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Innovation Investments During The COVID-19 Pandemic

A quantitative study into the potential innovation investment risk for U.S. companies and its effect on company performance during economic turmoil and crisis situations.

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I. Abstract

The authors of this paper identified a gap in the debate revolving around innovation during a crisis and recognized the importance of exploring whether being highly innovative is universally desirable across all sectors during times of crisis. While previous research has emphasized the positive impact of innovation on performance, it is essential to investigate the negative impact of innovation and whether there are limitations or thresholds beyond which excessive innovation may have diminishing returns or unintended consequences for small and medium sized companies. Furthermore, the strength of the relationship between investments in innovation and economic performance during times of crisis remains uncertain.

The study takes a quantitative approach with the aim to deepen the knowledge regarding the relationship between investments in innovation and economic performance for small and medium-sized companies defined as companies with a market cap equal to or less than $2B across different sectors during the COVID-19 pandemic. By examining the relationship between innovation and performance in small and medium-sized companies publicly traded on the U.S. exchange during pandemic. This study will aim to contribute to the literature on innovation and performance, providing practical implications for organizations seeking to enhance their innovation strategies and achieve sustainable performance outcomes in times with increased market volatility due to a crisis.

The study finds that there were no statistically significant relationship between investments and innovation during and after the pandemic. However, a negative statistically significant relationship in 2018 was identified. The study also finds no statistically significant difference between the three levels of R&D expenditure ratio examined. Furthermore, the study finds no statistical significance supporting the notion that the health care sector would benefit greater from innovation investments than the rest of the sectors examined in the study. The study then discusses the implications of these results from a risk management perspective, hoping to add to the current literature and aid in the conversation about risk management to prevent managers from overinvesting in innovation to achieve desired economic outcomes in challenging circumstances.

Keywords: Innovation investments, Risk and crisis management, Abnormal returns, Economic performance, R&D, COVID-19 Pandemic.

II. Acknowledgements

We are grateful for the time and effort Phil Flores invested in reviewing our work, providing constructive feedback, and challenging us to think critically. Therefore, we would like to extend our thanks to our supervisor, Phil Flores. His guidance and expertise has been of great value throughout the writing of this thesis.

III. Table of Contents

1. Introduction

This chapter provides a background for the study and the need for deeper insight into investments in innovation during times of crisis. It describes the role of risk management in these investments as well as why businesses could harm their economic performance without these insights. Following this, a presentation of the purpose and the research question. Lastly, the hypothesis, desired additions to the field of study, and delimitations are described.

1.1 Background

The recent COVID-19 pandemic impacted business on an unprecedented scale in the 21st century, making innovation critical for firms survival (Zerhouni, Nabel & Zerhouni, 2020; Marques Santos, Haegeman & Moncada-Paternò-Castello, 2021). The pandemic significantly restricted flows of commodities, services, workers and customers resulting in significantly lower global economic growth and higher levels of unemployment, causing widespread business disruptions (Albertoni & Wise, 2021). Many businesses that failed to adapt to the new lived reality and necessities started to experience negative results as the world around them shifted amid the pandemic crisis (Zerhouni et al., 2020; Albertoni & Wise, 2021).

Making innovation a necessity for companies' ability to overcome challenges as innovation allows for greater adaptability to change (Negulescu, 2020). *"The positive and significant effect of innovation on business performance meant that if the level of innovation increased, then business performance was higher"* - Ombi (2018, p. 54). Innovation can foster economic growth under normal and abnormal circumstances and allows businesses to separate their brand and products from their competition (Negulescu, 2020). However, according to Namky (2022) and Prorokowski (2014), innovation is not always a good thing as it's often depicted, debating that innovation can even hurt firms' economic performance if incorporated poorly.

Innovation is a broad term, often used in varying ways and contexts, such as *"Innovation is the specific function of entrepreneurship, whether in an existing business, a public service institution, or a new venture started by a lone individual in the family kitchen. It is the means by which the entrepreneur either creates new wealth-producing resources or endows existing resources with enhanced potential for creating wealth."* - Peter Druckner (2002). Although the definition of innovation in academic literature is hotly contested (Taylor, 2017; Baregheh, Rowley & Sambrook, 2009) for the sake of this study the authors of the paper have chosen to

define it as follows; a firm's ability and willingness to adapt and adopt new ideas and concepts. Ideas and concepts that, in turn, might lead to the development and launch of new products or services

Innovation often is portrayed as a sort of holy grail when it comes to company success. "*Innovation is widely regarded as the pinnacle success factor in a highly competitive and global economy.*" (Rajapathirana & Hui, 2018, p.1). Due to the overwhelming empirical data and studies on the positive effects of innovation, the shadow innovation casts on other important aspects and elements of managing companies' innovation strategies might be overlooked.

The current academic view on innovation is one very angled toward its benefits and potential, but alas, the downside of innovation is often overlooked or even forgotten in the pursuit of the next big innovation. Therefore as often suggested in other parts of managerial and company studies (Chen, Viardot & Brem, 2019), utilizing modesty and long-term thinking when operating various company aspects, such as innovation, are crucial for healthy company growth and stable economic performance, as bluntly put by Jezz Bezos in 2018 *"'If you cannot afford to be misunderstood, don't do anything new or innovative."*. But this way of thinking revolving around company modesty and long-term gain seems to sometimes be absent in the pursuit of innovation. Such a thing as overcommitment and overenthusiasm related to the concept of innovation might be causing long-term harm instead of long-term good (Coad, Nightingale, Stilgoe & Vezzani, 2021; Chen et al., 2019; Namky, 2022).

In the midst of the COVID-19 pandemic the global implications for companies stretched far and wide, often leaving companies with both collective and individual problems to face in a very short timeframe (Zerhouni et al., 2020; Adam, & Alarifi, 2021). Larger companies can historically be seen to manage in times of crisis due to their immense resources and government backing, whilst small and medium-sized companies generally had to fend for themselves in order to survive (Bhattacharyya & Saxena, 2016). Small and medium-sized companies had to improvise, adapt and overcome the turmoil created by the pandemic, some succeeding and some failing (Adam & Alarifi, 2021). The companies with higher innovation efforts, no matter the industry, argued in the literature to have had a better chance of survival

in economic turmoil (Perel, 2002; Țîțu et al., 2015).

These academic suggestions and deduction has been held strong up to the initial year of the pandemic when the research in the field halted or was deemed sufficient for the time being. This can be observed in the report from the EU Joint Research Centre published in 2021 by Marques Santos et al., on how to handle the COVID-19 pandemic, a report that didn't get updated after the 2021 edition. The report encourages companies to innovate in order to tackle this crisis, much like previous crises. However, a lot of the previous crises for companies have primarily been caused by economic crashes and not a globally influencing pandemic like Covid-19.

