

VACCINE COMPANIES VERSUS THE RETAIL INVESTOR

Implications of share price behavior in COVID-19 vaccine
development candidate companies on retail investors

Stephanie Tian
Student, Finance & Accounting
stian@wharton.upenn.edu

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Faculty Advisor:
Sergei Savin
Associate Professor of Operations,
Information and Decisions

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Abstract:

The price reactions of COVID-19 vaccine development candidate companies are examined in order to explain how prices behave in highly-publicized scenarios and how retail investors are impacted. Findings indicate that retail investors were susceptible to inappropriate timing of the market and sustained losses on average. Various methods of prior analysis and their limitations are introduced including observation of trading volume makeup, event-themed reactions, and financial statement extraction that may guide subsequent navigation of volatile trading landscapes. Portfolio methods of mitigating losses due to lack of information or misinformation are also explained.

Keywords:

Biotechnology, Finance, Markets

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INTRODUCTION

Biotechnology company stock price behavior is one of the many phenomena that have arisen from the economic recession caused by the spread of the coronavirus disease (COVID-19) discovered in 2019. The stock market crash of about 33% over 30 days, named the “Coronavirus Crash,” was warranted as economic conditions deteriorated. In November alone, there were more than four million new cases and 25,500 deaths in the United States. Worldwide, as of the beginning of December, there had been nearly 62 million cases and almost 1.5 million deaths. The markets, however, reversed in record fashion as well, reentering a bull market by April 2020 despite growing daily cases.

Notwithstanding abnormal conditions, small/mid-size biotech companies are recognized as a few of the most volatile publicly traded companies. Among these companies, correlation with the overall market is low, and standard deviations of returns are high. Yet, they face some of the lowest effective tax rates, the highest potential returns on investment (R&D), and the fastest reaction times to positive press releases (Betas 2020). The pandemic refocused attention on the stock patterns of biotech companies especially those who are candidates for vaccine production because a vaccine was largely identified as a catalyst for economic recovery. Consequently, retail investors became increasingly exposed to this sector’s volatility. A retail investor is an investor who purchases securities for a personal account. In contrast, a professional investor is one who invests on the behalf of other people or institutions and is usually highly trained. Retail investors are well-known for acting irrationally, trading with short-horizons, and falling victim to unfortunate market timing. Brokerage and investing platforms that market trading as uncomplicated are complicit when they do not provide sufficient information. This study deconstructs the rationality of price reactions of “vaccine-candidate companies” and summarizes the implications for an investor in the company with a focus on the retail investor.

Although COVID-19 cases are still being reported, the timeline for the study is not inappropriate because full life cycles of funding, clinical trial launches, and approval of a vaccine have been completed.

Main questions discussed

- *Have common investors benefited/lost thus far from investing in vaccine candidate companies?*

Section IV discusses why an average investor could have lost significant value (up to -300% annualized) by investing in candidate companies. Following the trend or other forms of mistiming the market make investors susceptible to losses. Measurements of returns and risk can be manipulated or miscalculated to falsely inflate performance.

- *What patterns could aid an investor in pre-determining the risk of investing in a certain*

company?

A less unexpected factor is that larger companies showed more stability of price as well as a higher likelihood for advancing in clinical trials; however, the impact of creating a vaccine is less impactful for a large company than for a small company. Large company returns are also highly correlated with market indexes and overall less likely to be explained by events surrounding vaccine-development. More compelling findings include the positive relationship between the volume of retail investors holding shares and irrational behavior or the differences in price changes following certain types of events between companies. Also, financial reporting and scientific vaccine information do not appear to translate significantly to equity prices. Considerations of investing *long-term* in vaccine candidate companies are also discussed in Section 5.3.

- *What strategies could investors have employed in order to maximize performance?*
Along with studying the trend characteristics associated with individual companies, employing modern portfolio theory proves to be a powerful tool. Because each investor's risk appetite differs, emphasis is on outlining factors that help investors identify the most likely behavior of a company of interest.

Audience

Investors:

The focus is on implications for a retail investor because they are a unique subset of investors more likely to take risks and engage in a trade involving vaccine candidate companies and be less professionally-trained to recognize or mitigate the risks. A retail investor using the following study as a tool should find information about the returns profile of the vaccine competitive space and why it has formed that way. Professional investors often avoid small-cap biotech companies altogether due to lack of liquidity or unpredictability or minimize risk by diversifying, but these investors could also utilize the report as additional justification and evidence or to understand missed opportunities.

Unlike most preceding studies, this paper monitors variables only within a specific subset of companies and within the context of a crisis. Retail and professional investors alike often scrutinize the ability of companies to withstand and perform in crises. The findings and methodology can be extrapolated to other industries and companies in highly-publicized scenarios (tech companies in antitrust hearings, tech companies with popular products, auto and oil companies) but less so the general market as a whole or companies highly correlated with the market. Many speculative investors are attracted to healthcare stocks precisely for their unpredictability by traditional means. The volatility presents extreme movements by which investors can realize large rewards but at the cost of high risk. The ability to eliminate uncertainty is valuable.

Company/Investor Relations/Other Parties:

The company itself may presumably be interested in the research especially section 5.2 which discusses reactions of investors to news releases. Companies may wish to limit their stock's volatility or seek to protect their investors. Price and price prediction is also important for a company that may be considering engaging in share repurchases or share issuances. Companies should, however, not manipulate information to receive favorable prices.

Outside parties may include forensic accountants, regulators, corporate bondholders, company competitors, and any other company stakeholders such as employees, customers, or suppliers.

I. LITERATURE REVIEW

Framework:

The present study incorporates myriad methodology from the fields of finance, accounting, and other academic areas. Prior academic articles on the subject of financial prediction have progressed to include new models that require high computing power that several hedge funds seeking to outperform the market index rely upon. It is important to understand the statistical and financial assumptions and drawbacks of each. It is also important to recognize that more prediction-focused models may not provide accurate interpretations. The following explains the background of these methodologies and their applications concerning how they may be employed for this study.

Event-Based Market Behavior:

To introduce the development of the body of work behind this research, Ball and Brown (1968); and Beaver (1968) are the points of reference for the “empirical revolution” of event-based research that sought to link accounting quantitative methods to predict capital market outcomes. Beaver (1968) concluded that trading volume and return volatility vary at earnings announcement dates. These dates will be of interest to this study. Ball and Brown (1968) test the efficient market hypothesis, showing that the market incorporates information released into forecasts steadily until the earnings announcement date on which the new earnings are fully incorporated into the stock price. Doyle, Lundholm, and Soliman (2006) analyze the following periods in which any surprise earnings are integrated into future forecasts. Eventually, analysts’, those producing and releasing their estimates before the earnings announcement, forecast errors converge to zero for a firm after 2-4 quarters. This phenomenon is referred to as “post-earnings drift.”

Referencing Beaver (1968), investors trade most frequently immediately after earnings announcement dates, and financial analysts are perceived to be the dictators of a firm’s financial performance (Filzen & Peterson, 2015; Kasznik & McNichols, 2002). The forecast error prediction prior to the earnings announcement would be equivalent to a prediction of short-term stock price movements.

The assumption that the biotechnology market exhibits similar trends of increased volume around earnings announcement dates and significant events in the direction of analyst forecast errors is not guaranteed, and it is explored in section 4.1 of this study.

Factor-Analysis:

The paper by Soliman also presents charts to show characteristics of different portfolios based on the level of forecast error called “earning surprise portfolios.” These are inspirations for the initial exploratory data analysis of this study which explores if vaccine companies pricing behavior can be characterized and analyzed for factors, accounting or qualitative.

Sloan (1996) introduces a more accounting-intricate proposal that analysts fail to understand the disaggregation of earnings as a combination of accruals and cash flow from operations by analyzing coefficients of these terms when regressed to earnings and forecast error. Firms with higher levels of accruals show higher surprise metrics.

Richardson, Sloan, Soliman, and Tuna (2005) ran similar analyses with a further decomposition of accruals and cash flow from operations. They find that analysts also underestimate the predictability of accruals. The following year’s change in assets is determined in part by the persistence of cash flows but also by changes in and reversals of accruals.

Bradshaw, Richardson, and Sloan (2001) model changes in ROA with a DuPont analysis. This research continues the trajectory of recent trends within this specific sphere of research. Having disaggregated several measures for earnings in the early 2000s, researchers have transitioned to modeling increasingly macro-events with direct interpretability rather than accounting minutiae. For example, Petrenko, Aime, Recendes, and Chandler (2019) relate CEO humility to expected EPS. Ahmed, Neel, and Safdar (2019) have shown that ‘accounting comparability,’ or availability of accounting accruals information for the company and its peers, reduces the negative association between accruals and subsequent returns. Pettenuzzo, Sabbatucci, and Timmerman (2019) extended the study to find relations between cash flow shocks and future growth in dividends and consumption. Wu (2019) analyzes earnings call manipulation strategies. Tirodkar (2019) finds analyst pessimism towards polluting firms’ earnings.

