Evidence of Abnormal Trading on COVID-19 Pfizer Vaccine Development Information

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Abstract: The 2019 COVID-19 pandemic led to an economic slowdown worldwide and shook the investment world. Pharmaceutical investments were influenced by the anticipation of COVID-19 vaccine developments. Our study examines the real-time impact of public announcements concerning COVID-19 vaccine developments on stock returns and volatilities for Pfizer, Moderna, and the S&P 500. Market Return and Information Event methodology were used to analyze stock activities immediately before important public COVID-19 vaccine development announcements related to Pfizer and Moderna vaccines. This methodology was employed for vaccine news announcements between 2 January 2020 and 4 March 2022. Stock returns and volatility were analyzed with time-series regression analysis. Findings demonstrated that increased trade volatilities occurred immediately prior to COVID-19 vaccine development news was made public. Specifically, Pfizer stock returns were significantly higher (above the mean) immediately before positive COVID-19 vaccine development information was made public. Also, increased volume volatility was observed for Pfizer, Moderna, and the S&P 500 index stocks immediately before positive vaccine development information concerning Pfizer and Moderna vaccines were made public. These findings suggest that the vaccine information may have been leaked before being made public. If so, the findings may indicate that investors were taking advantage of insider information while trying to mitigate the appearance that they engaged in insider trading.

Keywords: COVID vaccine; stock market volatilities; Pfizer; Moderna; high-frequency data

1. Introduction

COVID-19, or severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), led to a global pandemic that had significant negative impacts on many United States (US) financial sectors. The COVID-19 pandemic led many nations to implement drastic measures such as business lockdowns and restrictions on people's travel, resulting in economic slowdowns and loss of jobs. Therefore, it is not surprising that Mason (2020) found that the COVID-19 pandemic caused lower GDP and labor productivity in the US. In addition, the pandemic influenced investment activity.

To combat the COVID-19 pandemic, pharmaceutical companies began the development of a COVID vaccine. Several companies developed COVID-19 vaccines; however, our study focused on the impact of vaccine developments on Pfizer, Moderna, and S&P 500 stock volatilities. Pfizer and Moderna were the pharmaceutical companies selected for the investigation because their vaccines received the most public attention, acquired the largest government contracts, and are the most widely used in the US.

Within the US, vaccine regulation is under the purview of the U.S. Food and Drug Administration (FDA). There are three primary stages in vaccine development: an exploratory stage, a pre-clinical stage, then clinical trials. The exploratory stage involves basic laboratory research. During the pre-clinical stage, vaccines are tested on animals. Clinical

vaccine development occurs in three phases. In Phase I, the trial vaccine is administered to small groups of people to test for safety. The Phase II clinical trials expand the research to a larger sample size, and the vaccine is administered to people with characteristics (e.g., physical health and age) consistent with the intended target for the vaccine to test for efficacy. During Phase III, the vaccine is given to thousands of people and tested for efficacy and safety, and is generally compared to currently available treatment options. The larger sample size used in Phase III also allows for identifying potentially rare side effects. If the FDA deems the efficacy and safety results from Phase III to meet standards, then the drug gains approval for use in the general public. After FDA approval, it is common for ongoing research to be generated to study the long-term efficacy and safety of any vaccine.

Throughout the vaccine development process, Pfizer and Moderna were required by the US Security and Exchange Commission (SEC) to disclose information that could impact the value of their firms' equity (SEC News Release 2000). More specifically, under SEC Rule 101, when a publicly held company discloses material information internally, it must immediately disclose that information to the public. Furthermore, the SEC requires that a publicly traded firm make information disclosure "promptly". Promptly is defined to be as soon as reasonably practicable within 24 h of when a senior official is aware of such information.