1.2 Research Gap & Problematization

In the 21 century, countries worldwide have experienced tremendous economic growth because of increasing international trade, a large increase in foreign investments, and globalization. The COVID-19 pandemic in early 2020 was an unexpected shock to the global economy. It differs from other financial crises, such as the 1997 Asian crisis and the 2008 global financial crisis, because it did not start as a financial crisis, but the pandemic's economic implications were even larger and far more reaching (Marques Santos et al., 2021; Worldbank, 2022). Governments around the world responded to the global pandemic by closing borders, restricting the movement of their citizens and trade, and mandating quarantine lockdowns to slow the spread of the virus. However, this greatly impacted the global economy (Alberytoni & Wise 2021; Au Yong & Laing, 2021).

While all sectors were affected by the pandemic, the impact the COVID-19 pandemic had on day-to-day business differed from sector to sector, where some sectors were hit harder than others (Au Yong & Laing, 2021), thus, creating a varying need for innovative solutions. Stemmler (2022) examines how key versus non-key firms were affected. Businesses sectors that were deemed essential were allowed to remain open in most countries and operate more or less as before the pandemic, these sectors less often reported a decline in the sale or demand of their goods and had to lay off a smaller number of their workforce compared to the non essential sectors that was impacted the most (Stemmler, 2022; Marques Santos et al.,

2021).

However, non-key firms had to face a harder reality which meant changing and innovating to survive, for example, due to the lack of natural walk-in customers caused by the lockdowns. Many offline businesses began to employ and deploy measures to ensure that their online business activities were fruitful and changed the way their products or services were offered through investments in innovation to meet new market trends and restrictions (Stemmler, 2022; De Massis, Moncada Paterno, Castello, Marques Santos & Haegeman, 2021; Marques Santos et al., 2021). This reflects the necessity of innovation to adjust to current economic and market fluctuations to be able to tackle accelerated changes in supply and demand in order to pertain their economic growth. Additionally, innovation can have positive spillover effects on the broader economy, leading to job creation and economic growth (Taalbi, 2021) in an economic crisis, something that could be seen as universally desirable in a crisis.

It has also been observed in research that innovation tends to make investors overconfident during economic bubbles resulting in stock prices soaring higher than the innovative products and services, produced through innovation investments, are worth (Adcock, 2014). It was also observed that competing firms' innovations caused an underreaction in competing firms' stock prices, rendering their market value largely unaffected despite their competitors' stock market gains from their innovativeness (Haddad, Ho & Loualiche, 2022). This disconnect between stock value and true worth is argued to be caused by disagreements between investors over specific firms, within each industry, rather than the innovations themselves. The authors Haddad et al., (2022) also found that the stock prices overreacted by around 40 percent compared to the innovation's true value during bubble episodes from 1962 to 2017.

Studies about stock volatility and innovation investments have observed a relationship between investments in innovation and performance, which shows that the more innovative firms experienced higher volatility (Gharbi, Sahut & Teulon, 2014; Li, Hao, Luan, Li & Cao, 2021). The uncertainty and volatility increased for almost all firms during the COVID-19 pandemic, and research suggests that innovation was necessary for a firm’s survival in non-key sectors (Stemmler, 2022). These findings spurred the question of whether the relationship between over-investments in innovation and performance is visible in stock

pricing during times of crisis, where companies might want to rethink their investments and expenditures to ensure a desired economic performance.

The significant impact on U.S. stock price volatility shattered the previous 2008 record on the CBOE volatility index (VIX) on the 16th of March 2020 (Baek, Mohanty & Glambosky, 2020). As previously mentioned, the research suggests that innovation increases economic risk but, at the same time, is essential for many firms' survival during a crisis for instance, a pandemic. It's possible that increased company efforts toward innovation calm investors rather than create further uncertainty (Adcock, 2014) during these unprecedented pandemic years and highly fluctuating markets.

While innovation's effect on companies' performance has been studied throughout the years in the literature, many focus primarily on the more disruptive sectors, such as the tech industry found in Silicon Valley, and have seemingly come to the same conclusion: Innovation is a necessity for a company's survival. This view is important to take into consideration when managing risks and investments in companies, but the view often leaves out the aspect of too much investment in innovation, as highlighted by Nechaev, Ognev & Antipina (2017).

This overconfidence in innovation can be seen more visibly currently in 2023, as the silicon valley economic growth bubble is leaving companies with overly optimistic evaluations, investments, and goals. A growth bubble potentially shifting as mentioned by a Forbes writer who summarizes it quite well; "*Wow, it's been a hectic Q4 in Silicon Valley. Almost 100,000 people have been laid off and it seems that's only the beginning. VCs are much more reluctant to invest in startups, valuations have gone spiraling down, and startups are closing shop. It's a bloodbath out there!*" (Aslanyan, 2023, p. 1).

Many papers conclude that innovation is essential to a company's survival during crises. Alarifi & Abdalla (2021) further strengthens the argument while studying small and medium-sized companies that innovation is essential, especially to them, for survival during crises. However, many studies fail to establish to what degree innovation should be used in a crisis. Di Minin et al., (2021) examined the implications of innovation on European

companies entering the COVID-19 pandemic. They conclude that innovative firms' economic performance was affected considerably less than non-innovative firms' performance.

Companies unable to balance the scale between investments in a risky market and preservation of economic growth may struggle to survive in a global economic downturn due to the often high costs related to innovation, leaving them with little runway to weather out a crisis (Chen et al., 2019), like the COVID-19 pandemic The relationship between innovativeness and stock market performance has been examined in the past in both low-tech and high-tech industries. Taking different mediating factors into account (Rubera & Kirca. 2012). Studies have found that there is a positive relationship between the two. However, this relationship has not been thoroughly investigated during the recent COVID-19 pandemic, which presented the global economy with unprecedented uncertainty and risk.

1.3 Aims & Objectives

The COVID-19 pandemic has posed significant challenges to firms' innovation and performance but has also created opportunities for firms to innovate and adapt (Heinonen, 2020). As such, understanding the relationship between innovation and performance in crises such as the COVID-19 pandemic is an interesting area and topic for research. This study aims to understand how investments in innovation and economic performance relate to small and medium-sized companies (SMCs) in the context of the COVID-19 pandemic. To do this, the study will use relevant theories and strategies from the fields of organizational performance, strategic economic management, and innovation management. Incorporating these fields and theories offer a more comprehensive view of the variables affecting economic success when looking at the relationship between investments made in innovation and economic performance during COVID-19.

This study aims to investigate how innovation and research and development (R&D) spending during the COVID-19 pandemic influence economic performance. In order to understand how these variables interact and affect economic performance, this investigation will focus on the links between stock pricing and investments made in innovation, visible as R&D spending. By integrating these fields into the study's analysis, a more comprehensive

understanding of the relationship between investments in innovation and economic performance in the context of SMCs during the COVID-19 pandemic can be achieved.