Factor-Analysis, Applied to Healthcare:

Fewer works have analyzed industry-specific trends, particularly within healthcare services. Most similarly, work on R&D as a predictor of earnings and a signal of agency conflict between managers and shareholders (Gentry and Shen 2012) applies accounting analysis to interpret R&D heavy businesses. Other related studies may not seek to identify the relationship between earnings and various accounting factors but have analyzed the effects of changes in the finance and accounting environment on the industry. Researchers question the success of care regulations - in the EU, agencies failed to prevent several high-profile care quality breakdowns, leading to management changes (Beaussier, Demeritt, Griffiths, and Rothstein 2015). These factors may translate into variables for an earnings mode for healthcare services: Clemente studies new accounting methods that incorporate the industry’s increasing costs (Clemente 2019). The managerial accounting strategies for decisions on whether to outsource are complex (Nielsen, Mitchell, Norreklit 2014). There is also difficulty in implementing these new

accounting and budgeting systems and tax dodging (Aidemark 2010; Cictar 2020). Quantitatively, works have found a relationship between rising healthcare costs and technological investment with ‘inescapable’ demographic change (Gebreiter and Ferry 2014); costs and also cost efficiency is also correlated with rising costs of pharmaceuticals (Shree and Monica 2020). More specific operational measures implemented could signal efficient cost management: Diagnosis Related Group (DRG) systems, and costing practices (Chapman, Kern, Laguecir 2014).

The pharmaceutical industry has been more extensively reviewed for forecast predictability. Each company relies upon key decisions: sales force allocation, geographic resource allocation, acquisition, licensing, and R&D. Most consensus forecasts are inaccurate; analysts have difficulty predicting the duration of clinical development and approval (Cha, Rifai, and Sarraf 2013; Hao, Forgione, Guo, and Zhang 2017). The size of the company, information availability, intangible assets information (Gu and Wang 2005), and analyst coverage determine analysts’ accuracy. Chen, Chi, and Wang 2014 model biotech earnings manipulation with less interpretability, using neural network and principal component analysis, achieving an accuracy of 98.51%.

Aggregation of the above may serve as the inception of accounting research in healthcare. Understanding patterns can engage several parties: healthcare managers facing rising costs can reallocate resources accordingly, value chain companies (pharmaceuticals, patients, third parties) can adjust the economics of their businesses, and shareholders can deploy capital efficiently within the industry. Since 1992, investors have been wary of unpredictability and lack of information, coining the reference to the sector, “health scare,” (Lutz 1992), and developing hedging portfolio strategies for “healthcare inflation” (Rahimi and Mahendra 2012).

In a paper on the effects of leading pharmaceutical stocks listed on the Indian stock exchange, NSE finds persisting momentum trends but also the brand reputation showed correlation with companies that “sustained the crisis.” The study found structural differences between stock behavior before and during the crisis and calculates that the spread between abnormal returns of winning stocks vs losing demonstrated persistence of momentum. It noted that the perception that a pandemic would increase demand for pharmaceutical stocks was false which is another point of a possible misstep for a retail investor (Aravind and Manojkrishnan 2020).

Present study:

As noted above, although several factors and models have been built for the healthcare biotech/medical devices industry, short-time horizon analysis of the coronavirus crisis is limited. Ubiquitous and comprehensive information on company performance is widely available in the form of financial statements, news releases, and opinion sources. The study defines the relevant factors and extracts their predictability. This paper will also outline how the factors other papers

have identified as significant will be represented differently under circumstances such as the pandemic.

Secondly, while past papers were largely preoccupied with aggregate, and presented findings through creating portfolios of companies, investors are often also concerned with individual security valuation. For this reason and also because there are few publicly traded top vaccine companies, this paper further explores stock price behavior company-by-company and outputs results that analyze an individual company's behavior and whether it aligns with that of others. Whereas for professional investors, idiosyncratic (company-specific) risk is not relevant because portfolio managers use methods like diversification to minimize it, retail investors are often exposed to it by seeking optimal returns rather than optimal risk-return relationships. A final limitation is that financial data from during the crisis only comprises the first through third quarters and the annual report. A regression that tests for structural breaks before, after, and during the crisis will have large variation and may not be a beneficial depiction.

II. INTRODUCTION TO COMPANIES OF INTEREST

2.1 Vaccine companies of interest

The top companies are selected from a directory published by the World Health Organization - a “DRAFT landscape of COVID-19 candidate vaccines.” This document includes 213 candidates as well as their status of clinical trials and has been consistently updated since April 2020.

Top companies highlighted by WHO include:

Moderna

Moderna applied for emergency FDA approval on November 30, 2020. Moderna’s mRNA vaccine reported 94.1% effectiveness in an interim trial. Moderna announced an agreement June 25, 2020, with the drug manufacturer, Catalent, Inc. to manufacture their mRNA-based COVID-19 vaccine candidate (mRNA-1273) at Catalent’s facility in Bloomington, Indiana to support the production of an initial 100 million doses of the vaccine candidate intended to supply the U.S. market starting in the third quarter of 2020. Moderna began development in January with nearly \$1 billion from the US government. The company has tested mRNA vaccines for several diseases but has yet to bring one to market. On August 11, 2020, the United States government awarded the company an additional \$1.5 billion in exchange for 100 million doses if the vaccine proves safe and effective. On Nov. 25, the company reached an agreement with the European Commission to supply up to 160 million doses. Moderna has made similar deals with Canada, Japan, and Qatar.

Pfizer/BioNTech

Pfizer applied for emergency FDA approval of an mRNA vaccine on November 20, 2020, with a promised production capacity of 50 million doses within a year following preliminary data showing 90% efficacy on November 9, 2020. BioNTech/Pfizer’s vaccine was the first to be approved for use other than Russia and China which approved vaccines without Phase 3 clinical trial data. The vaccine was approved on December 3, 2020, in the UK and on December 11, 2020, in the US. The company has secured multiple agreements with countries including Japan, Canada, the US, and the UK to supply doses.

AstraZeneca/University of Oxford

November 23, 2020, AstraZeneca announced 90% efficacy for their vaccine for those who received a half-dose, though a manufacturing error created false results in their full dose participants (only 62% efficacy). Their vaccine is developed using a viral vector, allowing harmless viruses carrying coronavirus genes to enter cells which induces the body to produce antibodies. The United States awarded the project \$1.2 billion in support for 300 million doses should the vaccine prove effective. In August 2020, the European Union agreed for AstraZeneca

to deliver 400 million doses should the vaccine prove effective. The company claims 2 billion vaccine doses in annual manufacturing capacity.

Johnson & Johnson (J&J)

J&J signed an agreement on April 29, 2020, with Catalent, Inc. to prepare their facility in Bloomington, Indiana, and to hire 300 additional personnel for manufacturing of J&J's vaccine candidate. Similar to AstraZeneca's vaccine, J&J's vaccine is developed using a viral vector. The method was used by J&J to create a vaccine for Ebola and requires only one dose. In August 2020, the federal government agreed to pay \$1 billion for 100 million doses contingent on approval. The European Union reached a similar deal on Oct. 8 for 200 million doses. The company is aiming for the production of at least a billion doses in 2021.

Sinopharm

Sinopharm is a state-owned Chinese company. The Chinese government gave Sinopharm approval to administer to vaccinate select groups (government officials and healthcare workers), and the company reported nearly a million vaccines had been distributed by November. Sinopharm applied to market their vaccines to China on November 25, 2020. However, many scientists view inactivated virus vaccines as outmoded and difficult to make in high volume with Warp Speed rejecting the approach. This vaccine is not studied independently because it is not listed on a US exchange, but the impacts of Sinopharm's vaccine development and results are included in the study.

Sinovac Biotech

Production has started at a new plant in Beijing with an annual capacity of roughly 300 million doses as of August 28, 2020, and also uses an inactivated viral vector approach. This vaccine is not studied independently because it is not listed on a US exchange, but the impacts of Sinovac's vaccine development and results are included in the study.

CanSino

Chinese company CanSino Biologics launched the world's first vaccine trial in Wuhan in March 2020 though their vaccine elicited a weaker-than-expected antibody response. Their vaccines are viral vectors. CanSino's vaccines were approved for military use in China. This vaccine is not studied independently because it is not listed on a US exchange, but the impacts of Cansino's vaccine development and results are included in the study.

Novavax

Maryland-based Novavax developed a protein-based vaccine (vaccines introduce coronavirus proteins via microscopic particles) a method that the company has used for various other diseases. The company launched trials in May 2020, and the Coalition for Epidemic

Preparedness Innovations has invested \$384 million in the vaccine. In July 2020, the U.S. government awarded Novavax another \$1.6 billion to support the vaccine's clinical trials and manufacturing. In September 2020, Novavax reached an agreement with the Serum Institute of India, a major vaccine manufacturer, that they said would enable them to produce as many as 2 billion doses a year. If the trials succeed, Novavax expects to deliver 100 million doses for use in the United States by the first quarter of 2021. On Nov. 4 they announced another agreement to deliver 40 million doses to Australia.