1.1. COVID-19 Vaccine Development

Moderna and Pfizer established themselves as pharmaceutical leaders in COVID-19 vaccine development. The COVID-19 vaccines developed by Pfizer and Moderna are classified as a new immunogen called Messenger RNA (mRNA) vaccines. The mRNA vaccines do not inoculate people with a whole virus. Rather, the mRNA vaccines inoculate people with an altered virus and encode a messenger RNA (mRNA) with the information to produce the COVID-19 spike protein as the virus does. In short, the mRNA vaccines work by teaching our cells how to make a protein that triggers the body to generate an immune response. The COVID-19 mRNA vaccines moved quickly through clinical trials in the US with a "warp speed" policy adopted by the US federal government, providing emergency authorization as opposed to the typical FDA approval protocol. Another factor that accelerated Phase III clinical trials was the rapid spread of COVID-19, which allowed vaccine efficacy endpoints of over 90% to be achieved quickly.

Moderna and Pfizer were allowed to submit combined results to the FDA Phase I and II simultaneously. Moderna submitted vaccine Phase I/II clinical trial data on 14 July 2020 and Pfizer followed with similar reports on 12 August 2020. According to Brothers (2020), findings from both companies' clinical tests demonstrated promising COVID-19 antibody production and drug safety for those receiving the vaccine. Given the promising results, Phase III trials began. Moderna focused on US test subjects, whereas Pfizer took a global approach. More than 70,000 people participated in clinical testing. Both Pfizer and Moderna had Phase III trial results showing an efficacy rate of approximately 95% with only slight adverse events in about 2% of the subjects. FDA emergency use authorization (EUA) for Pfizer was announced on 11 December 2020 and was followed by approval for the Moderna vaccine on 19 December 2020.

1.2. Media Effect on Investments

Investors typically research publicly available news about potential investment options before making a buy or sell decision about a particular security. Therefore, the media can moderate stock price and trade volumes by influencing investors' actions related to a given company or industry sector. News is transmitted extremely quickly in the 21st century and can cause quick, if not immediate, effects in financial sectors. The "media effect" is the impact of a public announcement (news) on a given stock or on financial markets in general. A negative outcome from a news event can be referred to as headline or media risk (Chen 2020). Of course, positive news about the economy or a specific company can generate positive reactions from investors. For example, positive news about the FDA

approval of a new drug can create positive movements in a given industry or with a given stock.

1.3. COVID-19 Impact on Financial Markets

Chaouachi and Slim (2020) utilized an Autoregressive Distributed Lag (ARDL) cointegration approach to examine the moderating effect of the COVID-19 pandemic on the stock market in the Kingdom of Saudi Arabia (KSA). The cointegration bounds test was observed for daily series from 2 March 2020 until 20 May 2020. The findings indicated that COVID-19 adversely impacted the KSA stock market.

Liu et al. (2020) evaluated the COVID-19 pandemic impact on 21 leading stock market indices for several nations, including the US, Germany, South Korea, Japan, Singapore, United Kingdom, and Italy. Their event-study model demonstrated quick and significant reductions in respective stock markets in all observed nations shortly after the COVID-19 outbreak. The Asian financial markets experienced adverse effects of abnormal returns compared to North America and Europe. Liu et al. (2020) argue that the negative impacts on financial markets were due to investors' pessimism about future returns and uncertainties.

Alam et al. (2020) investigated the impact of India's business lockdowns on its stock market. The study examined the market reactions before and after the lockdown period and examined the effects with the Market Model Event study methodology. For the study, observations were taken for 31 companies on the Bombay Stock Exchange over a period of 35 days in 2020. The official lockdown announcement served as the event. An event window of 35 days was utilized, defined as 20 days before to 15 days after the announcement. The results indicated that the market reacted with significant changes in Average Abnormal Returns. Furthermore, the study confirmed that lockdowns had significant impacts on stocks.

According to Oxford Analytica (2020), millions of investors make equity investments every microsecond based on their expectations of the future. As a result, investors are likely to shift their investments as news of vaccine success or failure impacts financial sectors. It is possible that some of these changes may have lasting impacts on given financial sectors.