The health sector holds a special significance in the face of a pandemic, as it plays a critical role in responding to and managing public health emergencies. The study recognizes the immense pressure and challenges faced by healthcare systems, healthcare providers, and medical facilities during the COVID-19 pandemic. Due to the nature of the crisis being a pandemic, the study will also dive deeper into the health sector in order to establish if this essential business sector was affected more or less than other sectors due to its special relationship to the crisis created by the COVID-19 pandemic. By exploring these aspects, the study aims to provide evidence-based information that can inform policy-making, resource allocation, and future crisis management strategies within the health sector and across other sectors affected by the pandemic.

The above mentioned fields were included because they can offer a more in-depth understanding of the connection between innovation and economic performance. In particular, during adversity like the COVID-19 pandemic, the field's organizational performance, strategic economic management, and innovation management can provide insightful perspectives on how businesses should approach innovation investing.

These fields can provide insight into the approaches and measures taken by small and medium-sized businesses with respect to their investments in innovation as they enter, navigate through, and exit the pandemic. They can also be used to take account of how market players use innovation management strategies and perceive risks associated with innovation, which can affect how decisions are made (Rothwell, 1994; Dereli, 2015; Barbieri & Álvares, 2016). By incorporating these fields into the analysis, the study aims to create a more thorough understanding of the relationship between investments in innovation and economic performance in the context of SMCs during the COVID-19 pandemic.

1.4 Research Question & Purpose

Previous research suggests that innovation is an essential part of a company's survival and

economic performance and that this relationship between innovation and economic performance holds true, especially for tech firms, even under normal circumstances (Stojčić, 2018). But in times of crisis, the research struggles to establish how strong the relationship between investments in innovation and economic performance is. There is therefore an inherent risk for managers to overinvest when trying to foster innovation to reach desired economic performance in troubling times. Furthermore, the previous research fails to answer if the relationship differs before, during, and after the COVID-19 pandemic.

Research question: *How strong was the relationship between investments in innovation and performance in SMCs across different industries publicly traded on U.S. exchanges before, during, and after the COVID-19 pandemic, and was there an optimal level of investments in innovation related to economic performance?*

The research question aims to explore the strength of the relationship between investments in innovation and performance in small and medium-sized companies (SMCs) across different industries publicly traded on U.S. exchanges and how or if this relationship evolved during the various stages of the COVID-19 pandemic. Additionally, the question investigates whether an optimal level of innovation investments is associated with performance outcomes. This study's purpose is to try and answer some of the relevant gaps in previous literature and try to add context to the argument of innovations' role on companies' performance during a crisis or economic turmoil.

1.5 Additions to the Field

This study aims to contribute to the existing body of knowledge on the relationship between innovation investments and economic performance in SMCs, provide insights into the unique challenges and opportunities faced during the COVID-19 pandemic, and offer practical implications for firms aiming to enhance their innovation strategies and overall economic performance in turbulent times.

The study seeks to provide a more comprehensive understanding of the relationship between innovation investments and economic performance in SMCs across different U.S. industries and how this relationship was affected by the COVID-19 pandemic. The authors of this paper

will try to identify whether an optimal level of innovation investing exists and whether being highly innovative is universally desirable across all sectors during times of crisis.

1.5.1 Theoretical Implications

The research will aim to contribute to the field of innovation management strategies and innovation investments. The study hopes to contribute to the literature and management practice by looking deeper into the nature of innovativeness and its potential drawbacks for small and medium-sized companies. By addressing the proposed research question, this paper aims to contribute to the literature and managerial practice field. First, the paper extends the literature by considering the role of investments in R&D in the firm's innovation capability and performance.

Investments in R&D are expected to generate a stronger innovation capability, which should result in increased performance (Rajapathirana, 2018). Second, the research contributes to the research suggesting that there exists alternative explanations and factors affecting companies economic performance other than increasing innovation investments. Testing to see if companies' different innovation investments can lead to different economic performance outcomes during times of crisis.

Third, the paper presents results from different sectors to establish a broad-stroke overview approach to looking at investments in innovations affecting companies' performance during the COVID-19 pandemic. By including different sectors in the study an overview approach can be used, an overview accounting for both different firm and market sizes. Sizes which can influence the individual sectors' potential performance and innovativeness (Liao & Rice, 2010; Ngo, 2012).

By including all sectors in the sampled data it allows a further comparable insight into each individual sector. These individual insights make it possible to isolate if certain sectors' performance are varying, or if all sectors experience similarities, for instance the healthcare sector. A sector which includes essential firms which should experience different challenges than non-essential firms (Stemmler, 2022). Adding to the knowledge and research in this

field.

1.5.2 Practical Implications

This paper aims to provide insights into how small and medium-sized companies should allocate funds for their innovation efforts in competitive or changing environments, such as new or old markets, to reach or keep desired performance. Additionally, building on previous discourse and debate on how companies should tackle economic crises. The paper aims to contribute to this managerial knowledge and debate revolving around investments in innovation and its effect on economic performance during crisis scenarios, by looking at the COVID-19 pandemic.

The findings of this study hope to provide valuable insights for managers, policymakers, and industry stakeholders, aiding and informing their decision-making processes regarding innovation strategies during crises. If an optimal level of innovation exists and is identifiable, it will enable organizations to strike a balance between being sufficiently innovative to remain competitive and avoiding potential risks associated with excessive innovation.

1.6 Delimitations

SCOPE AND THESIS LIMITATIONS:

The research encompasses various industries and organizations, aiming to provide insights into the broader applicability of innovative risk management approaches during times of crisis.

COMPANY DEFINITION AND DATA DELIMITATIONS:

The definition for small- and medium-companies varies from country to country, for example, the European Union (EU) defines SMEs as those with fewer than 250 employees, while in the United States (U.S.), the Small Business Administration (2023) defines them depending on the industry. Some definitions may also consider factors such as annual turnover or balance sheet total, depending on market geography (SBA, 2023).

Furthermore, in the United States, the Small Business Administration has established a

classification system for small businesses based on various factors such as ownership structure, number of employees, earnings, and industry. For instance, in the manufacturing industry, a firm with 500 or fewer employees is considered a small and medium-sized enterprise (SME), while businesses involved in the mining of copper or nickel ore can have up to 1,500 employees and still be classified as SMEs (Hait, 2021).

To address these issues, the authors of this paper have proposed the use of a collaborative title like SMCs to encompass all types of small and medium-sized companies and corporations. This term (SMCs) aims to act as an umbrella term to provide clarity and structure for the study and reader. By using an umbrella term title, researchers can ensure that their work is accessible and understandable to a broader audience, regardless of the particular definition used in a particular context, like academic terminology (Thelwall, 2017).

