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Abstract

The aim of this paper is to study the impact of social media engagement and public attention on Pfizer during the COVID-19 pandemic. Our study focuses on Twitter to investigate Pfizer's social media activity and engagement during the pandemic. We analyze different social media engagement metrics, such as conversation rates, speed of information diffusion, and public approval ratings. In addition, we use Google Trends to track changes in public attention towards pandemic-related keywords like "COVID-19" and "COVID-19 booster shot" and examine their relationship with Pfizer's stock returns. Our findings suggest that social media engagement during the pandemic has a significant positive impact on Pfizer's returns. Furthermore, we show that, while high levels of public attention towards COVID-19 negatively impact Pfizer's returns, social media engagement has a positive incremental effect on the company's returns during periods of heightened public attention.

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1 Introduction

On January 30, 2020, the World Health Organization (WHO) declared the COVID-19 outbreak a Public Health Emergency of International Concern. Since then, the outbreak has not only caused significant health concerns but also widespread economic and social disruptions, dramatically changing our daily lives. Most governments worldwide have imposed lockdowns and social distancing measures, affecting our daily routines and habits, including the way we work, shop, and interact socially. As a result, the pandemic has accelerated the shift towards digital communication and social media platforms, and companies worldwide have turned to these channels to inform and engage with their target audience and stakeholders. In this context, this paper analyzes the relationship between Pfizer's social media activity and engagement, public attention, and the company's market value. Given the critical role the company played in developing and distributing vaccines worldwide, the results obtained in this paper provide insightful information regarding the role of social media in influencing public opinion and driving company performance during times of health emergencies and crises.

The COVID-19 pandemic has severely impacted the healthcare system, particularly the pharmaceutical industry. It has exposed and exacerbated existing problems, highlighting the urgent need to improve digital communication ([44], [1], [29], [46]). Even before the pandemic, social media platforms such as Twitter, Facebook, LinkedIn, or Reddit, among others, had already gained a great deal of popularity. Nowadays, an increasing number of users rely on these platforms as their primary source of news and information ([33]), as well as for personal and social needs ([53]). Hardly surprising, high-profile individuals, corporations, and world leaders have turned to social media platforms to establish a direct communication channel with their target audience and stakeholders ([41], [35]). Although they make up a small proportion of users, these entities contribute the majority of influen-

tial content and discussions ([27]). There is a substantial body of literature on stakeholder theory ([16], [49], [52], among others), but ongoing research is still dedicated to mapping and understanding online stakeholder engagement ([51], [5], [42]) and the role of social media. In this paper, we contribute to the extant literature by examining the impact of different social media engagement metrics, such as conversation rates, speed of information diffusion, and public approval ratings, on Pfizer's market returns. Furthermore, the pandemic has polarized public opinion, leading to divisions between pro-vax and anti-vax groups, economic versus public health policies, and those in favor versus against lockdown measures, among other issues. Pfizer's vaccine has not been exempt from controversy and public scrutiny. There have been numerous debates and rumors regarding the availability, pricing, distribution, intellectual property rights, and safety of the Pfizer vaccine. Hence, we also investigate the relationship between public attention toward COVID-19 and COVID-19 booster shot and Pfizer's social media engagement.

The rest of the paper is organized as follow. Section 2 presents the theoretical framework. Section 3 illustrates the data, variable construction, and methodology. Section 4 presents our results and empirical findings. Finally, Section 5 presents some concluding comments.

2 Theoretical framework

Stakeholder engagement

Stakeholder and engagement theory have historically defined the very foundations of ethical governance and accountability mechanisms. Stakeholder theory suggests that by engaging with stakeholders through social media, firms can enhance their reputation and brand image, improve customer satisfaction, and build trust and loyalty among their stakeholders, leading to higher returns and profitability ([25], [50], [45]).

Moreover, by listening to the needs and feedback of their stakeholders, firms can identify new opportunities for innovation and growth, and develop new products or services that meet the changing needs of their customers. Social media provides not only a communication channel with the potential to reach a large audience but also enables an iterative learning process between stakeholders and organizations, providing valuable information on stakeholders' expectations and enabling growing stakeholder participation and engagement ([26]). In this vein, [43] analyze how Fortune 500 companies use Twitter to facilitate dialogic communication with stakeholders and find that organizations with a dialogic orientation in Twitter encourage users to stay and participate in the social media platform.

In the context of the pandemic, social media activity can also impact the company's stock value through the content of its messages. Messages promoting public health and safety, including those related to social distancing and mask-wearing, can have a positive impact on investor sentiment and the company's reputation, which can ultimately impact the stock value. However, a mere social media presence is not sufficient to create stakeholder engagement and market value ([9]), social media activity has to transcend the simple message and encourage users to participate and exchange in the discussion. In this regard, using Twitter to study the impact of social media strategies on stock price, [7] find that firms that actively engage with stakeholders and facilitate two-way interactions tend to generate a stronger market reaction.