Sanofi/GlaxoSmithKline

Sanofi has developed both an mRNA and a protein-based vaccine. Sanofi has negotiated a \$2.1 billion agreement with the United States to provide 100 million doses. On Sept. 18 the European Union agreed to have Sanofi produce 300 million doses and Canada agreed for 72 million doses. Sanofi agreed to provide 200 million doses to COVAX (an organization discussed in section 2.3). Sanofi claims the capacity to produce one billion doses in 2021. This vaccine is not studied independently because it does not report quarterly and annual reports to the SEC which could produce a confounding variable.

Vaccine companies highlighted by market price appreciation:

The following companies' share prices appreciated significantly but their vaccines had not progressed as far as the vaccines from companies highlighted above.

Altimune inc.

Altimune's expertise is in liver disease and immune-modulating therapies. The company's vaccine is based on an influenza vaccine that is delivered intranasally. The company's vaccine was preclinical as of November 26, 2020.

Vaxart Inc.

Vaxart's vaccine candidate is an oral recombinant vaccine coated in a material that allows it to reach the small bowel. The company's vaccine was preclinical as of November 26, 2020. The company announced participation in Operation Warp Speed (OWS) in June 2020 but was later given a subpoena from the Justice Department in July for overstating its involvement with OWS.

Inovio Pharmaceuticals

Inovio's vaccine is a DNA-based vaccine that is delivered into the skin with electric pulses from a hand-held device called CELLECTRA. The device uses electrical pulses to open pores in the cell reversibly to allow the plasmids to enter. The company announced the launch of stage 2 on December 12, 2020. The company also received funding from the US Department of Defense for the development of its delivery device.

Heat Biologics

Heat Biologics' vaccine is a gp96-based vaccine that induces systemic and tissue-specific (lung) memory CD8+ T cells that can eradicate infected cells. The company released preclinical results on August 26, 2020.

iBio, Inc.

iBio's vaccine is a protein subunit vaccine called LicKM. The company is known for its trademark plant-based biologics manufacturing. The company's vaccine was preclinical as of November 26, 2020.

2.2 Factors characterizing vaccine value

Vaccines procured by the United Nations and by other agencies such as Gavi, the vaccine alliance, require WHO Prequalification. WHO released a document on April 9, 2020, outlining its key considerations when evaluating vaccine candidates and are summarized as follows: **(1) Safety**; a newer technique of introducing only a portion of the coronavirus virus, the spike protein, into human cell genetic material (mRNA) is used in the Moderna and AstraZeneca vaccine thus keeping the entire virus from being produced inside the body (Anderson 2020). **(2) Efficacy**; Clinical trial performance is primarily measured by antibody production levels among non-placebo participants. Stages 1/2 mainly examine vaccine safety, side effects, and efficacy on a smaller participant size. Submission for US FDA's emergency use authorization or WHO prequalification necessitates at least 50% efficacy and prefer 70% efficacy. Approval traditionally depends on performance in later clinical trial stages in which participant size is large (30,000 for most COVID-19 vaccine trials). **(3) Delivery efficiency**; among vaccine candidates that have progressed the furthest, most require 2 doses. Merck and J&J are among several companies developing single-dose vaccines as well. WHO prefers vaccine transportation conditions to be flexible allowing at least a shelf life of 12 months at 60-70 degrees celsius. Many leading vaccines, including the Moderna and Pfizer mRNA vaccines, require deep freeze during transportation. **(4) Production efficiency**; to reduce the time in clinical trials, companies have combined phases (eg. Phase 1/2 and Phase 2/3). The production of the vaccine is occurring during the later stages of trial and will be ready to be deployed immediately The Moderna vaccine phase 3 trials are estimated to be complete on October 27, 2022, though full-scale production is aimed to begin in early 2021. The negotiated price per dose varies between companies as well from about \$10 per dose for J&J's vaccine to \$32-37 per dose for Moderna's vaccine.

2.3 Organizations supporting vaccine production

Operation Warp Speed (OWS)

Operation Warp Speed is a partnership between the U.S. Department of Health and Human Services (HHS) and the Department of Defense. was announced May 15, 2020, and initiated by the US government with \$10 billion for the CARES Act (Coronavirus Aid, Relief, and Economic Security). The program promotes private and public partnerships to accelerate the development and approval of COVID-19 vaccines. OWS claims to shorten the process from 72 months to 14 months via coordination between government support and private companies through development, manufacturing, and distribution. The Trump Administration appointed Moncef Slaoui as chief advisor and General Gustave F. Perna as the chief operating officer of Operation Warp Speed (OWS). The goal of the organization is to have “substantial quantities of a safe and effective vaccine available for Americans by January 2021” (HHS.gov)

OWS supported vaccines (6): Johnson & Johnson (US), AstraZeneca/University of Oxford (UK), Moderna (US), Novavax (US), Merck/IAVI (US/Multinational), Sanofi/GlaxoSmithKline (France/UK). Pfizer/BioNTech rejected research and development funding from OWS but accepted an agreement for an advanced purchase order for 100 million doses contingent upon approval.

The Access to COVID-19 Tools (ACT) Accelerator/COVAX

The ACT Accelerator is a global collaboration led by Gavi (Gavi, the Vaccine Alliance), the Coalition for Epidemic Preparedness Innovations (CEPI), and the World Health Organization (WHO) aimed at accelerating the development, manufacturing, and equitable distribution of vaccine candidates to all countries. The emphasis of this organization is equal access. COVAX is the segment of ACT Accelerator that supports the development and production of vaccine candidates and negotiates prices on the behalf of nations.

COVAX supported vaccines (9): Inovio (US), Moderna (US), CureVac (Germany), Institut Pasteur/Merck/Themis (multinational), AstraZeneca/University of Oxford (UK), University of Hong Kong (China), Novavax (US), Clover Biopharmaceuticals (China), University of Queensland/CSL (Australia)

Individual donor organizations have committed funds to vaccine development and production. The **Bill & Melinda Gates Foundation** committed \$1.6 billion to Gavi, the Vaccine Alliance, on June 4, 2020. The foundation has been a long-time supporter of vaccine development and has committed a total of \$4.1 billion to Gavi.

ACCORD (Accelerating COVID-19 Research & Development)

ACCORD is an organization sponsored by the UK government (the Department of Health and Social Care (DHSC) and UK Research and Innovation (UKRI)) which reduces the time required

for vaccine approval by streamlining the clinical trial process. ACCORD recruits patients for small-scale trials aimed at determining the initial efficacy of vaccine candidates and rapidly advances those with positive results to large-scale trials.

III. DATA AND METHODS

Data

Only companies listed on either the NASDAQ American exchange or The New York Stock Exchange (NYSE) from the WHO published “DRAFT landscape of COVID-19 candidate vaccines” are graphed and compared because those companies that were private or are listed on other exchanges are not as frequently accessible by individual investors which introduces an additional confounding variable. These exchanges also work with regulatory organizations such as the Commodity Futures Trading Commission (CFTC), Financial Industry Regulatory Authority (FINRA), and the U.S. Securities and Exchange Commission to protect investors, and quarterly financial information is available.

Features of companies (traded on NASDAQ or NYSE) were aggregated from various company press releases and sources. Company quarterly and annual financial information were selected from SEC.gov. Accounting ratios were then calculated. Financial price information is available through various public sources:

- Financial information can be found in the WRDS Compustat database, at SEC.gov, in company investor relations, or on EPS analyst consensus sites (Estimize, WSJ.com, Thomson Reuters, or Bloomberg).
- Event information can be found on company press release/investor relation sites or in earnings call transcripts and presentations. Outside news sources offer unbiased information as well as public sentiment information.
- Industry-specific information can be found at Thomson Reuters, Bloomberg, IBISWorld, or in other academic articles.

Methods

Variable identification:

Past papers identified variables based on the purpose of each paper (some were concerned with fraud detection or accruals errors, for example, and their variables reflected this). Interesting factors were “hand-picked” along with a control variable to control for non-relevant factors.

This study chooses variables that are separated by category – (1) events and time, (2) trading volume, (3) vaccine characteristics, and (4) financials and fundamentals – and analyzed in sequence for their relationship with the dependent variables returns and volatility/risk. Each of the dependent variables is separately considered as well to evaluate for correlation and abnormalness.

Data Analysis

Information presented includes time-series charts over time and identifying significant events; returns, volume, and price volatility are analyzed for abnormal behavior and correlation with the market index. Commentary is provided on trading techniques and tendencies, especially for a retail investor.