In order to maintain a clear and fair representation in the study, the authors choose to look only at U.S. companies listed on U.S. stock exchanges with a market cap of $2B or less. The data sample captures nano, micro, and small-cap companies which arguably would fall under the SMC umbrella. Therefore, the authors of this paper justify the use of the term SMCs as an umbrella term that includes all types of small and medium-sized companies and corporations that fall under the scope of this thesis. The scope and limitations under which these SMCs were chosen will be further elaborated on in the methodology chapter.

1.7 Outline of the Thesis

This thesis is structured into different chapters, designed to fulfill the research objectives effectively and allow for easier digestion of the paper for the reader.

This first chapter serves as an introduction to the research topic, providing the background information, identifying a research gap and problematization, stating the aims and objectives of the study, introducing the research question and research purpose, describing the intended contribution of the study and setting the scope as well as the delimitations of the research.

The second chapter offers a comprehensive overview of the existing literature on the subject

matter, ensuring that readers gain familiarity with the topic and theories. The literature review contextualizes the study by presenting and incorporating the selected relevant literature to the reader within its appropriate context. Ending with the hypothesis development.

Chapter three presents the underlying research philosophy and its methodological implications are explained. The research design, data collection methods, and data analysis techniques are outlined and discussed. Furthermore, a critical reflection on the chosen research approach is provided.

Chapter four presents the empirical findings obtained from the collected data. The rigorous analysis is structured around the notion of answering the chosen research question during the entire coding process. This chapter serves the purpose of addressing the research question and achieving the research objectives. The chapter also places the findings into a broader context by critically reflecting on them in relation to previous research. Any contradictions or similarities with existing literature are emphasized, and new insights generated by the study are highlighted, providing a deeper understanding of the field of study.

The final chapter concludes the study by revisiting the research question and research purpose. It presents the study's practical implications and theoretical contributions, discusses limitations, and provides suggestions for future research, ensuring a comprehensive closure to the thesis.

2. Literature Review

This chapter presents fundamental concepts of risk management and their connection to over investments whilst also exploring the potential negative consequences of excessive innovation and the associated risks. Furthermore, it describes innovations effect on performance and aims to grant the reader an overview of possible innovation activities related to economic growth provided by the literature. The chapter also depicts the need for certain business activities during times of crisis identified in previous literature and business support activities is provided together with an overview of barriers faced by small and medium sized companies, depicted as SMCs.

2.1 Innovation & Risk

Innovation is often celebrated as a driving force behind organizational growth and success (Rajapathirana & Hui, 2018). However, it is essential to recognize that innovation can also have adverse effects, particularly for small and medium-sized companies (Danneels, 2004; A, Berglund, 2007). It is essential to acknowledge the potential negative consequences that can arise from over-investment in innovation (Coad et al., 2021; Dillerup, Kappler & Oster, 2018). Over-investing in innovation, according to Namky (2022) and Nechaev et al., (2017), can result in increased risk, loss of focus and clear direction, and decreased financial performance, among other negative outcomes. Results that could potentially be avoided using risk management theory and measures.

While innovation is crucial for the growth and competitiveness of companies, it is essential to acknowledge the potential negative consequences that can arise from over-innovation (H, Berglund, 2007; Coad et al., 2021; Danneels, 2004). The authors Coad et al., (2018) and Nechaev et al., (2017) emphasize the importance of understanding the "dark side" of innovation and the potential negative consequences of excessive innovation in their systematic review and research agenda. By understanding and actively managing this adverse side of innovation, SMCs can mitigate risks, maintain their strategic focus, and ensure a sustainable financial performance. This recognition of the challenges and risks associated with innovation can guide managers towards a more balanced and effective approach to leveraging innovation for long-term success (H, Berglund, 2007; Dillerup et al., 2018).

To mitigate the negative consequences of innovation, the dark side of innovation, companies

must adopt a proactive approach to risk management (Danneels, 2004). By implementing robust risk assessment processes, companies can identify potential risks associated with innovation projects and make informed decisions regarding resource allocation and strategic direction (H, Berglund, 2007). A structured risk management strategy enables organizations and managers to anticipate and manage the potential negative consequences of innovation (Ajupov, Sherstobitova, Syrotiuk, & Karataev, 2019). By systematically assessing risks, SMCs can develop risk mitigation strategies and contingency plans to address the challenges that may arise from excessive innovation, according to Chen et al., (2019).

Authors Chen et al., (2019) investigate the challenges and risks of innovation for SMCs, such as the risk of investing too heavily in new technologies and products that may fail. Their research shows that for SMCs, innovation can be a double-edged sword. While innovation can have significant benefits, it can also have negative consequences if not managed correctly. SMCs may suffer from these negative consequences as a result of over-investing in innovation (A, Berglund 2007; Beck, Chen, Lin & Song, 2016), companies must also strive towards striking a balance between risk management and innovation (Chen et al., 2019). They must carefully assess the potential risks and benefits of innovation and make informed decisions (Ajupov et al., 2019; Nechaev et al., 2017). They should also consider developing innovation strategies that align with their short and long term goals and capabilities to avoid over-innovation, which could have negative consequences (Abulrub,Yin & Williams, 2012; Chen et al., 2019).

In addition, organizational learning plays a vital role in managing the dark side of innovation. As mentioned by Chen et al., (2019) and Chesbrough (2003), Companies should establish mechanisms for knowledge sharing and reflection, allowing them to capture valuable insights from both successful innovations and failures. This learning-oriented approach can help organizations improve their risk management practices and enhance future innovation initiatives to tackle potential crisis situations.

Companies can adopt various risk management strategies, such as identifying and assessing risks, implementing appropriate risk mitigation measures, and creating a risk management culture (H, Berglund, 2007). Innovation can also play a critical role in mitigating risks and

creating competitive advantages for companies (Ajupov et al., 2019; Nechaev et al., 2017). By innovating and, for example, adopting new technologies, smaller companies can improve their operational efficiency, reduce costs, and enhance their products and services (A, Berglund 2007, Abulrub & Lee, 2012).

2.2 Innovation & Performance

To get a competitive advantage, Porter (1990) suggests that *"a company should seek out pressure and challenge*" (p. 6). According to Dereli (2015), one of the best sustained competitive advantages available to organizations is innovation. It has been suggested that innovation can be a means of enhancing companies' societal viability and commercial viability (Taalbi, 2021; Porter, 1990). Also, it has been demonstrated that innovation is positively correlated with the outcomes of positive financial performance (Țîțu, Răulea, & Țîțu, 2015; Whelan & Fink, 2016).