Twitter offers various metrics to gauge different dimensions of engagement, interaction, and information diffusion. User activity related to a company's social media can be assessed through metrics such as Replies, Retweets, and Likes.

Hypothesis 1: Social media platforms provide a resilient, robust, and instantaneous channel of communication with a high penetration rate across demographic groups. Pfizer's market value is significantly influenced by its social media engagement, which can be mea-

sured through metrics such as Replies, Retweets, and Likes.

COVID-19 pandemic

The COVID-19 pandemic has fundamentally changed most aspects of our social and professional lives. In the early stages of the pandemic, the lack of knowledge about the epidemiological characteristics of COVID-19 and the absence of a vaccine or effective treatment forced governments worldwide to impose confinement and social distancing measures, disrupting the global economy and polarizing public attention. The pandemic has also brought unprecedented levels of uncertainty and social anxiety that, combined with the lack of knowledge about the epidemiological and clinical aspects of the disease, have created fertile ground for fake news, conspiracy theories, and misinformation. Several studies have shown that epidemiological uncertainty promotes fake news and pseudo-scientific statements on social media platforms ([13]). Particularly concerning, [3] found that even though it represents a small portion, when prominent public figures spread misinformation about the pandemic, their messages report extremely high levels of engagement. Meanwhile, [28] showed that even if the presence of fake news is detected and flagged, the fake news flag has no impact on the validation of the message.

Social media users have a tendency to validate information that best aligns with their own opinions ([28], [21], [17]), making the discourse of global leaders and policymakers on social media a critical factor in shaping public attention and concern. Public attention has been shown to play a significant role in the performance of individual stocks and the broader market ([18], [19], [23]). It helps define and shape investor and market sentiment, which in turn can influence the buying and selling decisions of investors, leading to significant movements in stock prices.

Hypothesis 2.a: High levels of social, financial, and psychological anxiety associated

with the pandemic have increased public attention and influenced social and market behavior. Due to the unprecedented level of uncertainty and the polarized public perception of the pharmaceutical industry, periods of high public attention toward "COVID-19" have a significant and negative impact on Pfizer's market value.

Hypothesis 2.b: Due to the controversy surrounding messenger RNA technology and the potential side effects of Pfizer's vaccine, public attention toward "COVID-19 booster shot" has a significant and negative impact on Pfizer's market value.

Legitimacy

The pharmaceutical industry has a responsibility not only to its shareholders but also to the wider community; it must comply with the social norms, values, and expectations of society at large. There is no doubt about the social impact of pharmaceutical research and development in modern society. However, the COVID-19 vaccine R&D process has not been exempt from controversy, negatively affecting public perception of the industry and influencing public attention, which in turn, affects the legitimacy and reputation of the industry. Social media has played a significant role in redefining the instruments and mechanisms of accountability and legitimization. It provides a massive and instantaneous platform for disclosing and presenting information, and extends the industry's interaction with society at large ([4], [14], [8]). [10] identifies several reasons and motivations for voluntarily disclosing information. Of particular relevance to our study are i) managing powerful stakeholder groups (see [48], [40], [15], [30]), ii) dealing with threats to the organization's legitimacy and responding to negative media attention (see [11], [12], [32]), and iii) complying with community expectations ([10]).

As one of the leading pharmaceutical companies working on a COVID-19 vaccine, Pfizer's social media activity related to the development and progress of their vaccine can

have a significant impact on the company's stock value. Regular updates on the status of the vaccine, the results of clinical trials, and the regulatory approval process can help to project a socially aware image of the organization and legitimize the commercial use of the vaccine. Moreover, Pfizer's social media activity can impact the company's stock value by providing a channel for the company to respond quickly and effectively to any negative news or rumors. This can mitigate potential damage to the company's reputation and stock value.

Hypothesis 3: Social media provides a massive and instantaneous platform to interact with society at large, helping firms to swiftly respond to negative public attention, enhancing their legitimacy and reputation. During periods of high public attention toward the pandemic, the company's social media activity has a greater impact on its market value.

3 Data and methodology

3.1 Pfizer

Pfizer collaborated with the German biotechnology company BioNTech to develop a COVID-19 vaccine based on messenger RNA (mRNA) technology. mRNA technology uses a molecule called "messenger RNA" that introduces a sequence containing the genetic instructions to build specific proteins, thereby allowing vaccinated people's own cells to trigger an immune response.