The effects of the pandemic were felt in the pharmaceutical industry, which worked to create a vaccine for the COVID-19 virus (Ayati et al. 2020). With vaccine research underway by several pharmaceutical companies, the public had high anticipations for vaccine developments. As positive pharmaceutical clinical research news about vaccine development becomes publicly available, it is reasonable to expect that a given pharmaceutical company's stock might experience increased volatility in real-time (Phan and Narayan 2020). A behavioral psychology theory called S-O-R explains how an external stimulus (S) leads an organism (O) towards a response (R) behavior (Kumar et al. 2021; Mehrabian and Russell 1974; Xu et al. 2014). To apply S-O-R to investment decisions, it follows that positive COVID-19 drug treatment development news (external stimuli) influences investors' (organism) perceptions, thus impacting investors' stock purchase behaviors (response behavior). As such, our study examines whether public information of COVID-19 vaccine developments by Pfizer and Moderna introduced stock volatility for these two pharmaceutical companies.

1.4. Research Question

As significant news becomes available, markets tend to over-react, and as more information becomes available and people understand the ramifications more broadly, the market corrects itself. Based upon this general principle, it was expected that as communications about Pfizer and Moderna clinical trials and FDA approvals were made public, the respective company would experience greater stock volatility. Specifically, the following research question was investigated.

Research Question: Is there evidence that investment insiders had information about COVID-19 vaccine development before that information was made public?

2. Methodology

The dependent variable (DV) examined was stock volatility as measured by two metrics, namely changes in stock prices and trade volumes for Pfizer and Moderna within minutes before a given public announcement about vaccine development was released. The independent variables (IVs) were public vaccine development announcements for Pfizer and Moderna COVID-19 vaccines. Stock volatilities for Pfizer and Moderna were examined after a total of eight preliminary investigations, and final clinical research results and FDA authorizations were made public. After the eight public announcements regarding Pfizer and Moderna COVID-19 vaccines, Pfizer (PFE) and Moderna (MRNA) stock prices and trading volume levels, respectively, were examined. Below is a summary of the selected announcement events.

- Pfizer phase I clinical results reveal vaccine-elicited SARS-CoV-2–neutralizing geometric mean titers (GMTs)—published on 20 August 2020—08:00 p.m. US EST (Pfizer Phase I News Release 2020).
- Pfizer phase 3 clinical trials reveal vaccine efficacy over 94% across age, gender, race, and ethnicity—published on 18 November 2020 at 06:59 a.m. US EST (Pfizer Phase 3 News Release 2020).
- Pfizer COVID-19 vaccine granted FDA emergency use authorization—published on 11 December 2020 at 11:12 p.m. US EST (FDA Pfizer News Release 2020).
- Pfizer COVID-19 vaccine receives full US FDA approval for individuals 16 years and older—published on 23 August 2021 at 11:57 a.m. US EST (Pfizer Full Authorization News Release 2021).
- Moderna phase 1 results show COVID-19 vaccine safe, induces immune response—published on 14 July 2020 at 4:03 p.m. US EST (Reuters News Release 2020).
- Moderna Phase 3 COVID-19 vaccine clinical results reveal 95% efficacy—published on 16 November 2020 at 6:59 a.m. US EST (Moderna News Release 2020).
- Moderna COVID-19 vaccine granted FDA emergency use authorization—published on 19 December 2020 at 7:46 p.m. US EST (Moderna News Release 2020).
- Moderna COVID-19 vaccine granted US FDA full approval—published on 31 January 2022 at 12:34 p.m. US EST (Associated Press News Release 2022).

3. Data Collection

The market activity data were obtained from PiTrading.com and consisted of 1-minute quotes of S&P 500, PFE, and MRNA stocks between 2 January 2020 and 4 March 2022. The data consisted of 1-minute quotes, which were observed for trading days, including days in which the stock market was stopped in response to circuit breakers being triggered. Data observations during circuit-breaker events were recorded as '0'. The resulting data included 212,550 1-minute quotes. The quotes were adjusted for dividends/distributions, and the returns were calculated based on the adjusted quotes to yield total returns. After total returns were obtained, absolute returns were derived.