Innovation and performance are two interconnected variables that have attracted significant attention in academic research, *"The innovation, R&D expenditures and the investments in technology are premises for ensuring competitiveness and progress, and through them a sustainable economic growth."* (Pece, Simona & Salisteanu, 2015. p. 1). Similarly, company performance is a multifaceted construct that involves different dimensions, such as financial, operational, and strategic decisions and outcomes. The literature suggests that innovation can be a powerful driver of firm performance, leading to enhanced productivity, competitiveness, and profitability (Damanpour, 2014; Prorokowski, 2014; Miocevic et al., 2021; Rubera & Kirca, 2012).

As it has the potential to open up new opportunities, boost competitiveness, and promote sustainable growth, innovation is a key factor in the economic performance of small and medium-sized enterprises (Rubera & Kirca, 2012). The authors examine the various ways in which a firm's innovativeness can influence its performance outcomes. They emphasize how important it is for SMCs to use both tangible and intangible resources to gain competitive advantages through innovation.

Innovation can influence firm performance through different mechanisms, including new product and service development, process improvement, and organizational learning (Rubera & Kirca, 2012; Damanpour, 2014; Heinonen, 2020). For example, Chesbrough (2003) introduced the concept of open innovation, which may increase company performance by learning from both failed or successful innovation efforts and investments. The authors Rauter, Globocnik, Perl-Vorbach, and Baumgartner (2019) also highlight the importance of collaboration and knowledge sharing in innovation processes and argue it can bolster companies' stakeholder engagement, something that may affect company performance. By opening up to and investing in external sources of knowledge and expertise, firms can access new ideas and technologies that can drive their innovation and performance (Taalbi, 2021; Santoro, Mazzoleni, Quaglia & Solmio, 2021).

Several studies have examined the relationship between innovation and performance and found evidence of a positive association. The theory EVA (Economic value added) adds to this notion stating that investments made with company resources should lead to a net positive (Tito et al., 2015). For example, Author Damanpour (2014) found that innovation is positively related to various measures of firm performance, including productivity, profitability, and market share. Similarly, Prorokowski (2014), Rauter et al., (2019) and Rubera and Kirca (2012) argue that the usage of innovation can lead to improved financial and non-financial performance outcomes for firms. Innovation can indirectly affect economic performance by increasing the firm's resource base (Shin, Kim, Jung & Kim, 2022). By introducing new products or services, entering new markets, and differentiating from competitors, innovation can positively impact economic performance (Miocevic et al., 2021).

The authors Miocevic et al., (2021), Prorokowski (2014) and Shin et al., (2022) provide insight into the moderating factors that influence the relationship between innovativeness and economic performance. These factors could interact with a firm's resource base and strategy direction to impact how much innovation translates into economic performance. The authors implies that market dynamism, competitive advantages, and environmental factors can all influence the outcomes of SMCs' innovativeness efforts.

The COVID-19 pandemic has brought significant challenges and disruptions to companies

worldwide, leading to questions and knowledge gaps about its impact on innovation and performance. The pandemic has forced both larger and smaller firms to adapt to new ways of operating, adopt digital technologies, and innovate to survive and thrive (Di Minin et al., 2021). Studies have investigated the impact of the COVID-19 pandemic on innovation and performance and found mixed results. For instance, the EU-supported study by Marques Santos et al., (2021) suggests that the COVID-19 pandemic has had a negative impact on innovation in some sectors, particularly those that rely heavily on research and development and face-to-face interactions. However, other studies have suggested that COVID-19 pandemic has also created opportunities for firms to innovate and adapt, leading to positive performance outcomes (Shin et al., 2022).

2.2.1 Efficient Market Hypothesis

The efficient market hypothesis presented by Fama in 1970 dictates that all stocks are publicly traded at their fair value on public exchanges, making arbitrage impossible as share prices reflect all available information. Instead of looking into these previously mentioned dimensions individually, the efficient market hypothesis proposed by Fama (1970) would allow for the usage of stock pricing as a measurement of economic performance. Market efficiency theory is a concept from finance and economics that examines how well financial markets incorporate and reflect all available information in asset prices.

The theory provides insights into whether the market efficiently prices the impact of innovation investments on a firm's economic performance and how investors perceive and respond to such information (Fama, 1970). In the context of the study, the efficient market hypothesis can be relevant in understanding how the stock market reacts to companies' innovation strategies and performance outcomes during the COVID-19 pandemic.

2.3 Innovation & The COVID-19 Pandemic

The impact of the COVID-19 pandemic on firms' innovation and growth has been the subject of current research. The comparative analysis by Di Minin et al., (2021) and Marques Santos et al., (2021) found that while the pandemic had a significant negative impact on firm innovation activities, some sectors were better able to adapt than others. For instance, the

authors suggest that companies in the healthcare, ICT, and pharmaceutical sectors were better able to adapt to the challenges posed by the pandemic, while firms in the hospitality and tourism sectors would struggle.

The COVID-19 pandemic has also significantly impacted innovation and firm growth as investments become riskier during times of increased market volatility (Rothwell, 1994; Dillerup et al., 2018). As seen historically, innovation has been a critical driver of firms' success and survival during economic or global crises. This statement is supported by studies that have shown a positive correlation between innovation efforts and firm performance (Chesbrough, 2003; Damanpour, 2014; Shin et al., 2022). The meta-analysis of 156 studies by Damanpour (2014) found that there is a significant and positive relationship between innovation and firm performance, including financial and non-financial outcomes. Authors Chesbrough (2003) and Naseer, Khawaja, Qazi, Syed & Shamim (2021) have also found that companies that are able to harness the power of innovation are more likely to achieve competitive advantages and long-term success.

One way firms can adapt to current market needs and necessities is by carefully managing their innovation investments, which might involve changing how firms or resources are managed to improve their economic performance (Negulescu, 2020). The author Chesbrough (2003) presents the idea that both companies as a whole, and divisions within those companies should collaborate with either external or internal partners to increase effectiveness when innovating to create and commercialize new products and services. This idea became more relevant during the pandemic, as firms were forced to find new ways of reaching customers and making a profit, adopting higher levels of innovation and new strategies to stay competitive in the market. Authors Damanpour (2014) and Namky (2022) add to this necessity by discussing the importance of correctly managing innovation and potentially its impact on organizational performance.

In the COVID-19 pandemic crisis, firms have had to use innovation to find solutions and adopt new strategies to cope with the challenges posed by the pandemic(Albertoni & Wise, 2021). For example, many firms have had to shift to remote working, which requires innovative management practices to ensure that employees remain or even increase their

potential productivity. Thus the COVID-19 pandemic has highlighted the importance of firms innovating and adapting to survive (Di Minin et al., 2021). But surviving with limited resources poses its own challenges, and external support can play a critical role in supporting SMC innovation and growth, the role of external support and knowledge in promoting innovation and growth (Santoro et al., 2021). All forms of external support may impact the cost associated with innovation. Backed up by Ombi (2018) who found that external support in the form of government programs and policies can positively impact innovation and company performance.