The Pfizer-BioNTech vaccine was the first mRNA vaccine to receive emergency use authorization from regulatory agencies around the world and has been shown to be highly effective in preventing COVID-19. Pfizer-BioNTech received U.S. Food and Drug Administration (FDA) approval on August 23, 2021 for individuals aged 16 years and older. According to The New York Times vaccination tracker, as of March 2022, the COVID-19 vaccine developed by Pfizer-BioNTech is used in 156 countries and is one of the most widely

used shots worldwide.

However, Pfizer's vaccine has not been exempt from controversy. There have been numerous debates and rumors regarding the availability, pricing, distribution, intellectual property rights, and safety of the Pfizer vaccine. Compared to its competitors, Pfizer has received more media scrutiny and generated greater public debate and controversy. For these reasons, we opt to study the impact of Pfizer's social media engagement on its market value. We collected daily observations of opening and closing prices from January 31, 2020 to January 18, 2022 as extracted from Compustat. Pfizer trades on the New York Stock Exchange (NYSE), regular trading hours from 9:30 am to 4:00 pm Eastern Time.

3.2 Social media

The use of social networking platforms such as Twitter, Facebook, Reddit, and Instagram, among others, as a channel of communication with a target audience is a distinctive characteristic of the modern digital era. It has been increasingly used during periods of emergency, particularly amid the pandemic ([36], [37]). According to [39], who analyzed a 15-year summary of the use of information and communication technology (ICT) and social media in emergencies, social media communication has grown substantially during emergency and crisis events since the 9/11 terrorist attacks.

In this paper, we use Twitter to study the impact of Pfizer's social media activity, the leading COVID-19 pharma, during the coronavirus outbreak. According to [31], extreme events show that, among a wide pool of platforms, Twitter is the dominant social media platform for spreading information on social crises, while [20] find a high degree of conversational interaction on the platform. Twitter offers various metrics to gauge different dimensions of engagement, interaction, and information diffusion, such as Replies, Retweets, and Likes.

A reply is a response to another tweet. The simple act of replying to a post creates a

conversation structure and interaction among users, enabling them to voice their stances on the tweet. According to [24], this conversation structure allows users to determine the reliability of the information in the source tweet and validate the content of the post. Retweets and likes, on the other hand, can be regarded as mechanisms for propagating, spreading, and validating a tweet. According to Twitter "[Likes] are used to show appreciation for a Tweet", therefore, when users like a tweet, they are agreeing with and supporting the message. Retweeting is the action of reposting or forwarding a message tweeted by another user. In this regard, [6] suggest that retweeting generates content with pass-along value, allowing users to reach an audience beyond their own network, while [2] find that users retweet to amplify and spread a message to new audiences and to publicly agree with the source tweet. According to [47], the speed of information diffusion is critical to determine how fast the information is incorporated in stock prices. Diffusion process is not only affected by the number of followers but also by the extent to which tweets are retweeted.

Hence, we use snscrape to collect Pfizer's social media activity in Twitter from January 31, 2020 to January 18, 2022. We gauge engagement and conversation rate, speed of information diffusion, and rate of approval using Twitter metrics of Replies, Retweets, and Likes. Figure 1 presents daily social media activity. We observe that Retweets and Likes display highly correlated behavior, with similar peaks of activity, while Replies tend to increase towards the end of the sample. Table 1 presents the descriptive statistics and the evolution of Pfizer's social media activity both outside and during trading hours. Interestingly, we observe a significantly higher volume of Retweets and Likes outside trading hours, and a higher volume of Replies during trading hours.

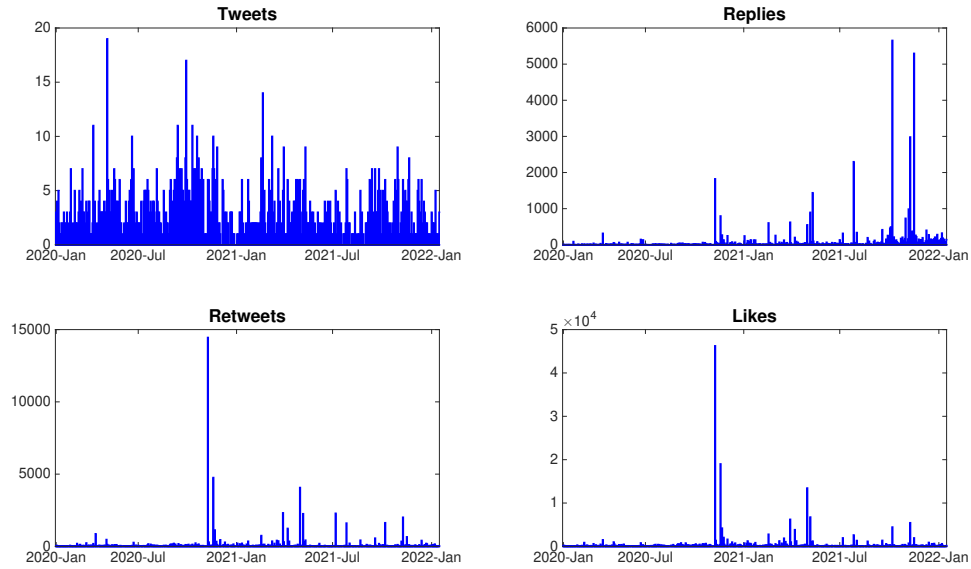

Figure 1: This figure presents Pfizer's Twitter activity from January 31, 2020 to January 18, 2022.