The event dummy variables for Pfizer and Moderna were obtained from various media outlets that provided the earliest time-stamped publications. The vaccine events included announcements of vaccine development milestones and regulatory approval. If an informational event took place after markets closed for normal trading and before the markets opened the next day, the previous day's closing minute return was used for analysis. Market return descriptive statistics for these 1-minute time intervals are provided in Tables 1–3.

Table 1. S&P 500 Index Return Descriptive Statistics.

SP500	Absolute Return, R_t
Observations	212,550
Mean	0.0003237
Standard Deviation	0.0006985
Minimum	0.0
Maximum	0.0812379

Table 2. Pfizer Stock Return Descriptive Statistics.

PFE	Absolute Return, R_t
Observations	212,550
Mean	0.0005315
Standard Deviation	0.0009621
Minimum	0.0
Maximum	0.1278334

Table 3. Moderna Stock Return Descriptive Statistics.

MRNA	Absolute Return, R_t
Observations	212,550
Mean	0.0001583
Standard Deviation	0.0026842
Minimum	0.0
Maximum	0.0266303

Capital markets tend to reflect public information about firms based on the firms' stock prices. As such, Market Return and Information Event (MRIE) methodology can be used to study how a given event changes a firm's prospects by quantifying the impact of the event on the firm's stock. This study utilized MRIE methodology, as proposed by Andersen and Bollerslev (1997), to examine stock market activity. Using MRIE, information events were analyzed on the conditional variance and mean of a stock market index using a time-series model via 1-minute observations. As suggested by Hussain (2011), the MRIE model is useful for examining the impact of specific information on the stock market minute-by-minute activity. For the MRIE analysis, market activity was conducted with Autoregressive Moving Average (ARMA) regression analysis via a Newey-West estimator. The data was collected for dates when clinical vaccine development results were public. Elkassabgi et al. (2019) demonstrated the usefulness of this model for capturing market volatility based on public information events.

The MRIE model 1 captured the effect of COVID-19 vaccine information events on Pfizer and Moderna combined (unspecified) on the S&P 500 Index absolute returns (SP500, a.). Also, model 1 analyzed Pfizer stock absolute returns (PFE, b.). In addition, model 1 examined Moderna (MRNA, c.) stock absolute returns. All three aspects of model 1 were analyzed using their own ARMA terms. S&P 500, PFE, and MRNA 1-min returns R_t were modeled as ARMAs (p,q), where $\Phi(L)$ and $\theta(L)$ were lagged functions of order p and q of the AR(p) and MA(q) processes, respectively, at j lags on each information event. The variables $InfoEvent_{k,t-j}$, $PFEInfoEvent_{k,t-j}$, and $MRNAInfoEvent_{k,t-j}$ were dummy variables related to the information event at time t for the combined events, Pfizer-specific event, and Moderna-specific events, respectively. Significant $\beta_{k,j}$ for any given dummy variable indicates that stock activity did respond to public vaccine announcements. The Schwarz information criteria analysis was used to choose the best number of lagged values in the model (Schwarz 1976). Based upon the Schwarz information criteria, the best number of lagged values was determined to be (−1). The MRIE was used for the S&P

500 Index returns (a.), then on Pfizer stock returns (b.), and then on Moderna stock returns (c.). Specifically, the model 1 formulas were as follows.

$$a.\ R_t = \Phi(L)R_t + \theta\varepsilon_t + \sum_{k=1}^{K}\sum_{j=0}^{J}\beta_{k,j}InfoEvent_{k,t-j}$$

$$b.\ R_t = \Phi(L)R_t + \theta\varepsilon_t + \sum_{k=1}^{K}\sum_{j=0}^{J}\beta_{k,j}PFEInfoEvent_{k,t-j}$$

$$c.\ R_t = \Phi(L)R_t + \theta\varepsilon_t + \sum_{k=1}^{K}\sum_{j=0}^{J}\beta_{k,j}MRNAInfoEvent_{k,t-j}$$