Similarly, the articles by Taalbi (2021) and Santoro et al., (2021) argues that external support can help to facilitate the diffusion of knowledge and technologies that can drive innovation. The article by Ombi (2018) also highlights the importance of external support in helping companies to access resources and expertise that they may not have in-house. This approach was enacted by the U.S. government during the pandemic, for example as all levels of government took direct action and aided the healthcare sector with additional resources such as financing from the federal reserve, increased knowledge sharing, and streamlining of legislation (ASPE, 2022).

The COVID-19 pandemic highlighted the urgent need for fast, innovative solutions to meet market necessities, such as vaccines, therapeutics, medical devices, and digital health technologies, to combat the public health crisis effectively (Marques Santos et al., 2021; Di Minin et al., 2021). Therefore investments in innovation may have been more essential for healthcare organizations to adapt, develop, and implement these innovations to address the specific challenges and necessities for this sector posed by the pandemic.

2.4 Innovation & SMCs

The COVID-19 pandemic has presented several challenges for SMCs regarding innovation, financing, and performance. SMCs may struggle to access financial resources and invest in innovation, which can hinder their growth and development in crises (Prorokowski, 2014). The COVID-19 pandemic has affected all sectors of the economy, with SMCs being particularly vulnerable due to their limited resources and financial capabilities. SMCs often

struggle with innovation financing and performance during times of crisis (Marques Santos et al., 2021).

The COVID-19 pandemic has presented several challenges for SMCs, including but not limited to: decreases in sales revenue, disrupted supply chains, and reduced access to financial resources (Ratten, 2020; Marques Santos et al., 2021). Additionally, the pandemic has created new challenges for SMCs in terms of productivity and efficiency because of changes in both consumer and consumption behavior (Singh & Bolpagni, 2023). Companies can accumulate knowledge and capabilities that contribute to their long-term competitiveness and sustained economic performance by for instance investing in R&D, building technological capabilities, market tools and fostering an innovation culture (Ombi, 2018; Miocevic et al., 2021). Therefore, it is important for companies to adapt and innovate to overcome these challenges and stay competitive in crisis-afflicted markets (Cooper, 2021; Prorokowski, 2014).

One of the main challenges that SMCs face when it comes to investing in innovation is a lack of financial resources. SMCs may not have access to venture capital or other types of funding, which can hinder their ability to invest in innovation in a fluctuating market (Marques Santos et al., 2021; Prorokowski, 2014). This can lead to a lack of innovation and slow down the growth of the company. Moreover, the COVID-19 pandemic has resulted in a decrease in sales revenue, which has made it more difficult for SMCs to invest in innovation. Companies may have to reprioritize their financial resources and allocate them toward more pressing needs (Ratten, 2020; Ratten & Jones, 2021), such as paying their employees or covering their fixed costs.

In terms of performance, the pandemic has created new challenges for SMCs. SMCs may struggle to maintain their level of productivity and efficiency, as the pandemic has forced them to adapt to new ways of working or implementing social distancing measures such as remote work (Marques Santos et al., 2021). Companies tackling the crisis may face supply chain disruptions or shortages of raw materials, which can further hinder their ability to perform (Albertoni & Wise, 2021), which in turn promotes innovation to reduce these disruptions to stay profitable (Liao & Rice, 2010).

Furthermore, the pandemic has led to changes in the market leading to changes in consumption and consumer behavior, which may impact SMCs' performance (Singh & Bolpagni, 2023). SMCs that rely on face-to-face interactions or physical locations may struggle to adapt to the new normal of online and remote interactions. SMCs may need to invest, adopt or innovate new technologies or marketing strategies (Adam & Alarifi, 2021; Liao & Rice, 2010). These changes might be necessary, not only to stay competitive and maintain their customer base but also to avoid the risk of lagging behind their competitors and being less flexible during an economic downturn or crisis (Ratten, 2020; Ratten & Jones, 2021).

During the COVID-19 pandemic, large corporations and small and medium-sized companies (SMCs) faced a variety of challenges related to innovation financing and performance (Albertoni & Wise, 2021). However, the challenges that each size of company and sector faced were distinct. Large corporations have greater access to capital and resources than SMCs, allowing them to invest and pursue innovation with greater zeal. Nonetheless, the pandemic has posed significant corporate operational, supply chain, and revenue challenges. The restrictions imposed during the pandemic disrupted global supply chains, reducing raw materials and finished goods availability (Marques Santos et al., 2021). As a result, corporations might have been forced to implement new innovation strategies to keep or reach desired productivity and production (Cooper, 2021).

Due to their limited resources and capabilities, SMCs might face even greater or varying challenges than large corporations. SMCs frequently lack the financial and technological resources needed to adapt to new ways of working and invest in innovation. The pandemic has disrupted SMCs' supply chains and reduced their access to financing, making it more difficult for them to continue operations (Marques Santos et al., 2021). As a potential effect and result, many SMCs have found it difficult to create new business models or invest in innovative activities. Another significant challenge that SMCs face is the need to quickly adapt to new market conditions and necessities. Small and medium-sized companies (SMCs) typically operate in highly competitive markets and rely on their agility to respond quickly to changes in market demand and necessity (Runyan, 2006), arguably granting SMCs a small

advantage over their larger counterparts in the COVID-19 crisis climate.

The pandemic has created unprecedented levels of uncertainty through increased market volatility and necessity by rapidly changing the market landscape, making it difficult for SMCs to plan and implement new strategies with sustainable short and long-term effects on their economic performance. To meet these changes, many companies have had to pivot their business models and/or diversify their service and product offerings (Cooper, 2021). While the specific challenges differed, both large corporations and SMCs faced significant challenges during the COVID-19 pandemic. Large corporations were better positioned to weather the storm due to their resources and access to capital, but their supply chains and operations were still disrupted (Marques Santos et al., 2021; Albertoni & Wise, 2021). SMCs were more vulnerable due to limited resources, but they were also more agile and better equipped to adapt to these new market conditions.

Although it is not easy to know how much adaptation and innovation is too much when facing economic struggles and new market challenges. This might lead to difficulties for companies, regardless of size, when determining how much to invest in innovation when facing a crisis, as experienced by many companies during the COVID-19 pandemic Because SMCs faced different difficulties and challenges than large corporations, the authors of this paper thought it would be interesting to investigate how SMCs dealt with the challenges of the COVID-19 pandemic. As previously stated, SMCs have limited access to financial resources, making it more difficult and crucial for them to invest correctly in their innovation efforts during the pandemic.

The pandemic has also caused widespread disruptions to the global supply chain, making it more difficult for SMCs to obtain raw materials, personnel equipment, and finished goods (Santoro et al., 2021; Ratten, 2020). For example, SMCs have fewer employees, making it harder for them to handle the increased workload caused by the pandemic's disruptions (Marques Santos et al., 2021). Therefore SMCs might be more vulnerable to supply chain disruptions than large corporations because they typically rely on a smaller group of suppliers, potentially affecting their economic performance.