		Mean	Std. Dev.	Min	Max
Opening	Tweets	1.17	1.47	0	13
	Replies	34.30	160.02	0	2469
	Retweets	98.28	716.96	0	13981
	Likes	312.53	2309.10	0	44644
Closing	Tweets	1.67	1.81	0	16
	Replies	56.27	329.98	0	5212
	Retweets	36	104.41	0	1610
	Likes	128.03	276.68	0	3853

Table 1: This table presents some descriptive statistics of the main explanatory variables from January 31, 2020 to January 18, 2022. *Panel Opening*: presents social media activity outside trading hours {from 4:00 pm (t-1) to 9:30 am (t)}. *Panel Closing*: presents social media activity during trading hours {from 9:30 am (t) to 4:00 pm (t)}.

3.3 Public attention

Google is one of the most popular search engines in the world. Millions of people turn to google to search for pandemic-related information during the outbreak ([38]). We use Google Trends to gauge the evolution of public attention toward certain pandemic-related keywords. Google Trends reports the historical search volume interest (SVI) and search trends collected by Google's search engines and analyzes the popularity of top search queries. In order to cover different dimensions of the pandemic, we analyze the search query popularity of "COVID-19" and "COVID-19 booster shot" from January 31, 2020 to January 18, 2022. Figures 2 and 3 show the SVI of "COVID-19" and "COVID-19 booster shot", respectively. Hardly surprising, public attention towards COVID-19 reaches a popularity peak at the beginning of the sample, while interest in the COVID-19 booster shot increases in popularity after the second half of 2021.

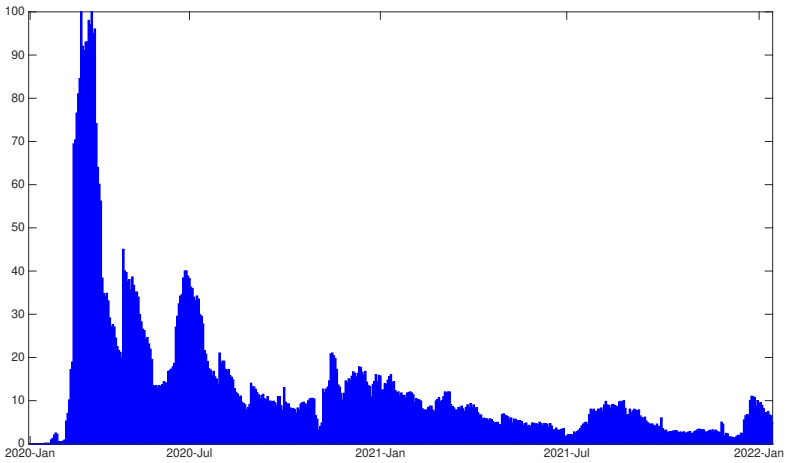

Figure 2: This figure presents the Google search query evolution of the term "COVID-19" from January 31, 2020 to January 18, 2022.

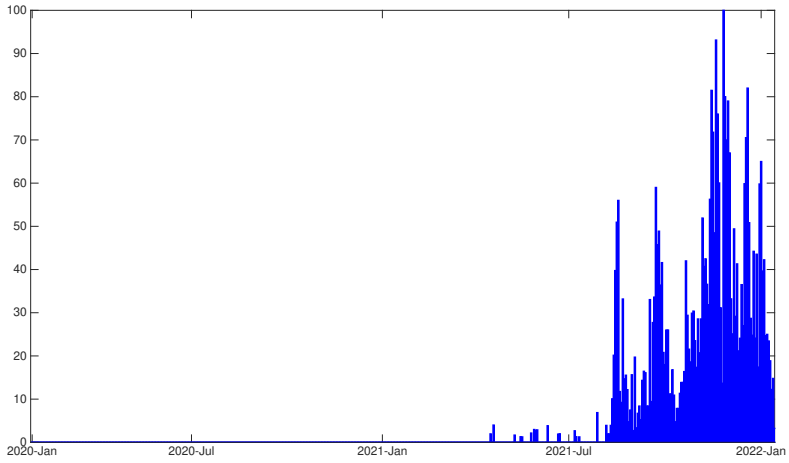

Figure 3: This figure presents the Google search query evolution of the term "COVID-19 booster shot" from January 31, 2020 to January 18, 2022.