The Volatility Response and Information Event (VRIE), model 2, dependent variables $|\hat{\varepsilon}_t|$, were based upon the absolute value of the residuals obtained from model 1. The independent variable side of model 2 demonstrates whether the S&P 500, PFE, and MRNA volatilities were driven in part by their ARMA terms or by seasonal intraday volatility patterns. The variable N represents the number of intervals within any given trading day. The seasonal intraday pattern component was the last variable of the model, and it is a Flexible Fourier Form (FFF) with daily periodicity (Andersen and Bollerslev 1997; Fan and Wang 2008; Hussain 2011). The nature of the Flexible Fourier Form is a repeating integrated Sin/Cos cycle that repeats infinitely and throughout the study data observed. The Flexible Fourier Form of this model comprises a parameterized quadratic component with one intraday undulation fitted on the mean of each 1-minute return for each day of the entire data set for S&P 500, PFE, and MRNA stocks. The FFF was tested for significance of the representation of the average intraday volatility of each return and was highly significant with $p < 0.001$. As such, this methodology indirectly incorporates the method presented by Gallant (1981) and applied by others (Andersen and Bollerslev 1997; Elkassabgi et al. 2019; Hussain 2011). The market volatility PFE and MRNA Information Event models were for the S&P 500 Index returns (a.), then on Pfizer stock returns (b.), and then on Moderna stock returns (c.). The model 2 formulas used were the following.

$$a.\ |\hat{\varepsilon}_t| = \Phi(L)|\hat{\varepsilon}_t| + \theta\mu_t + \sum_{k=1}^{K}\sum_{j=0}^{J}\beta_{k,j}InfoEvent + \beta_i\left(\sum_{j=0}^{J}\left[\begin{array}{c}\mu_{0j} + \mu_{1j}\frac{n}{N_1} + \\ \sum_{q=1}^{Q}\left(\delta_{qj}\cos\left(\frac{qn2\pi}{390}\right) + \varphi_{qj}\sin\left(\frac{qn2\pi}{390}\right)\right)\end{array}\right]\right) + u_t$$

$$b.\ |\hat{\varepsilon}_t| = \Phi(L)|\hat{\varepsilon}_t| + \theta\mu_t + \sum_{k=1}^{K}\sum_{j=0}^{J}\beta_{k,j}PFEInfoEvent + \beta_i\left(\sum_{j=0}^{J}\left[\begin{array}{c}\mu_{0j} + \mu_{1j}\frac{n}{N_1} + \\ \sum_{q=1}^{Q}\left(\delta_{qj}\cos\left(\frac{qn2\pi}{390}\right) + \varphi_{qj}\sin\left(\frac{qn2\pi}{390}\right)\right)\end{array}\right]\right) + u_t$$

$$c.\ |\hat{\varepsilon}_t| = \Phi(L)|\hat{\varepsilon}_t| + \theta\mu_t + \sum_{k=1}^{K}\sum_{j=0}^{J}\beta_{k,j}MRNAInfoEvent + \beta_i\left(\sum_{j=0}^{J}\left[\begin{array}{c}\mu_{0j} + \mu_{1j}\frac{n}{N_1} + \\ \sum_{q=1}^{Q}\left(\delta_{qj}\cos\left(\frac{qn2\pi}{390}\right) + \varphi_{qj}\sin\left(\frac{qn2\pi}{390}\right)\right)\end{array}\right]\right) + u_t$$