The techniques of Bradshaw, Richardson, and Sloan (2001) are representative of the analysis of the factors' effects on price behaviors. The original paper separated companies into 10 portfolios of about equal size and ranked by the size of accruals. Results showed that the extremes produced the most abnormal returns when compared to analyst forecasts. Also, when plotting the forecast error across periods, they found that errors decreased over time. These methods can be replicated with individual securities and price changes surrounding an event.

IV. RETURNS AND VOLATILITY RESULTS & DISCUSSION

The following discussion presents an analysis of the returns, volatility, and volume changes of companies engaged in COVID-19 vaccine development. This section also studies where quantitative misinformation may arise that can hinder an investor's better judgment. Section 5 below analyzes the underlying factors explaining the changes in price behavior.

A widely-used method in practice to observe event-related price changes is to plot a time series of events. **Figure 4.1** displays the prices of each of 12 WHO-recognized vaccine companies over the 1 year ending December 3, 2020, along with categorized events by **Table 4.1**.

[Figure 4.1]

[Figure 4.1]

4.1 Returns

Results show that an average investor would have lost money by investing in certain vaccine companies. News sources, however, highlight the figures shown in the first column of **Table 4.1**, the 52-week return of holding shares in each company's stock. This column displays most companies as an opportunity for gain. The returns are as high as 2694.65% in the case of Novavax. HTBX, IBIO, and VXRT started the year as penny stocks (priced < \$1) and reached double digits towards the end. Other small-cap companies, ALT, INO, and NVAX were priced below \$5 in January 2020 and had reached even triple digits by the end of the year. In comparison, large-cap companies returned a modest < 10% or -6% for Merck, underperforming the S&P 500 which returned 12.87%.

Table 4.1 Returns

Company	52-Week Return	Majority Return		Max Loss	
		Majority Return	Annualized	Max Loss	Annualized
Heat Biologics	136.17%	-43.65%	-114.63%	-69.3%	-182.07%
iBio	1123.08%	-75.20%	-203.31%	-75.2%	-203.31%
Altimune	451.16%	-41.39%	-103.49%	-64.4%	-160.93%
Vaxart	2175.00%	-9.45%	-21.70%	-57.1%	-131.08%
Inovio Pharmaceuticals	376.89%	-15.05%	-20.27%	-62.2%	-83.81%
Novavax	2303.83%	215.12%	384.89%	-29.7%	-53.15%
BioNTech	453.68%	36.81%	101.78%	-2.5%	-7.01%
Moderna	623.68%	50.76%	134.27%	-6.4%	-16.87%
AstraZeneca	10.36%	-9.01%	-24.37%	-12.6%	-34.12%
Merck Sharp & Dohme	-5.99%	-4.66%	-5.65%	-11.1%	-13.45%
Pfizer	10.35%	7.79%	123.67%	-1.7%	-27.62%
Johnson & Johnson	7.85%	11.38%	16.81%	-4.7%	-7.00%
S&P 500	12.87%				

* Majority Return = Price at Max Volume - End Price
 * Max Loss = Max Price - End Price

Table 4.1 Companies are ordered by ascending market capitalization. Shaded companies are those furthest to achieving approval or have already achieved approval.

Column 2 contrasts the 52-week return with a more realistic return profile for an investor. This return assumes that the investor bought shares when the volume of trading was highest and followed by a spike in prices and held until today. Spikes can be identified in **Figure 4.2**. Assuming positive volume spikes are when investors are most compelled to join in momentum trading due to high exposure to the company via news or brokerage listings, investing in most of the lagging vaccine companies would have produced negative returns.

Any individual investor may have sustained losses higher or lower than those exhibited. Also, an informed and an experienced investor may have timed the market and bought before the spike and sold during, but this estimate is imperfect even for an experienced investor. The calculated return for these results and the results for the following sections consider only the “majority” investor which is characterized as one that partakes in when the most transactions and is most

susceptible to poor market timing. Section 4.1 explains that this assumption is reasonable using alternative data from Robinhood, a popular brokerage app. The last 2 columns show the max loss an investor could have sustained had they bought at the peak and held to December 2, 2020.

Column 1 is not a true representation of returns for several reasons. Firstly, the 52-week period is not an appropriate time horizon to judge return potential. Though the WHO had declared a global health emergency by January 30, 2020, the first announcements of vaccine development by companies began only in March 2020. Those who had invested at the time would have achieved returns similar to those seen in column 1. Additionally, at the time of the WHO's announcement, the list of potential vaccine candidates exceeded 200 with little indication of the potential for success beyond an individual's judgment. The list also included companies vaccine-makers who made false claims that their companies were developing vaccines, later delisted from the stock market or had their trading put on hold by regulatory agencies. In summary, it would have been difficult for an outsider with a less technical background in biotechnology to correctly identify the top candidates studied in this report.

Results demonstrate how most companies (HTBX, IBIO, ALT, VXRT, INO, AZN, and MRK) would have produced a significant loss (up to -200%) for the majority investor. The annualized return allows the returns to be compared by standardizing the holding period to be a full year. Only the top contenders furthest in vaccine development clinical trial, Novavax, BioNTech, Moderna, Pfizer, and Johnson & Johnson would have produced positive returns after the peak volume. This brings forth the possibility that competitive dynamics influenced pricing. Heat Biologics, iBio, and Altimune were only in the preclinical stage at the end of the data sample, December 2, 2020. This proves the sensitivity of price to vaccine success and speed and that an investor who bought a high-quality vaccine development company even at peak volume would have been protected had they chosen "correctly."

Nevertheless, current outperformance does not guarantee future positive returns nor a real increase in underlying company value which is analyzed further below in Section 5.3. Just as the companies with losses appeared attractive around March-July 2020, the top companies as of December 2020 may similarly experience losses if approval is not reached.

4.2 Volatility

In addition to understanding returns, analyzing volatility is important for an investor especially one whose investing horizon is short because short holding period trades are susceptible to losses due to price fluctuations. This is a reason why short-term investors are willing to invest in companies whose fundamentals are not strong if there is a possibility for large positive volatility. Sharp positive spikes are exhibited in the small-cap vaccine candidates which provides an opportunity for a skilled investor to realize gains on a position. Equity call options traders also find value in volatility because there is no possibility of unanticipated loss. Put traders can

engineer a trade that is protected from unanticipated loss. Long-term investors commonly view volatility as negative or indifferent. Despite having a long-term focus, most investment managers must report quarterly or annual returns that clients consider, so they are biased to produce results that outperform that span.

A prevalent metric used in practice to evaluate portfolio managers is the Sharpe ratio (excess returns over a risk-free rate over volatility measured by the standard deviation of returns). The information value of Sharpe is controversial, and many professional investors prefer to look at custom metrics like value at risk or qualitative factors over Sharpe, but it is nevertheless widely accepted.

Table 4.2 Volatility Over 52-Weeks

Company	Average Daily Return	STD Daily Return	Sharpe
Heat Biologics	1.04%	13.44%	7.73%
iBio	1.79%	19.36%	9.25%
Altimune	1.30%	10.89%	11.95%
Vaxart	2.22%	14.82%	15.01%
Inovio Pharmaceuticals	1.19%	11.58%	10.27%
Novavax	1.92%	10.80%	17.74%
BioNTech	0.84%	8.47%	9.93%
Moderna	1.13%	6.42%	17.54%
AstraZeneca	0.06%	2.29%	2.67%
Merck Sharp & Dohme	-0.02%	2.05%	-1.06%
Pfizer	-0.34%	6.89%	-4.89%
Johnson & Johnson	0.03%	1.96%	1.79%
Equal-Weighted Portfolio	1.43%	5.63%	25.37%

Table 4.2.1 Volatility 6/1/20 - 12/2/20

Company	Average Daily Return	STD Daily Return	Sharpe
Heat Biologics	0.42%	8.88%	4.75%
iBio	0.46%	10.28%	4.45%
Altimune	0.59%	9.16%	6.49%
Vaxart	1.57%	14.03%	11.17%
Inovio Pharmaceuticals	0.30%	9.80%	3.06%
Novavax	1.02%	7.07%	14.39%
BioNTech	0.82%	5.19%	15.86%
Moderna	0.77%	4.98%	15.49%
AstraZeneca	0.00%	1.88%	0.02%
Merck Sharp & Dohme	0.02%	1.35%	1.45%
Pfizer	0.15%	1.79%	8.45%
Johnson & Johnson	0.00%	1.12%	0.28%
Equal-Weighted Portfolio	0.85%	4.86%	17.45%

Of the 12 vaccine companies highlighted, although average daily returns are higher for companies with smaller market caps, their volatility metrics, measured by the standard deviation

of returns, are far greater. Note that the period of analysis, 1 year, creates statistics that are not the best representations of the population statistics, however, they lend information for the analysis of a market situation like the COVID-19 pandemic and what the best course of trading action could have in hindsight.