4 Analysis

The aims of this section are twofold. First, we aim to measure the impact of Pfizer's social media engagement during the COVID-19 pandemic. Second, given the polarizing effect and social, financial, and psychological anxiety associated with the pandemic, we aim to investigate the extent to which public attention toward certain key pandemic-related terms affects Pfizer's return and its relationship with social media activity. More precisely, we measure the impact of the "COVID-19" SVI and, given the controversy over the vaccine booster shot, we also account for the impact of the "COVID-19 booster shot" SVI.

4.1 Social media engagement

We measure how Pfizer's social media activity (Tweets) and engagement (Replies, Retweets and Likes) affect its market returns. Since Twitter provides a 24/7 platform, we might expect that social media activity generated during and after trading hours might have a

differentiated effect on closing and opening prices, respectively. Hence, considering NYSE trading hours (from 9:30 am to 4:00 pm Eastern Time), we create a time series accounting for aggregates of posted tweets by Pfizer (and respective metrics) as follows:

$$\vec{X}_{(t,\text{opening})} = \text{Aggregates from 4:00 pm (t-1) to 9:30 am (t)} \quad (1)$$

$$\vec{X}_{(t,\text{closing})} = \text{Aggregates from 9:30 am (t) to 4:00 pm (t)} \quad (2)$$

where $\vec{X} = \{\text{Tweet, Replies, Retweet, Likes}\}$. Pfizer's returns, on the other hand, are calculated as follows:

$$r_{(t,opening)} = \ln(P_{(t,opening)}/P_{(t-1,closing)}) \quad (3)$$

$$r_{(t,closing)} = \ln(P_{(t,closing)}/P_{(t,opening)}) \quad (4)$$

We propose the following regression model to study the impact of social media:

$$r_{(t,i)} = \alpha + \beta \cdot \vec{X}_{(t,i)} + \gamma \cdot \text{CV}_{(t)} + \epsilon_{(t,i)} \quad (5)$$

where $\vec{X} = \{\text{Tweet, Replies, Retweet, Likes}\}$, $i = \{\text{opening, closing}\}$, β measures the social media impact on Pfizer's financial returns, $\epsilon_{(t,i)}$ represents the estimation error, and the vector $\text{CV}_{(t)}$ represents the control variables, namely:

i) S&P 500 Index[a]

ii) S&P Pharmaceutical Industry Index[a]

iii) Pfizer Media Coverage[b]

[a]Source: Compustat

[b]Extracted from Gdelt project (https://www.gdeltproject.org) and considering the following sources: nytimes.com, washingtonpost.com, foxnews.com, cnn.com

iv) Pfizer's follower count history in Twitter

v) Size[c]

vi) Economic Policy Uncertainty index, EPU[d]

vii) Daily Infectious Disease Equity Market Volatility Tracker (DIDEMV)[e]

viii) COVID New Cases[f]

ix) 7-Day Moving Average COVID cases[f]

We first run an ordinary least-squares linear regression of the model describe in equation 5 considering the entire dataset, which comprises both opening and closing returns. Table 2 presents different regression models explaining the relationship between Pfizer's social media activity and engagement. We observe that estimates of models 1 and 2 are not statistically significant. This suggests that Pfizer's daily aggregates of tweets have no relationship with the company's stock returns. Moreover, the coefficient of determination indicates that their explanatory power is negligible. Daily aggregates of tweets only measure the frequency of Pfizer's posts and do not provide information about the content, stakeholder engagement, or message validation. Although most of the social media posts analyzed were related to the pandemic, a significant portion referred to other topics with little to no public engagement. Furthermore, those related to the pandemic ranged from general information about COVID-19 to more specific tweets about vaccine research and development.

Moreover, we observe that estimates of Replies, Retweets, and Likes (presented in models 3-4, 5-6, and 7-8, respectively) present a positive and highly statistically signifi-

[c]Computed as Pfizer's market value (Stock price × Common shares outstanding)
[d]Extracted from https://www.policyuncertainty.com/
[e]Extracted from https://www.policyuncertainty.com/infectious_EMV.html
[f] Source: World Health Organization

cant relationship with Pfizer's financial returns. As mentioned earlier, replying creates a conversation structure and voices other users' stances on the content of the tweet. When a tweet generates more replies, the interaction among users and the repercussion of the source tweet will be higher, creating a positive impact on Pfizer's returns. On the other hand, retweeting and liking are mechanisms for propagating, spreading, and validating the content of a tweet. The more retweets and likes a tweet generates, the greater the likelihood of it reaching new audiences and higher levels of engagement. Moreover, high numbers of retweets and likes are associated with relevant content in the source tweet and a high degree of validation, triggering a positive market reaction and an increase in the company's financial value. These results provide evidence supporting Hypothesis 1, which suggests that Pfizer's social media engagement has a significant impact on the company's market value.