Figure 1 illustrates the first 6 consecutive days (2 January 2020 through 9 January 2020) of the approximately 2 years of minute-by-minute (Timeall) data analyzed. The graph shows the S&P 500 Absolute Returns (AbsReturn) and the Flexible Fourier Form (FFF) used to factor for intraday volatility of the returns. Graph 1 exemplifies the structure of the typical intraday trading activity and the utilization of the Flexible Fourier Form to control for the intraday volatility inherent in a trading session. Higher volatility was observed at the beginning and end of each trading day and lower volatility towards the middle of the trading day. The parameters of the quadratic formula for the FFF are consistent with prior literature (Andersen and Bollerslev 1997; Elkassabgi et al. 2019; Hussain 2011) and are significant to the average intraday volatility of the S&P 500 volatility, with a $p < 0.001$.
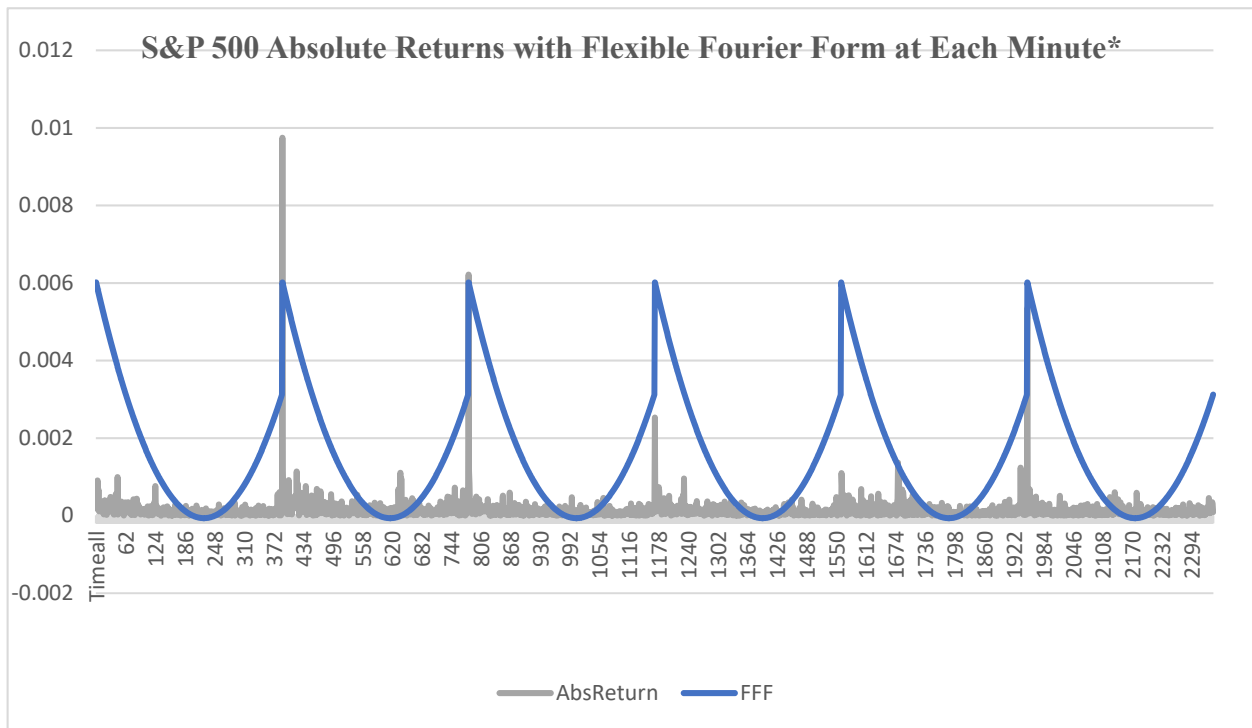
Figure 1. S&P 500 Absolute Returns and Flexible Fourier Form, * observation days were 2–9 January 2020.

4. Results

The findings presented in Table 4 demonstrate the impact of COVID-19 vaccine public announcements on stock returns and volatility for Pfizer, Moderna, and the S&P 500, respectively. Table 4 shows the results for models 1–2, the return model, and the volatility response model. The right column shows the corresponding betas for PFE, MRNA, and SP500 information events on return and volatility, as well as their corresponding standard error (in parenthesis).

