for each event considered for the study. The estimation window is given under the column "Window", divided in minutes, starting from the time of the event (t=0).

Event	1	2	3	4	5	6	7	8
Company	Tesla	Amazon	Etsy	GameStop	Bitcoin	Shopify	Sandstorm	Bitcoin
Window	CAR	CAR	CAR	CAR	CAR	CAR	CAR	CAR
0 to 5	-5.1	0.14	7.19	127.8	18.06	-0.17	-0.08	-9.86
0 to 10	-22.56	0.15	4.58	124.67	17.42	-1.41	-0.54	-11.17
0 to 30	-122.56	0.31	2.44	132.54	16.26	-1.69	-1.47	-11.1
0 to 60	-388.39	-0.12	2.14	119.09	12.61	-0.73	-2.08	-11.41
0 to 120	-395.54	-0.32	0.26	141.43	14.84	-1.21	-2.55	-15.02
0 to 180	-419.59	-0.32	0.66	117.49	15.37	-2.27	-2.88	-15.01
0 to 240	-414.36	-0.13	0.51	119.61	15.65	-2.02	-2.75	-11.46
0 to 300	-426.01	0.33	0.97	105.61	16.94	-1.52	-2.93	-11.84
0 to 360	37.57	0.29	0.4	108.35	14.26	-1.66	-2.4	-12.28

Source: Authors own

4.4 Results Analysis and Observations

Significant cumulative abnormal returns are indicated by events 1, 3, 4, 5 and 8. Event 1 pertaining to negative remarks about Tesla's share prices led to a negative CAR of -122.56% within the first 30 minutes of posting the tweet. The plunge in the returns continues till 5 hours, resulting in a CAR of -426.01%. This trend indicates that the significant CARs can be directly attributed to the event's occurrence. A positive remark on Etsy by Elon Musk impacted a CAR of 7.19% in the first 5 minutes since the tweet was made. Still, it remained short-lived as the CAR began to fall to reflect preceding data of returns, i.e., before the event's occurrence.

Event 4 alludes to the GameStop frenzy. With Elon Musk jumping on the bandwagon by tweeting "Gamestonk!!!", the calculated CAR stood at 127.8% within the first 5 minutes of the occurrence of the

event itself. As the day progressed, the CAR grew significantly to 141.43% within 2 hours and eventually fell to 108.35% in the next 4 hours, showing signs of dwindling prices over time. Concerning Bitcoin, Musk remarked both in support and raised caution against using the famed cryptocurrency on the micro-blogging site. With the addition of '#bitcoin' in his Twitter bio, a significant CAR of 18.06% was recorded within the first 5 minutes of the activity. It remained substantially prominent despite a declining trend over the day. However, with the negative remarks being made public, the same cryptocurrency began a steady downfall in terms of price, with a CAR of -9.86% being recorded at the very beginning of the event's occurrence. The CAR stood at -15.02%, 2 hours since the event before indicating signs of recovery in 4 hours of intra-day data.

Events 2, 6 and 7 do not indicate any significant CAR, which may be attributed to Elon Musk's Twitter activity. His remarks against Amazon.com Inc. seemed to have no impact on the prices of the shares; the calculated CARs are indicative of external market factors. However, it observed a positive impact on Shopify and Sandstorm Inc.'s shares in the pre-trading data which does not form a part of our study. Thus the impact may have weaned off at the beginning of trading activity in the American stock markets.

5. Discussion

The table below summarises the study's observations while attempting to establish a relationship between the sentiment analysis and the cumulative abnormal returns generated. The study noted that computational sentiment analysis might not accurately identify the genuine sentiment or emotion behind the author's tweets. Thus, it is imperative to parallelly conduct manual sentiment analysis and compare the two to determine and publish the relevant analysis.

Table 4: Summary of Analysis and Observations

Event	Tweet or Activity	Sentiment Analysis	Actual Sentiment	Movement in CAR
1	Tweeted: <i>Tesla stock price is too high IMO</i> (Musk, 2020)	Positive	Negative	Decrease in CAR
2	Tweeted: <i>Time to break up Amazon. Monopolies are wrong!</i> (Musk, 2020)	Negative	Negative	No significant CAR observed
3	Tweeted: <i>I kinda love Etsy</i> (Musk, 2021)	Positive	Positive	Increase in CAR
4	Tweeted: <i>Gamestonk!!</i> (Musk, 2021)	Neutral	Positive	Increase in CAR
5	Activity: Added #bitcoin to Twitter bio. (Musk, 2021) Tweeted: <i>In retrospect, it was inevitable</i> (Musk, 2021)	Neutral	Positive	Increase in CAR
6	Tweeted: <i>Shopify is great too. SpaceX used them.</i> (Musk, 2021)	Positive	Positive	No significant CAR observed
7	Tweeted: <i>Sandstorm is a masterpiece</i> (Musk, 2021)	Neutral	Positive	No significant CAR observed
8	Tweeted: <i>That data, like all data, is subject to latency & error. The system will evolve to that which minimises both.</i> (Musk, 2021)	Negative	Negative	Decrease in CAR