As mentioned earlier, Twitter is a platform where social media traffic is constantly generated, shared, and discussed around the clock. Since Twitter's algorithm promotes recent and popular content, tweets typically receive the most retweets, replies, and likes within the first few hours of posting. According to [22], the majority of retweeting occurs within an hour of posting a tweet. Therefore, we hypothesize that social media activity generated during and after trading hours may have a distinct effect on closing and opening prices, respectively. To test this hypothesis, we analyzed a subsample of the data that considers the opening(closing) data, as described in equations 1 and 3 (2 and 4). Table 3 presents the regression results and confirms the aforementioned hypothesis. Interestingly, we observe a positive and highly significant relationship between $r_{(r,opening)}$ and Pfizer's social media activity and engagement but no statistically significant relationship between $r_{(r,closing)}$ and social media generated during trading hours. In this regard, closing prices are affected by many factors that occur during the trading day, including news releases,

economic data, and market trends. In contrast, opening prices may be more susceptible to the influence of social media activity, especially if the tweets contain information that has not yet been reflected in the market.[g]

[g]For different regression models analyzing the effect of Replies, Retweets, and Likes we have conducted a two-stage least squares (2SLS) regression and performed tests for endogeneity and autocorrelation. In each case, we found that we cannot reject the null hypotheses that the variables are exogenous and that there is no autocorrelation in the residuals of the regression model. Results available upon request.

	Pfizer							
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Tweet	0.0000907	-0.0000367						
	(0.000257)	(0.000285)						
Replies			0.00000484***	0.00000578***				
			(0.00000165)	(0.00000182)				
Retweets					0.00000766***	0.00000836***		
					(0.000000789)	(0.000000886)		
Likes							0.00000237***	0.00000258***
							(0.000000246)	(0.000000276)
Control variables:								
S&P 500	0.622***		0.623***		0.608***		0.606***	
	(0.0597)		(0.0594)		(0.0570)		(0.0571)	
S&P Pharma	0.0410		0.0383		0.0346		0.0362	
	(0.0334)		(0.0333)		(0.0319)		(0.0320)	
Media Coverage	0.0000251		0.0000219		0.0000233		0.0000235	
	(0.0000216)		(0.0000215)		(0.0000206)		(0.0000206)	
Followers	-4.04e-09		-5.47e-09		-1.74e-09		-1.06e-09	
	(1.05e-08)		(1.05e-08)		(1.00e-08)		(1.00e-08)	
Size	7.93e-14***		7.50e-14***		7.51e-14***		7.57e-14***	
	(2.30e-14)		(2.30e-14)		(2.20e-14)		(2.20e-14)	
EPU	0.00000549		0.00000541		0.00000633		0.00000652	
	(0.00000453)		(0.00000451)		(0.00000433)		(0.00000433)	
DIDEMV	0.0000238		0.0000218		0.0000198		0.0000209	
	(0.0000558)		(0.0000556)		(0.0000533)		(0.0000534)	
New Cases	-1.92e-08		-1.91e-08		-1.64e-08		-1.61e-08	
	(1.38e-08)		(1.37e-08)		(1.32e-08)		(1.32e-08)	
7MA Cases	8.82e-09		9.47e-09		5.43e-09		4.60e-09	
	(1.68e-08)		(1.67e-08)		(1.60e-08)		(1.60e-08)	
Intercept	-0.0170***	0.000437	-0.0156***	0.000123	-0.0173***	-0.000177	-0.0177***	-0.000183
	(0.00440)	(0.000624)	(0.00435)	(0.000479)	(0.00416)	(0.000459)	(0.00416)	(0.000459)
N	990	991	990	991	990	991	990	991
R-sq	0.214	0.000	0.221	0.010	0.283	0.083	0.282	0.081
adj.R-sq	0.206	-0.001	0.213	0.009	0.276	0.082	0.274	0.080
AIC	-5733.1	-5516.9	-5741.7	-5526.9	-5823.9	-5602.3	-5822.2	-5600.2
rmse	0.0133	0.0149	0.0133	0.0149	0.0127	0.0143	0.0127	0.0143

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table 2: This table presents the estimates of different regression models explaining the relationship between Pfizer's financial returns and social media activity from January 31, 2020, to January 18, 2022.