Using the Sharpe metric, the companies with the best risk-reward relationship over the 52-week period are the small/mid-cap companies. These findings contrast that of the previous section because it appears that investment in small-cap companies is ideal. However, as mentioned previously, the 52-week period is not an appropriate time horizon because it includes periods in which COVID-19 vaccine development had not begun. The results are helpful to understand where misinformation may appear from. Table 4.2.1 shows a less favorable view of small-cap stocks and shows how investing quality perception may change depending on the situation. Another form of analysis of optimal trading behavior that an investor may engage in is outlined in Section 4.3.

4.3 Naive Portfolios

Is there a way to invest optimally without prior knowledge of vaccine companies and potential development?

The final rows of **Table 4.2** and **4.2.1** present a portfolio that has equally-weighted all companies in the sample. This portfolio creates a Sharpe that outperforms that of each individual security. This is consistent with modern portfolio theory proposed by Harry Markowitz in which holding a diversified portfolio optimizes the return for a minimal risk level. Even though the 12 companies studied are highly similar in industry and function, their differing price movements negates dramatic price movements and thus create less deviation and risk for loss. The correlations between most companies are negligible as seen in **Table 4.3**.

Table 4.3 Correlations

	Heat Biologics	iBio	Altimune	Vaxart	Inovio Pharmaceut icals	Novavax	BioNTech	Moderna	AstraZeneca	Merck Sharp & Dohme	Pfizer	Johnson & Johnson	S&P 500
Heat Biologics	1.00												
iBio	0.25	1.00											
Altimune	0.24	0.47	1.00										
Vaxart	0.04	0.21	0.25	1.00									
Inovio Pharmaceuticals	0.06	0.07	0.25	0.30	1.00								
Novavax	0.04	0.35	0.27	0.37	0.26	1.00							
BioNTech	0.07	0.09	0.03	0.25	0.11	0.28	1.00						
Moderna	0.11	-0.03	0.01	0.16	0.19	0.20	0.36	1.00					
AstraZeneca	0.14	-0.10	-0.06	0.00	0.03	0.13	0.17	0.10	1.00				
Merck Sharp & Dohme	0.16	-0.06	-0.08	0.00	-0.01	0.10	0.21	0.08	0.58	1.00			
Pfizer	0.01	-0.04	0.13	-0.01	0.01	-0.09	-0.02	0.05	-0.22	-0.27	1.00		
Johnson & Johnson	0.06	-0.09	-0.15	-0.02	-0.05	0.11	0.33	0.12	0.58	0.76	-0.19	1.00	
S&P 500	0.10	-0.05	-0.06	-0.09	-0.08	0.13	0.20	0.02	0.60	0.74	-0.24	0.77	1.00

Only the large-cap companies Merck, AstraZeneca, and Johnson & Johnson showed significant correlations with each other as well as the market index. Small-cap companies have nearly 0 or

negative correlation with large-cap stocks. Thus, portfolios are one method for an individual investor to protect from loss especially loss due to information gaps. “Diversifying” in this way is sophisticated behavior and less common among new investors because it is counterintuitive; new investors would recognize that the success of competing companies would cause another company’s vaccine to be less valuable and thus generally choose to hand-pick companies, and new investors are biased to companies with higher return potential for low investment cost which are mostly the small-cap companies.

From another perspective, the average annualized return from investing equally in all the companies even at their point of highest trading volume and holding until December 2, 2020, is 22.33% (simple average of column 3, Table 4.1) which outperforms the 52-week return of the S&P 500 by nearly 10%, so it also appears that creating a portfolio of vaccine companies rather than choosing individual stocks protects from timing the market incorrectly.

Table 4.4 Optimal Portfolio of Vaccine Companies

Company	Weights (Full 52-wk)	Weights (6/1-12/2)
Heat Biologics	6.4%	0.0%
iBio	1.2%	1.0%
Altimune	11.4%	6.0%
Vaxart	10.4%	4.8%
Inovio Pharmaceuticals	2.5%	0.0%
Novavax	20.8%	2.9%
BioNTech	0.0%	34.8%
Moderna	47.4%	46.0%
AstraZeneca	0.0%	0.0%
Merck Sharp & Dohme	0.0%	4.5%
Pfizer	0.0%	0.0%
Johnson & Johnson	0.0%	0.0%
Average Daily Return	0.9%	1.4%
Standard Deviation	4.0%	5.6%

It is possible to look backward at returns and calculate the optimal portfolio, or the portfolio that generates the highest return for a low level of risk. **Table 4.4** compares an optimal portfolio by risk-return relationship for the entire 52-week sample with just the latter half of the data (6/1/20 to 12/2/20). Using non-negative constraints, the optimal fully-invested portfolio of vaccine companies would not include any of the largest companies if the full year is considered because the returns of the small companies are so high, but as discussed previously, this timeline is not appropriate. Using only the second half, more emphasis is placed on mid-large cap companies BioNTech and Moderna which were more stable but also produced large positive returns. The contrast demonstrates once again how returns can be misconstrued to retail investors. Note that these weights do not recommend a future-looking portfolio because they are based on historical returns and prices. An investor who would prefer to invest in the companies must consider their

projections of future company returns and volatility to create a proposed optimal portfolio to invest in. As proved above, an equally-weighted portfolio can be an easy way to avoid bias or misguided guesses.

V. PREDICTOR VARIABLES RESULTS & DISCUSSION

The previous section displayed the makeup of returns and volatility of companies developing COVID-19 vaccines and identified areas of possible false information. This section explores whether an investor could use various predictors to identify precarious trading patterns.

5.1 Volume as Predictor of a Bubble

During the pandemic, trading volume among biotech companies grew significantly in several instances. Pre-pandemic, biotechnology companies comprised an already favored sector for short-term investors because of their volatility and tendency to spike around positive news. During the pandemic, biotechnology companies gained further exposure because the public increasingly emphasized a vaccine as the primary catalyst that could end the downward spiral of value. News is followed closely not only by investors in these companies but also by the mass public. **Table 5.1** compares trading volume over the year 2020 to historic trading volume.

Table 5.1 Volume

Company	Market Cap. (M)	52-Week Volume Max	52-Week Average	Average (Prior 4 Years)	Change in Av. in %
Heat Biologics	\$167.71	238,918,600	14,485,781	332,339	4258.7%
iBio	\$219.44	270,139,500	20,976,569	405,349	5074.9%
Altimune	\$407.10	58,738,100	2,373,187	349,879	578.3%
Vaxart	\$801.53	230,619,000	15,732,036	178,023	8737.1%
Inovio Pharmaceuticals	\$1,930.00	195,142,300	25,378,689	1,209,942	1997.5%
Novavax	\$7,130.00	74,649,600	7,147,552	496,084	1340.8%
BioNTech	\$29,700.00	15,899,700	2,131,089	1,890,310	12.7%
Moderna	\$62,300.00	125,552,300	16,701,468	267,879	6134.7%
AstraZeneca	\$141,890.00	58,738,100	2,426,058	1,623,839	49.4%
Merck Sharp & Dohme	\$210,980.00	27,948,600	10,256,454	2,926,691	250.4%
Pfizer	\$232,460.00	230,153,900	31,310,202	25,510,660	22.7%
Johnson & Johnson	\$401,540.00	21,754,000	8,057,056	7,041,019	14.4%

Trading volume, or the number of transactions over a period, tends to indicate bubbles in asset prices. Small-cap vaccine candidate companies had average trading volumes for 2020 up to 88 times higher than their historic volume. This can be compared to only a slight (15-20%) increase in trading among large-cap vaccine candidates. Such a trend implies that small bubbles in asset prices had formed around certain potential vaccine companies, but the increase was due to an uptick in popularity rather than due to true underlying growth in company value. This is a phenomenon discussed in previous literature (Hong 2006). Observing the price charts in **Figure 4.1**, it is clear that the abnormal prices had reached a peak in late July 2020 and had rapidly subsided by late August 2020.

Could investors have foretold and avoided bubbles by observing changes in volume?

The relationships between volume and price are noticeably different among small-cap vs large-cap vaccine-makers in several instances. These are summarized below chronologically:

- 1) There was an isolated jump in volume after the WHO announced a global health emergency on January 30, 2020, most noticeable in iBio, Vaxart, and Inovio without any corresponding discernible news releases on vaccine-development. The occurrence is bizarre because it is not seen in all companies which would have been expected had investors been allocating funds equally to all potential vaccine-makers in a naive manner. Possibly, insider trading or those familiar with the company could be an explanation.
- 2) Among large companies, Johnson & Johnson, Pfizer, and Merck, trading volumes were mostly constant except for an increase during the March 2020 market crash which bottomed on March 23, 2020. Volume was high while prices were decreasing because people were selling off shares which was behavior reflected across the market. Afterward, volume levels returned to a constant state. Pfizer had an additional spike around November 10th, 2020 which was the date that the company and BioNTech released positive clinical results. During this crash period, Moderna, BioNTech, Novavax, Altimmune, iBio, and Heat Biologics experienced jumps in volume and price, indicating a shift in assets from large and value-oriented (companies that have strong current intrinsic value) to small and growth companies (companies whose value derives from future earnings potential).
- 3) Small-mid cap companies also showed dramatic jumps in volume and price starting July 14, 2020, and this was prominent among all companies except for the largest 3 Merck, Pfizer, and Johnson & Johnson. Although no significant company-specific news was reported that would have affected all vaccine-related companies, the number of daily cases in the US was rising at an increasing rate, peaking at 75,000 daily cases around July 16 and was continuing to grow worldwide. Prices began to fall after the rate of new cases began falling as well. The companies that gained and lost the most value were Heat Biologics, iBio, Altimmune, Vaxart, and Inovio.
- 4) In late November 2020, towards the end of the data sample, price growth and volatility began rising among large-cap companies as they progressed and released clinical results and as worldwide COVID-19 cases grew.