Source: Authors own

The differences observed between computational sentiment analysis and actual (manual) sentiment analysis has occurred due to the ongoing research and development of algorithms behind the

computational analysis. Over a period of time, such algorithms may become robust enough to accurately determine the genuine sentiment or emotion inherent to a text or a word while considering factors including sarcasm and colloquiality.

The table above represents Events 1, 3, 4, 5 and 8 having significant changes in their cumulative abnormal returns (CAR) as an effect of the tweets made by Elon Musk. In Event 2, a lack of significant CAR was generated. We believe Amazon is too big a company to be influenced and has a splendid reputation and a significant market share in the e-commerce space, limiting the influence of its prices by tweets of noted personalities. In Events 6 and 7, both the stock prices of Shopify and Sandstorm had an abnormal increase in the pre-trading session, and it eventually went undetected, as this study incorporates the period of official trading hours. Besides, it may be noted that all the company stocks and cryptocurrencies had abnormal increases or decreases in their pre-trading session. However, their stock prices continued to significantly increase or decrease in the official stock market hours captured in the study.

6. Conclusion

With the primary objective to study the impact of Musk's tweets on seven companies, the study incorporated the twin measures of sentiment analysis to measure and state the emotion or sentiment inherent to the tweet, and cumulative abnormal returns attributable to his tweets.

By measuring the sentiment analysis computationally, the study incorporated the emotion behind each tweet (event) and categorised them as positive, neutral or negative. As stated in the analysis, there are five positive tweets and three negative tweets in the basket of events. Using that as our base, we conducted the descriptive statistical analysis to calculate the cumulative abnormal returns. Significant CAR was observed for event numbers 1, 3, 4, 5 and 8.

- Event 1 - "*Tesla stock price is too high IMO*" (Musk, 2020): Significant CAR of -122.56% was observed in the first 30 minutes since the tweet was made, which further increased

reflecting the impact caused by Musk's tweet on the stock price of his own company.

- Event 3 - "*I kinda love Etsy*" (Musk, 2021): CAR of 7.19% in the first 5 minutes was observed since the tweet was made, but it remained short-lived as the CAR began to fall to reflect preceding data of returns, i.e., before the occurrence of the event.
- Event 4 - "*Gamestonk!!!*" (Musk, 2021): CAR stood at 127.8% within the first 5 minutes since the tweet was made, which grew significantly to 141.43% within 2 hours.
- Event 5 - "*In retrospect, it was inevitable*" (Musk, 2021): CAR of 18.06% was recorded within the first 5 minutes of the activity and remained substantially prominent, albeit with a declining trend over the course of the day.
- Event 8 - "... *That data, like all data, is subject to latency & error. The system will evolve to that which minimises both.*" (Musk, 2021): CAR of -9.86% was recorded at the very beginning of the occurrence of the event. The CAR was calculated to be -15.02% 2 hours since the event, but the impact eventually dwindled as the day progressed.

Events 2, 6 and 7 have observed no significant CAR. There was no impact of Musk's tweets on Amazon Inc., while the impact on Shopify and Sandstorm was observed in the pre-trading data, which was not accounted for in the study. Cumulative abnormal returns observed in the official trading hours of 9:30 AM to 4 PM were considered to align with the study's objective. As for the relationship between sentiment analysis, cumulative abnormal returns, manual sentiment analysis, and the CAR, indications are toward the existence of a correlation; if the event was identified to be inherently positive in emotion, the CAR reflected a positive growth, while inherently negative emotion reflected a negative CAR.

The study notes a significant impact on short-term trading of stocks by the tweets made by him. It is restricted to intra-day trading since the market eventually corrects itself to reflect the prices as per the market forces of demand and supply. Musk's tweets cause

deviations in the price and trading volumes only for a short period, both positively and negatively.

7. Implications

During the study, ambiguity pertaining to computational sentiment analysis was observed. It may be noted that computational analysis has not developed enough to accurately detect the inherent emotion of the author's text and uses a pre-defined set of processes to classify the text as positive, neutral or negative. Besides, the study considers the price-level changes and returns during the official stock market timings, which does not capture some of the immediate event impacts on the prices of the stocks when the tweets were made outside the trading hours. The magnitude of the impact on prices and invariably the impact on cumulative abnormal returns thus go undetected.

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