	Pfizer							
	Opening				Closing			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Tweet	0.000864**				-0.000194			
	(0.000360)				(0.000360)			
Replies		0.0000233***				0.000000309		
		(0.00000313)				(0.00000198)		
Retweets			0.00000733***				0.00000444	
			(0.000000655)				(0.00000618)	
Likes				0.00000227***				0.000000532
				(0.000000204)				(0.00000235)
CV	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	495	495	495	495	495	495	495	495
R-sq	0.365	0.423	0.489	0.488	0.164	0.164	0.164	0.164
adj.R-sq	0.352	0.411	0.479	0.478	0.147	0.146	0.147	0.146
AIC	-2999.6	-3047.2	-3107.8	-3106.8	-2795.9	-2795.6	-2796.1	-2795.6
rmse	0.0116	0.0110	0.0104	0.0104	0.0142	0.0142	0.0142	0.0142

Standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 3: This table presents the estimates of different regression models explaining the relationship between Pfizer's financial returns and social media activity from January 31, 2020, to January 18, 2022. *Panel Opening*: using equations 1 and 3. *Panel Closing*: using equations 2 and 4.

4.2 Public attention

COVID-19

We first propose the following models to measure the impact of public attention toward COVID-19 and the interaction between public attention and social media:

$$r_{(t,opening)} = \alpha + \delta \cdot \mathrm{PA} + \gamma \cdot \mathrm{CV}_{(t)} + \epsilon_{(t)} \quad (6)$$

$$r_{(t,opening)} = \alpha + \delta \cdot \mathrm{PA} + \beta \cdot \vec{X}_{(t,opening)} + \theta \cdot \mathrm{PA} \cdot \vec{X}_{(t,opening)} + \gamma \cdot \mathrm{CV}_{(t)} + \epsilon_{(t)} \quad (7)$$

As mentioned earlier, Google Trends reports the historical search volume interest (SVI) and search trends collected by Google's search engines, analyzing the popularity of top

search queries. As shown in Table 1, SVI measures range from 0 to 100, where 0 and 100 represent the lowest and highest popularity levels, respectively, during the analyzed period. Since SVI provides a standardized measure, the variable PA is a dummy variable that takes the value of one during periods of high popularity (SVI $>$ 50) and zero otherwise. Defining PA as a categorical variable allows us to identify and interpret how the interaction term modifies the effect of social media engagement on stock returns during periods of high public attention.

Table 4 presents the results obtained from different regression models. We can observe that public attention toward COVID-19 has a negative and statistically significant relationship with Pfizer's returns. The effect remains robust and significant across different regression models, confirming hypothesis 2. The COVID-19 pandemic has caused not only a health crisis but also economic and social disruptions, increasing the uncertainty level to unprecedented levels and polarizing public opinion. Due to the psychological anxiety and social distress associated with lockdown and social distancing measures, an increase in attention towards COVID-19 generates fear and volatility, which, in turn, triggers a negative market reaction.

Table 4-models 3, 4, and 5, present the interaction between public attention and Pfizer social media engagement. Notably, we observe that although the main effect of public attention toward COVID-19 remains negative and statistically significant, during periods of heightened public attention, social media engagement has a positive incremental effect on Pfizer's returns, thus confirming hypothesis 3. Despite the negative connotation associated with high public attention towards COVID-19, social media provides a powerful tool to respond and react to negative public attention, thus enhancing Pfizer's legitimacy and reputation.

	Pfizer				
	Model 1	Model 2	Model 3	Model 4	Model 5
PA	-0.00608**	-0.00693**	-0.00917***	-0.0102***	-0.00975***
	(0.00295)	(0.00338)	(0.00329)	(0.00341)	(0.00348)
Tweet		0.000521*			
		(0.000298)			
PA × Tweet		0.000646			
		(0.00106)			
Replies			0.00000919***		
			(0.00000257)		
PA × Replies			0.000759**		
			(0.000361)		
Retweets				0.00000237***	
				(0.000000568)	
PA × Retweets				0.000125**	
				(0.0000556)	
Likes					0.000000749***
					(0.000000177)
PA × Likes					0.0000412*
					(0.0000220)
Control Variables	Yes	Yes	Yes	Yes	Yes
N	495	495	495	495	495
R-sq	0.382	0.388	0.403	0.410	0.409
adj. R-sq	0.369	0.372	0.388	0.395	0.394
AIC	-3226.9	-3227.3	-3240.2	-3245.7	-3244.7
rmse	0.00921	0.00919	0.00907	0.00902	0.00903

Standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 4: This table presents the estimates of different regression models explaining the relationship between Pfizer's financial returns and public attention toward COVID-19 from January 31, 2020 to January 18, 2022.