In summary, the companies that reached later stages in clinical development and had large market capitalizations showed more stability throughout in volume and price. This may be attributed simply to size dynamics as large companies are likely to have a more consistent institutional, long-term investor base, but it also suggests that investors are rewarding companies that have progressed. Smaller companies showed larger spikes in the volume surrounding events. The one pattern difference that differentiates companies that lagged in vaccine development is that they showed large overreactions to events like company news or growth in daily US cases. Heat Biologics's stock price grew 258% over July 14-16, and iBio's price grew 189% over the same two days. Despite positive news releases following this event, the prices reverted and had

the most gains by late August 2020. In contrast, Moderna's stock price grew less rapidly at 55% over 10 days to reach peak price.

Although these findings are backward-looking, so it cannot help an investor avoid a bubble, it can characterize the nature of certain stocks, for example as one in which investors are less likely to rely upon fundamentals to value a company and more likely to cause asset bubbles, or one that has more stable patterns but lower return. Secondly, results prove again that it is more common to find better prices before or after a large influx of buying volume rather than during. Finally, more often than not, the spike in volume precedes the peak price as witnessed in HTB, ALT, VXRT, INO, NVAX, and AZN, so risk-loving investors may find an arbitrage opportunity, though if the stock has reached a peak without the investor realizing, they are nearly guaranteed to suffer negative returns.

Volume of Retail Investors

When segmented by type of investor, retail or institutional for example, it can signal irrational or rational trading behavior. Robintrack is an alternative data source that shows the number of Robinhood users holding shares of companies. Popularity among retail investors can signal overexcitement for a company and thus overvaluation. More popular companies among retail investors will show higher numbers or higher growth in Robinhood users. Retail investors are known to introduce additional irrational behavior and frequent trading due to uninformed investing, causing unnecessary volatility. There is more overreaction to positive or negative news among retail investors whereas long-term investors are more likely to have anticipated news or be willing to tolerate negative news if they deem a company's fundamentals strong.

Unfortunately, Robinhood stopped sharing data to the platform in August 2020, but information until August is available which covers the market crash in March and the vaccine company spike in July 2020 (**Figure 5.1**).

[Figure 5.1]

Key patterns include:

- Among smaller companies, the number of Robinhood users holding shares of the company rose faster than the rise in the price of these companies. Number of users noticeably spiked when prices rose. This suggests that ownership of these companies were overweight retail investors and makes one suspect why professional investors are not holding in as large quantities. Late July 2020, as prices began to fall amongst these companies, the number of Robinhood users holding shares remained constant and high suggesting that most users sustained losses. This is evidence for the assertion that retail investors are susceptible to mistiming of the market.
- In mid-size companies (BioNTech and Moderna) the number of Robinhood users holding shares generally increased in-line with the increase in prices and the number of users spiked lower than the price. This is a healthy and positive sign that these companies are not overweight retail investors who introduce additional complications outlined above and that professional investors include these companies in their portfolios. Once again, however, when prices dip in early August 2020, the number of retail investors holding shares does not also fall.
- Among the largest companies, Merck, Pfizer, and Johnson & Johnson, the number of Robinhood users holding mostly rose steadily thereafter uncorrelated with dips and increases in price. This may be due to the overall increase in the number of Robinhood users. One deviation from this is that the number of users holding stock rose immediately at the beginning of the reversal from the crash which could be characterized as “buying the dip,” or buying when prices are irrationally low to take advantage of the undervaluation.

The companies who were leading in the production of a COVID-19 vaccine by December 2020 showed a large mix of institutional ownership rather than overweight retail holdings, suggesting support from professional analysts. An investor seeking stable returns could be biased towards these patterns.

Wall Street Coverage and Projections

According to a study by Ball and Brown discussed above in the literature review, the outperformance or underperformance of expected EPS (earnings per share) as estimated by wall street analysts. The study found on average that if quarterly EPS reports exceed expectations, price often rises favorably and vice versa for underperformance. Not surprisingly, the smaller firms have little to no coverage by Wall Street and crowd-sourced EPS estimates (Estimize.com). This is another reason institutional investors are less likely to hold shares and why retail investors prevail among these companies because institutional investors utilize sell-side equity reports to decide investments. Moderna saw an increase in analysts covering the company. It is

also interesting to find that projections for all companies' EPS figures (except AstraZeneca and the 3 largest market cap companies) appear to exponentially increase in a "J-curve" shape. For an investor, this means that high expectations for the company have been set, so despite positive performance, if the company does not sufficiently meet Wall Street's expectations, prices could fall. This occurred in Quarter 3 for Novavax; prices closed 12.8% lower the following day after falling 3.48% prior.

5.2 Event-Driven Investing

Do the reactions of share prices after events and news reports indicate quality?

This section studies the effects of significant events on share price. To introduce the analysis, a few theoretical background concepts are first defined and their implications for retail investing are discussed briefly. The semi-strong efficient market hypothesis states that stock price movements reflect all publicly-available information. Thus, prices change as new information is introduced and digested by investors. The efficient market hypothesis is not a theory of thought that all investors prescribe to as some rely more heavily upon fundamental analysis of companies' strength in order to anticipate positive events before they occur or are reported. These investors arbitrage by holding companies they deem valuable before any positive news which would alert others of the value of the company and cause prices to rise.

It is also important to recall that a large component of a company's variation can be attributed to systematic risk, or macroeconomic events that affect the market as a whole. This is especially true with companies that are highly correlated with the market index such as Merck, Pfizer, and Johnson & Johnson. Idiosyncratic variation or risk attributable to company-specific events or news constitutes the remaining cause for variation. Many portfolio managers can negate the effects of idiosyncratic risk via diversification as demonstrated above with the higher Sharpe risk-return relationship of an equal-weighted. However, individual investors who are unconcerned with or even seek volatility may be interested in the reactions of company news to events.

Due to their low correlations with the market and each other, there is reason to believe that small-cap companies' price reactions to events are more-idiosyncratic reactions and related to company events rather than overall market fluctuations, so results are interpretable. The large companies are excluded from this analysis because their correlation with the market index is high, so reactions to events cannot be assumed to relate wholly to company-specific behavior, and thus they may distort results. Because reactions to events may be higher in earlier periods, events are separated into two time periods before and after June 1, 2020, and each news event is categorized into one of 14 broad types of reports.

Table 5.2.1 Category Classification

Broad Categories	Description
Announcement_Preclinical	Announcements of vaccine development
Announcement_Phase1	Announcements of Phase 1, 2, or 1/2
Announcement_Phase3	Announcements of Phase 3 or 2/3
Launch_Preclinical	Start of preclinical
Launch_Phase1	Testing first patients
Launch_Phase3	Testing Phase 3 or 2/3
Preclinical_Results	Preclinical results
Clinical_Results	Preclinical results
Quarterly_Report	Quarterly financial report
Annual_Report	Annual financial report
Funding	Announcement of funding
Manufacturing	Announcement of manufacturing capacity
Partnership	Announcement of partnership for vaccine development
Non_Covid	A non-COVID related event

[Table 5.2]

Table 5.2.2 shows the number of events announced by the company of each category from **Table 5.2.1**. **Table 5.2.3** summarizes the daily price change reactions stocks to certain events information released. Note that the sample size is not large (587 distinct news events), so significance can not be assumed, but certain figures are sufficiently large to warrant analysis.