Table 4. Index/Stock Returns and Volatility Responses to Information Events.

Model 1 Return and Model 2 Residuals	PFEInfoEvent β (Std. Errors)	MRNAInfoEvent β (Std. Errors)	InfoEvent β (Std. Errors)
Market Return Response Estimates			
PFE Stock Absolute Returns (−1)	0.000587 *		
	(0.0003608) *		
MRNA Stock Absolute Returns (−1)		0.00014278	
		(0.000176)	
SP500 Absolute Returns(unspecified) (−1)			0.0001179
			(0.0004701)
Lagged Market Volatility Response Estimates			
PFE Stock Absolute Returns (−1)	0.0005639 **		
	(0.0000733) **		
MRNA Stock Absolute Returns (−1)		0.00015322 **	
		(0.00002934) **	
SP500 Absolute Returns (unspecified) (−1)			0.0001016 **
			(0.0050778) **

** Statistically significant coefficients at 1% level. * Statistically significant coefficients at 10% level.

The results of the market return response show a significant positive return, above the mean, for Pfizer stock of 0.000587 immediately before the announcement of an event. This significant abnormal increase in returns possibly indicates insider buying immediately before an announcement. There was also a significant increase in return volatility immediately before announcement events (while controlling for normal intraday volatility).

As for the Moderna and S&P 500 index, the results of the market return response did not show a significant return. However, there were significant increases in return volatility related to trade volumes immediately before the announcement events. The increased volatility indicates possible investor knowledge of the vaccine development news before it was made public. With the advanced knowledge of vaccine development news, trade volume could have been influenced as investors repositioned equity holdings in order to take advantage of the news.

5. Discussion

This research explored evidence of information leaks pertaining to key pharmaceutical COVID-19 vaccine developments and FDA approvals for Pfizer and Moderna vaccines. The results show significant returns above the mean for Pfizer stocks right before COVID-19 vaccine approval decisions by the FDA were released. When assessing stock and index volatility on each individual company and both combined, we found that there was a significant positive increase in volatility for the S&P 500, Pfizer, and Moderna stocks, respectively.

The more pronounced effect of COVID-19 vaccine development and approval news for Pfizer equity might be explained by the fact that the Pfizer vaccine completed its clinical trials first. In the pharmaceutical industry, the first-to-market gains a competitive marketing share advantage, thus making them more attractive to investors. Since Pfizer was the first-to-market with a vaccine to mitigate COVID-19, it follows that Pfizer would gain greater investor interest and activity. The significant changes in Pfizer stock prices and trading volatility support this notion.

Although significant return results for Moderna and the S&P 500 were not observed, increases in volatility were observed. These findings suggest potential market reactions to leaks of information. For example, positive information about an effective COVID-19 vaccine might have influenced investors to buy S&P 500 stocks such as hotels and cruise line companies that would benefit from vaccine information that indicates a lessened impact of COVID-19. Similarly, positive vaccine developments could influence investors to sell, or to short, stocks of companies such as Zoom and Roku, which benefited from the pandemic. However, it appears that many equity trades were timed to occur immediately before the information was revealed. A possible explanation for this observation is that trades were made before, but as close as possible to when vaccine development information was made public to mitigate the appearance of insider trading.

6. Conclusions

Our study revealed that COVID-19 vaccine development announcements triggered volatilities in the US financial market. In addition, the study provides some evidence that important COVID-19 vaccine development news leaked out before it became public. Specifically, Pfizer stocks showed significant volatilities prior to an important COVID-19 vaccine clinical test and approval announcements. The implication is that the information seems to have been known to investors prior to being made public. If so, the findings may indicate that investors were taking advantage of insider Pfizer COVID-19 vaccine information while trying to mitigate the appearance that they engaged in insider trading. Therefore, financial policymakers may need to improve safeguards to protect pharmaceutical trial data in order to mitigate information from being improperly leaked to market participants.

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