COVID-19 booster shot

The pharmaceutical industry has been thrust into the spotlight and the center of heated discussions, particularly surrounding the research and development of COVID vaccines, messenger RNA technology, efficacy rates, side effects, booster shots, and other related topics. According to [34], the epidemiological and social crises associated with the pandemic have intensified social anxiety and increased skepticism towards vaccines. The combination of social anxiety, uncertainty, and limited knowledge about the epidemiological and clinical aspects of COVID-19 has created a fertile ground for fake news, conspiracy theories, and misinformation, ultimately influencing public attention. In this section, we follow a methodology similar to that of the previous section and measure the impact of public attention towards the COVID-19 booster shot on Pfizer's returns.

Table 5 presents the results obtained from different regression models, which suggest a negative and statistically significant relationship between high levels of public attention towards the COVID-19 booster shot and Pfizer's returns, thus confirming hypothesis 2.b. The controversy surrounding messenger RNA technology and concerns regarding the safety and potential side effects of the booster shot increased public skepticism towards the vaccine, ultimately leading to a negative impact on Pfizer's returns. While in the previous section, we observed that Pfizer's social media positively interacted with public attention towards COVID-19, the results obtained in this section suggest that there is no incremental effect during periods of heightened public attention towards COVID-19 booster shot. Therefore, we cannot validate hypothesis 3 when considering public attention towards COVID-19 booster shot. The results indicate that Pfizer failed to control the narrative surrounding the booster shot. Public trust in pharmaceutical companies has been declining due to several high-profile controversies and scandals, further reducing the efficacy of Pfizer's efforts to control the public's attention towards the booster shot.

	Pfizer				
	Model 1	Model 2	Model 3	Model 4	Model 5
PA	-0.00736***	-0.00911***	-0.00666**	-0.00752***	-0.00836***
	(0.00240)	(0.00281)	(0.00286)	(0.00251)	(0.00256)
Tweet		0.000493*			
		(0.000288)			
PA × Tweet		0.00211			
		(0.00163)			
Replies			0.00000904***		
			(0.00000258)		
PA × Replies			-0.0000125		
			(0.0000470)		
Retweets				0.00000235***	
				(0.000000569)	
PA × Retweets				0.0000110	
				(0.0000256)	
Likes					0.000000740***
					(0.000000176)
PA × Likes					0.0000119
					(0.0000102)
Control Variables	Yes	Yes	Yes	Yes	Yes
N	495	495	495	495	495
R-sq	0.388	0.395	0.404	0.410	0.412
adj.R-sq	0.376	0.380	0.389	0.395	0.397
AIC	-3232.1	-3233.7	-3240.6	-3245.6	-3247.4
rmse	0.00916	0.00913	0.00907	0.00902	0.00900

Standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 5: This table presents the estimates of different regression models explaining the relationship between Pfizer's financial returns and public attention toward the COVID-19 booster shot from January 31, 2020 to January 18, 2022.

5 Conclusion

The COVID-19 pandemic has brought unprecedented changes to our daily lives, disrupting the routines we once took for granted. Governments around the world have imposed health measures and social restrictions that have forced us to adapt to new ways of working, shopping, and interacting with one another. Social media, in particular, has experienced an exponential growth during the pandemic, helping to mitigate the impact of the most severe home confinement and lockdown measures. In this paper we examine the impact of Pfizer's social media activity and engagement, as well as the public's attention to the global pandemic, on the company's stock returns.

The results obtained in this paper suggest that Pfizer's social media engagement has a significant impact on the company's market returns. Metrics such as Replies, Retweets, and Likes on Twitter offer valuable insights into engagement levels, conversation rates, speed of information diffusion, and public approval ratings. High levels of these metrics indicate highly influential posts that can significantly impact the company's stock price. It is interesting to remark that our findings suggest social media has a significant impact on opening returns, but not on closing returns. We argue that various factors, other than social media, such as news releases, economic data, and market trends that occur during the trading day, influence closing prices. Therefore, opening prices may be more susceptible to the effects of social media activity that takes place after trading hours.

Furthermore, we find that high levels of public attention toward the terms "COVID-19" and "COVID-19 booster shot" negatively affects Pfizer's returns. The COVID-19 pandemic boosted uncertainty and volatility to unprecedented levels and heavily polarized public opinion on many relevant topics, triggering a negative market reaction during periods of high public attention. Interestingly, despite the negative effect, we find that during periods of high public attention toward COVID-19, social media engagement has a positive

incremental effect on the company's returns.

We have focused our study solely on analyzing Pfizer's social media activity during the COVID-19 pandemic, which should not be interpreted as having cross-sectional effects. It is essential to note that the impact of social media can vary significantly based on a company's specific factors and characteristics, even within the same industry. Additionally, social media and public attention are strongly influenced by environmental factors, such as economic uncertainty and volatility, which can produce varying effects over different time periods. We recommend and encourage further research on this topic that may identify potential commonalities in social media effects across companies and industries.

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