- Announcements of vaccine development and clinical trials were mostly received positively and elicited double-digit growth in price. In Vaxart and Altimmune, an announcement created a price change of 71.23% and 110.23% respectively within a day in the first half of the sample (before June 1, 2020). However, in the two top vaccine companies in the sample, Moderna and BioNTech, the first announcements caused only low single-digit increases in price or even negative price reactions. The reasoning for this lackluster response is unsure, but it could relate to several possible factors such as investors disliking additional unpredictability that vaccine development could introduce to earnings or investors having already anticipated development. The announcement of subsequent vaccine developments in the second half of the data elicited modest jumps in price in the mid-high single digits among all companies.
- Reactions to positive clinical results elicited mid-single-digit growth. For example, Moderna's highly publicized interim phase 1 results caused prices to grow 19.96%.
- Funding announcements generated the most consistently high positive price changes. This is most likely because funding announcements signaled the support of the various governments and credible organizations. Once again, small companies skyrocketed with Inovio growing 40.98% following the receipt of funding from Operation Warp Speed (the US government) for the development of their vaccine delivery device.
- Manufacturing funding and partnership announcements elicited positive price change in the first half of the year but became less important towards the latter half. Partnerships showed the same pattern.
- Among companies that received pre-orders from governments and organizations contingent on clinical trial results, announcements produced changes that were lower than expected – on average 1.68%.
- Trial complications in Inovio's halt of Phase 2/3 caused prices to fall 28.34%.

As hypothesized, earlier news on average produced greater growth in price change. Interestingly, although small-cap companies reacted highly to positive early news like announcements of vaccine development, it appeared difficult to predict or understand their behavior in reaction to later news. In later dates, positive news like preclinical results or funding often even correspond with falling prices. In addition, companies with low-quality fundamentals that reported quarterly and annual reports that underperformed expectations had prices fall once again. Investors who had bought into the initial news announcements would have suffered losses that were unpredictable later.

Could companies have manipulated news flow to engineer stock price growth?

Purposefully or not, smaller companies produced far more frequent COVID-19 vaccine-related reports; COVID-19 news also dominated their news releases far more frequently than their other products. Merck, Pfizer, and Johnson & Johnson reported on COVID-19 sparsely; other products mostly dominating the news. Merck only reported a single COVID-19 event which was their partnership with IAVI.

More information is generally more useful for an investor, but as the above results indicate, earlier events cause greater overreactions. However, news that adds little new information, for example, launches of clinical trials after trials have previously been announced, elicited smaller responses, so it can be argued that density of news is not a source of much investor confusion and irrationality. The exception to this may be that perhaps recognizing how markets react to funding news, Vaxart falsely announced participation in OWS on June 26, 2020, causing a price jump of 28.43%. The company was later subpoenaed by the Justice Department in July for overstating its involvement with OWS.

5.3 Fundamental Investing

Could a fundamentals-focused analyst (or a value investor) had identified companies that would become the top candidates?

Table 5.3 Qualitative Vaccine Characteristics

Company	Vaccine Platform	# Doses	Route of Administration	Storage	Av. Efficacy	Altruism	Phase	Pre Order (\$M)	Manufact. Capacity (M/yr)	Total Research Funding
HTBX	Protein Subunit	-	IM		-		Pre-Clinical	-	-	-
IBIO	Protein Subunit	-	IM		-		Pre-Clinical	-	-	-
ALT	Non-Replicating Viral Vector	1	Nasal		-		Pre-Clinical	1,750.00	3,100.00	\$4.70
VXRT	Non-Replicating Viral Vector	2	Oral	Room Temp.	-		Phase 1	-	-	-
INO	DNA	2	ID	Room Temp.	95%		Phase 2/3	-	100	\$105.10
NVAX	Protein Subunit	2	IM	Refrigerated	-		Phase 3	-	-	\$2,048.00
BNTX/PFE	RNA	2	IM	-70 degrees C	95%	Rejected OWS funding (citing reluctance to use taxpayer dollars)	Phase 3	2,000.00	1,300.00	\$454.98
MRNA	RNA	2	IM	-20 degrees C	94.10%		Phase 3	-	500-1,000	\$1,530.00
AZN	Non-Replicating Viral	2	IM	Refrigerated	70%	No-profit pledge	Phase 3	1,000.00	100	\$1,200.00
MRK	Replicating Viral Vector	1	IM		-	Mask donations	Phase 1	-	-	\$38.00
JNJ	Non-Replicating Viral	2	IM	Refrigerated	-		Phase 3	-	1,000.00	\$1,000.00

* Source WHO & company press releases; and estimates

Table 5.3 summarizes the key characteristics of each vaccine company. Among vaccine-related characteristics, it does not appear that the type of vaccine, the number of doses, or delivery temperature affect prices beyond the initial recommendations by the WHO. Moderna and BioNTech/Pfizer's vaccine candidates use a novel method of mRNA, and Moderna has not brought any previous vaccine to market, yet they have become top candidates. The amount of funding and support received from Operation Warp Speed and other organizations is understandably significant; however, by the time of announcement of funding or on the date, share prices will have already appreciated. Beyond clinical-stage level and funding, other

characteristics were not significantly determining factors. One possibility for Altimune and Vaxart's vaccine delay could be because they have unique delivery methods of nasal and oral, respectively that is uncommon and could add difficulty for mass delivery. Beyond the characteristics included in the chart, it is assumed that an investor would need additional expertise to predict the quality of vaccines.

Financial Strength

Another area to search for indicators is in the financial statements of these companies. Companies that may be producing false claims for funding and development may be revealed if financial statements do not show expenditures or cash inflows. Analysts also frequent SEC filings to review long-term company progress and fundamentals. Due to the instability of revenue streams of the biotechnology sector, financials are useful for backward-looking analysis but often not for forward-looking prediction. The nature of revenue recognition also varies. Most large companies recognize revenue as sales to customers whereas smaller companies recognize grant receipts as revenue as well which may inflate their revenue metric. Key interpretable metrics are summarized in **Table 5.3.1, 5.3.2, and 5.3.3.**

[Table 5.3]

No findings were significantly unusual; most small companies experienced dramatic growth among third quarter revenues compared to lower than usual revenues in the first quarter though this cannot be attributed to grants given to COVID-19 vaccine development without disaggregation of revenue. Despite revenue growth, few companies increased operating income over that of the previous year. This could be due to an increase in research and development (R&D) expenses, but several companies also had greater increases in general and administrative expenses than in R&D. Only the three largest companies were profitable on an operating margins basis and had stable, single-digit changes. Cash flow from operations had appreciated among most companies by the third quarter.

It is interesting to note that not all companies mentioned the receipt of grant money in their notes to the financial statements. Novavax and Altimmune, for example, listed major collaborations and grant sources and how much was recognized as revenue for the current period; other companies do not have a separate section that disaggregates their cash streams. The addition does not appear to affect stock price perhaps because investors can find the information elsewhere via press releases and earnings calls.

Will developing and bringing a vaccine cause a company's intrinsic value to grow?

The answer to this question is uncertain and requires additional expertise, but it is important to consider especially for a long-term investor. In the short-term, the above findings have asserted that it is often ineffective to attempt to estimate small-cap company share prices via company fundamentals because being heavily weighted retail investor shareholders causes irrationality. These companies can produce high returns but erratically. For large-cap companies, fundamentals also do not determine short term price changes because correlation with the market index is so high, suggesting that macro events (and beta, the sensitivity of the companies to macro events) are more likely to drive price changes than minute company events.

In the long-term, however, most companies theoretically revert to their true values which are determined by intrinsic strength and the ability to produce future cash flow for an investor. If the COVID-19 vaccine becomes a recurring necessity, it could produce a consistent stream of cash flow for a top vaccine company. For a company like Moderna which has never brought a vaccine to market, this justifies price increases and gives reason to believe that they will be sustained. If the vaccine becomes a one-time event, it could mean that prices are dramatically overstated and will revert. Competitiveness and profitability are other factors to consider. With so many companies nearing approval with high efficacy rates, it does not appear that vaccine development expertise creates barriers to entry. Competition could limit the profitability of the product. Furthermore, sources like NPR have estimated that influenza vaccine development only constitutes .18% of total annual pharmaceutical revenues. The impact of vaccine development

could be grossly overstated as a whole. Further expert study would be beneficial for an investor focused on the long-term.

VI. CONCLUSIONS

As of December 12, 2020, BioNTech and Pfizer's vaccine has been approved in the UK and the US. Of the remaining vaccine candidates, Moderna, AstraZeneca, Johnson & Johnson, and Novavax are most widely predicted to also bring a vaccine to market within the year. This does not exclude the remaining companies from also producing a successful vaccine as well.

Most of the trends noticed throughout the study relate to the size of the company which is measured by market cap. This is understandable because large companies are more likely to have the capacity to develop faster and bring candidates to trial. Established, multinational companies have faster access to capital funding at favorable rates, large cash balances, and can initiate partnerships for research and manufacturing. Furthermore, the effects of vaccine development are less impactful on the companies' financial metrics. Additional funding of \$1 billion comprises only 1.2% of Johnson & Johnson's 2019 annual revenue but exceeds Moderna's 2019 revenue 16 times. Funding and vaccine development should not impact the financials of large-cap companies significantly, thus muted price reactions to events should be expected as well as more correlation with the market index as a whole. Primarily mid-large cap companies that have demonstrated these stable, historic financials with large cash balances and funding opportunities are more likely to successfully and efficiently market a vaccine and navigate trial issues. For example, Pfizer was able to minimize concerns over the delivery temperature needs of BioNTech/Pfizer's vaccine by designing an "ultracold" transport box system. Large companies are also less likely to emphasize vaccine developments in their press, while vaccine news dominates small company news releases. For an investor, there will be less overemphasis and thus lower returns, but the investor bears less volatility risk and also failure risk because the impacts are lessened by existing financial stability; also, large companies generally have the resources to succeed.