Further knowledge in the field of how SMCs dealt with these challenges during the COVID-19 pandemic would provide valuable insights into how SMCs can be supported and tackle future crises. It could provide policymakers and stakeholders with information about the specific challenges that SMCs face and the interventions required to support their survival and growth during future crises. It is critical to study SMCs during the COVID-19 pandemic because they faced unique challenges when compared to large corporations. Understanding how SMCs coped during the pandemic and identifying the strategies they used to adapt and survive are important for ensuring future resilience and growth. By studying SMCs, the authors of the study hope to identify interventions and factors important to support and aid SMCs' survival and growth during future crises.

2.5 Hypothesis Development

The theories that were found to be particularly relevant in the context of the pandemic and risk management, which has introduced significant volatility and disruption across industries, were theories related to economic management, strategic innovation management as well as crisis and risk management, for instance, the efficient market hypothesis theory, EVA Theory, and volatility theory. These theories will be considered in the study to try and identify how companies navigate and respond to disruptive events like the COVID-19 pandemic, and how their innovation investments and economic performance outcomes are influenced by such circumstances.

Volatility theory suggests that firms with higher adaptability, flexibility, and responsiveness to changing conditions are better equipped to survive and thrive in volatile environments (Jondeau, Poon & Rockinger, 2007). The theory of EVA (Economic value added) contributes to the concept that investments made with company resources should lead to a net positive for either the market or the company when used correctly. The economic value-added theory used in this paper to bolster the notion that a company can only be profitable if it generates wealth and returns for its shareholders, exceeding its cost of capital explained by Tito et al., (2015).

In the context of SMCs, these theories can add to the understanding of how SMC´s managed and harnessed their innovation efforts to increase economic performance. This can provide further insights into the need for SMCs to bolster abilities such as investment strategies to tackle increased market volatility and to sustain or reach desired economic performance in a crisis.

Now after the COVID-19 pandemic, a crisis unique in its origin and not created by economic turmoil, a deeper look into the consensus that innovation is always good, could be more closely studied. This consensus originating mostly from history's economic crises like the Asian crash in 1997 and the global financial crash in 2008, might not be applicable in the same manner during a different type of crisis.

Diving deeper into the assumption that innovation is key to success is now possible and important since the general advice to all industries, as seen in the EU-published report from Marques Santos et al., (2021) was to continue with innovation. A consensus not accounting for the difference between different industries, company sizes, market risks, and volatility factors. Furthermore, the EU report does not take into account how this advice could cause a long-term variation in economic performance for companies taking this advice, stating that focusing on and utilizing investments in innovation was the way to ensure company success. Following the advice, the most innovation-focused companies should therefore, perform the best throughout the entire pandemic, not just the initial year. Whilst the companies with a more reserved approach to innovation should be positioned at the bottom, a view adopted when creating the first hypothesis.

H1: *There is a positive relationship between abnormal returns and research and development expenditure ratio before, during, and after the COVID-19 pandemic and abnormal returns.*

The current research is also limited on if there is something as being too innovative in times of crisis. The research struggles to establish if there is an optimal degree of investment in innovation, as innovation is often seen as the holy grail of economic growth (Rajapathirana & Hui, 2018) and often acts as a savior for companies in crisis (Filippetti, 2011). A coherent crisis measurement tool on how companies that perform the best are identified is not found;

also, if there is a level for diminishing returns on investments in innovation for small and medium-sized companies, it is not seemingly established. Creating the need for the second hypothesis.

H2: *The group of companies with high research and development expenditure ratio will generate higher abnormal returns than the other groups with low and medium research and development expenditure ratio during times of crisis.*

The literature also presents inconsistent findings that indicate a more complex relationship between innovativeness and performance than what might be initially assumed. Additionally, limited research on how over-investments in innovation affect companies in markets with rapidly increasing volatility is available.

While it is thoroughly observed in the literature that innovation is a key driver for companies' performance and growth during economic downturns, "*During the COVID-19 pandemic, several instances of innovation were reported in construction and other sectors, consistent with previously noted spikes in innovation activities during crises and environmental perturbations"* (Singh & Bolpagni, 2023, p.1). These several instances of innovation must have come at a cost for the companies, and few researchers have explored the relationship between investments in innovation and economic performance entering, during, and after the COVID-19 pandemic. Furthering the development of the second hypothesis.

Lastly the third hypothesis could be developed with the aid of the previous two, since the crisis was of public health in nature, not economical. This gave way to the third and final hypothesis focusing more closely on the healthcare sector

H3: *The healthcare sector's performance is more dependent on research and development expenditure ratio than the rest of the sample.*

This hypothesis is relevant in the context of examining innovation investments because it investigates the specific relationship between innovation and the most afflicted sector, being the healthcare sector, during the crisis scenario created by the COVID-19 pandemic. In contrast to the e.g., 1997 Asian crisis and the 2008 global financial crisis, which

predominantly impacted financial markets and businesses, the COVID-19 pandemic also affected public health. This divergence raises concerns about the significance of healthcare innovation investments and their potential effects on economic performance in times of crisis. Because of the unique nature of the pandemic, understanding the impact of investments in innovation on the healthcare sector is critical for similar future crises.

3. Methodology

This chapter describes the method adopted to fulfill the purpose of the study and answer the research question. The research design and methods for data collection and analysis are presented. Finally, the baseline for company selection as well as the level of innovativeness when conducting the study, is also discussed.

3.1 Research Approach

The most common view of the relationship between the chosen theory and research is the deductive approach. The researcher deduces a hypothesis based on what is known about a domain and its theoretical considerations. Deductive reasoning begins with basic principles or ideas and progresses through logical deduction to specific conclusions. It entails reasoning from the broad to the specific (Bryman & Bell, 2019).

Both deductive and inductive reasoning have benefits and drawbacks. Inductive reasoning allows for the investigation and discovery of new patterns or relationships, but it may be limited in its generalizability or suffer from biases due to a lack of evidence. Deductive thinking, on the other hand, allows for hypothesis testing and evaluating hypotheses' validity, although it may miss nuances or unexpected insights given by data (Bryman & Bell, 2019).

Quantitative research or hypothesis testing is frequently related to deductive reasoning. Researchers begin with a theory or hypothesis and then collect data to test the specific predictions that the theory generates. Deductive reasoning enables researchers to evaluate a theory's validity or application by evaluating specific instances or cases (Bryman & Bell, 2019). The deductive approach to research is most commonly associated with the research tradition known as positivism. Positivism is a philosophical stance that is often adopted in quantitative research. It assumes that reality can be measured through observable phenomena (Easterby-Smith et al., 2021). Therefore, the conductors of this study have chosen to utilize a deductive approach with a positivism stance to this research to relate our study to previous academic discourse.