Small companies can be identified as having risky investing profiles that produce extreme positive returns but at the risk of large, unpredictable negative falls in price. For the investor, there are several methods in which to gauge the opportunity such as surveying trading volume, returns, reactions to events, and coverage. The investing appetite is unique to the individual, but understanding the securities that an investor holds in a portfolio and the patterns they exhibit are beneficial.

Proven in Section 5.1, retail investors are especially at risk of suffering losses because it is common to time the market incorrectly and invest in risky companies when prices are at peaks. However, one method in which investors can earn returns even while neglecting the underlying information of the vaccine company is by investing in a portfolio of companies. The comovement and lack thereof creates a superior risk-reward relationship with minimal need for additional analysis or market timing.

For further study, an investor may be interested in large healthcare distribution and manufacturing partners such as AmerisourceBergen, Cardinal Health, McKesson, and international equivalents. It is most likely that multiple vaccines will emerge because one company's manufacturing capacity cannot service the entire human population. Companies have estimated about 1 billion doses capacity each. Healthcare distribution channels will be important given the storage and transportation needs of vaccines and the necessity to efficiently mass deploy. It was announced that the first Operation Warp Speed vaccine ancillary supply kits (each containing enough supplies to administer 100 vaccines) have already begun being distributed by McKesson Corporation.

Additionally, those with healthcare expertise have an advantage to understand the current and future landscape. This study did not consider the qualitative competitive dynamics between companies because the specifics are not common knowledge to a retail investor. As mentioned in section 5.3, a company with certain methods of development could be more likely to become a top vaccine candidate. Or a company with preexisting funding and manufacturing networks such as Novavax and CEPI's partnership would be in a better position to receive funding.

VII. REFERENCES

- Ahmed, Anwer S., Michael J. Neel, and Irfan Safdar. 2019. Accounting comparability and the mispricing of asset growth, accruals and earnings. *Accruals and Earnings (June 8, 2019)*.
- Aidemark, Lars-Göran. 2001. Managed health care perspectives: A study of management accounting reforms on managing financial difficulties in a healthcare organization. *European Accounting Review* 10 (3) (09/01): 545-60.
- Anderson, Evan J., Nadine G. Rouphael, Alicia T. Widge, Lisa A. Jackson, Paul C. Roberts, Mamodikoe Makhene, James D. Chappell et al. "Safety and immunogenicity of SARS-CoV-2 mRNA-1273 vaccine in older adults." *New England Journal of Medicine* (2020).
- Aravind M, and Manojkrishnan C G. 2020. "COVID 19: Effect on Leading Pharmaceutical Stocks Listed With NSE". *International Journal of Research in Pharmaceutical Sciences* 11 (SPL1), 31-36.
- Ball, Ray, and Philip Brown. 1968. An empirical evaluation of accounting income numbers. *Journal of Accounting Research* 6 (2): 159-178.
- Beaussier, Anne-Laure, David Demeritt, Alex Griffiths, and Henry Rothstein. 2016. Accounting for failure: Risk-based regulation and the problems of ensuring healthcare quality in the NHS. *Health, Risk & Society* 18 (3-4) (05/18): 205-24.
- Beaver, William H. 1968. The information content of annual earnings announcements. *Journal of Accounting Research* 6 : 67-92.
- "Betas". 2020. Pages.Stern.Nyu.Edu.
http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/Betas.html.
- Cha, Myoung, Bassel Rifai, and Pasha Sarraf. 2013. *Pharmaceutical Forecasting: Throwing Darts?*.
- Chapman, Christopher, Anja Kern, and Aziza Laguecir. 2014. Costing practices in healthcare. *Accounting Horizons* 28 (2): 353-64.
- Chen, Fu-Hsiang, Der-Jang Chi, and Yi-Cheng Wang. 2015. Detecting biotechnology industry's earnings management using bayesian network, principal component analysis, back propagation neural network, and decision tree. *Economic Modelling* 46 : 1-10.
- Clemente, Paulo. 2019. *Management Accounting and Control Systems in Healthcare*.
- Deloitte United States. 2020. *2020 Life Sciences Industry Accounting Guide*. Available at: <https://www2.deloitte.com/us/en/pages/audit/articles/life-sciences-accounting-and-financial-reporting-update-including-interpretive-guidance.html>.

Doyle, Jeffrey T., Russel J. Lundholm, Soliman, and Mark T. 2006. The extreme future stock returns following I/B/E/S earnings surprises. *Journal of Accounting Research* 44 (5): 849-887.

“Draft landscape of COVID-19 candidate vaccines”. 2020. World Health Organization. <https://www.who.int/publications/m/item/draft-landscape-of-covid-19-candidate-vaccines>

Filzen, Joshua J., and Kyle Peterson. 2015. Financial statement complexity and meeting analysts’ expectations. *Contemporary Accounting Research* 32 (4): 1560-94.

Gebreiter, Florian, and Laurence Ferry. 2016. Accounting and the ‘Insoluble’ problem of health-care costs. *European Accounting Review* 25 (4) (10/01): 719-33.

Gentry, Richard J., and Wei Shen. 2013. The impacts of performance relative to analyst forecasts and analyst coverage on firm R&D intensity. *Strategic Management Journal* 34 (1): 121-30.

Gu, Feng, and Weimin Wang. 2005. Intangible assets, information complexity, and analysts’ earnings forecasts. *Journal of Business Finance & Accounting* 32 (9-10): 1673-702.

Hao, Maggie, Dana A. Forgiione, Liang Guo, and Hongxian Zhang. 2017. Improvement in clinical trial disclosures and analysts’ forecast accuracy: Evidence from the pharmaceutical industry. *Review of Quantitative Finance and Accounting* 49 (3): 785-810.

Hong, Harrison, Jose Scheinkman, and Wei Xiong. "Asset float and speculative bubbles." *The Journal of Finance* 61, no. 3 (2006): 1073-1117.

King, Rodney G., Aaron Silva-Sanchez, Jessica N. Peel, Davide Botta, Selene Meza-Perez, S. Rameeza Allie, Michael D. Schultz et al. "Single-dose intranasal administration of AdCOVID elicits systemic and mucosal immunity against SARS-CoV-2 in mice." bioRxiv (2020).

Lutz, S. 1992. Prices of healthcare stocks languishing; companies seek ways to interest investors. *Modern Healthcare* 22 (22) (Jun 1): 40.

NewScientist. 2020. *Covid-19 news archive: Pfizer vaccine is 95 percent effective*. Available at: <https://www.newscientist.com/article/2244804-covid-19-news-archive-pfizer-vaccine-is-95-per-cent-effective/>

Nielsen, Lars Braad, Falconer Mitchell, and Hanne Nørreklit. 2015. Management accounting and decision making: Two case studies of outsourcing. *Accounting Forum* 39 (1) (03/01): 66-82.

Petrenko, Oleg V., Federico Aime, Tessa Recendes, and Jeffrey A. Chandler. 2019. The case for humble expectations: CEO humility and market performance. *Strategic Management Journal* 40 (12): 1938-64.

Pettenuzzo, Davide, Riccardo Sabbatucci, and Allan Timmermann. 2019. Cash flow news and stock price dynamics.

Rahimi, Khashayar Noroozadeh, and Yashojjwal Mahendra. "Hedging healthcare liabilities using a medical CPI weighted portfolio of healthcare stocks." (2019).

Shree, Ms Jainthi, and Benita S. Monica. 2020. Costing practices in the healthcare sector. *Our Heritage* 68 (30): 2115-23.

Sloan, Richard G. 1996. Do stock prices fully reflect information in accruals and cash flows about future earnings? *Accounting Review*: 289-315.

Soliman, Mark T. 2008. The use of DuPont analysis by market participants. *The Accounting Review* 83 (3): 823-53.

Tax, corporate. "global tax dodging by a german healthcare multinational." (2020).

Tirodkar, Mihir. 2019. Toxic expectations: Analyst forecasts and firm pollution. *Available at SSRN 3478504*.

World Health Organization. 2020. *WHO Target Product Profiles for COVID-19 Vaccines*. Available at: [https://www.who.int/blueprint/priority-diseases/key-action/WHO Target Product Profiles for COVID-19 web.pdf](https://www.who.int/blueprint/priority-diseases/key-action/WHO%20Target%20Product%20Profiles%20for%20COVID-19%20web.pdf)

Wu, Xiaoxi. 2019. *Essays on Financial Communication in Earnings Conference Calls*.