3.2 Data Collection

When gathering the data used and analyzed in this study secondary sources were utilized. Secondary data collection can, for example, entail the collection of stock prices and readily available corporate economic figures. Secondary data as a collection method allows for a more comprehensive view of investments in research and development and their effect on economic performance (Bryman & Bell, 2019).

This provides the researchers with a richer and more reliable source of information and data, e.g, offering numerous benefits in terms of sample size, historical analysis, and cost efficiency (Wickham, 2019). Although it is important to acknowledge the limitations and possible biases related to the secondary data. To limit the potential drawbacks of these limitations, the data collected was carefully examined and considerations were made as to where it was collected to ensure higher data and source quality.

3.2.1 Company Selection

The companies sampled in this study were selected using the Bloomberg Terminal, with the selection criteria of companies with a market capitalization of less than 2.000.000.000 U.S. Dollars as of 2018. This selection ensured the capture of data from only Nano, Micro, and Small-caps. The selection was also made to only look at United States companies, excluding cross-listed companies trading on U.S. exchanges.

Furthermore, only companies actively trading on U.S. exchanges as of 2023 were selected. Generating a list of 2441 companies matching these criteria in Bloomberg Terminal (2023). The sample excludes companies that went bankrupt, went back to private, merged, or were acquired during the sampling period. This introduces survivor's bias (Brown, Goetzmann, Ibbotson & Ross, 1992) to the study, which can positively skew the results as only firms that are still trading as of 2023 are included in the sample and firms that went bankrupt or went back to private during the hard financial times during the pandemic are not included.

The decision to only include U.S. firms listed on U.S. exchanges was made because the data availability is greater than in other demographics like the European exchanges. Firms listed on U.S. public exchanges also adhere to the same stock market rules. In contrast, firms listed on, for example, European exchanges play by somewhat different rules, which makes it harder to examine the data and get conclusive answers. The U.S. market, therefore, is the largest available sample that can be easily collected and examined.

3.2.2 Research & Development Expenditure

According to Reeb (2017), research and development expenditure can be an intuitive signal for measuring a firm's level of innovativeness. Where data is easily obtained from company SEC filings making it a valuable data point when statistically trying to determine a company's level of innovation.

The sample of 2441 company tickers obtained using the method described in the previous subchapter was then fed into Microsoft Excel. Then the research and development expenditure for 2018, 2019, 2020, 2021, and 2022 were obtained using the Bloomberg Terminal Excel add-in function BDP. The total operating expenses for each year was obtained in the same manner using the BDP Excel formula.

According to Reeb (2017), some companies decide not to disclose research and development expenditures for, for example, competitive advantage reasons. Companies not disclosing research and development expenditures for all years, examined in this study, were excluded from the sample. Furthermore, Reeb (2017) argues that two well-known sources of noise arise when using R&D as a measurement for innovation. The first noise is that managers are responsible for deciding what research and development is and how it is reported as within the company. An employee spending time doing R&D tasks might also be working on, for example, quality control which can make it very difficult for managers, responsible for reporting the expenditure on R&D to accurately report the cost associated with R&D. Making the reporting of R&D expenditure a discretionary choice of the manager. The second noise mentioned by (Reeb, 2017) is if current R&D spending and investing, reflects the benefits

from prior R&D investments and provides a noisy signal about future payoffs rather than present ones.

The first noise is unavoidable and present in the study, however, the second noise can be avoided using stock prices as these reflect all available market information according to the efficient market hypothesis by Fama (1970). This means that all available market information would immediately be reflected upon in the price of the companies' stock. Thus, eliminating the lag of the innovation efforts since the market is reflecting expectations on future performance.

Sector	Total	Incomplete	Complete
Communication Services	95	75	20
Consumer Discretionary	274	253	21
Consumer Staples	71	63	8
Energy	144	137	7
Financials	453	450	3
Health Care	591	223	368
Industrials	320	271	49
Materials	78	62	16
Real Estate	26	24	2
Utilities	22	22	0
N/A	61	61	0
IT (Excluded)	306	144	162
Total	2441	1785	656

Table 1. Shows the number of companies used in the study.

Out of the 2441 company tickers provided by Bloomberg Terminal, 1785 were missing data on research and development spending, with 656 companies having full and complete data for the timeframe in this study as shown in Table 1. As previously explained, the technology sector was excluded due to the already highly studied nature of this relationship, which left 494 companies (See Appendix C for a full list of included company tickers, full names & sectors).

3.2.3 Stock Pricing & Benchmark

The stock closing prices for each of the companies in 2018, 2019, 2020, 2021, and 2022 with complete data matching the selection criteria, were obtained using a Python script (See Appendix A), co-written by GPT-4 using Financial Modeling Prep's API in order to collect accurate historical data. It was then manually combed through for any missing data points and if any data points were absent in the collected data, these data points were manually completed using Yahoo Finance (2023) and MarketWatch (2023).

A benchmark was used in the study to lower the impact of market conditions on the results. The Russel 2000 Small-cap index was selected as the benchmark index for this study as it provides the best representation, although not perfect, for the sample companies. For example, the stock market as a whole performed worse in 2022 than in 2021, which then would provide an unfair view of a single company's performance if no benchmark was used. The closing prices of the index were collected in the same manner as previously described for the stock closing prices.

3.2.4 Company Size (Market Capitalization)

The size of the companies in the sample were collected using a Python script (See Appendix B), co-written with GPT4 utilizing the Financial Modelling Prep API, in order to collect the market capitalization of the sample companies at the end of 2018, 2019, 2020, 2021 and 2022. The size of the companies was accounted for, collected and used, in order to function as a control variable when investigating the relationship between abnormal returns and R&D expenditure ratio.

3.2.5 Sectors

The sector for each company in the sample was collected using Bloomberg Terminal (2023) and were divided into 11 different sectors using the S&P 500 standard: Information Technology, Health Care, Financials, Real Estate, Energy, Materials, Consumer Discretionary, Industrials, Utilities, Consumer Stables and, Communication. The sample includes companies in all sectors matching the selection criteria, but eliminates the

Information Technology (IT) sector as it has been investigated thoroughly in previous studies as previously discussed.

3.2.6 Grouping

In order to divide the companies based on their R&D expenditure ratio. The sampled companies were divided into three groups and sorted annually based on the mean of the sample and the standard deviation of the sample. The number of observations for each group per year can be seen in Table 2 below:

$$\textbf{Low: } x < \mu - \sigma$$

$$\textbf{Medium: } \mu - \sigma \leq x \leq \mu + \sigma$$

$$\textbf{High}: x > \mu + \sigma$$

Year / N-observations	2018	2019	2020	2021	2022
Low	108	107	107	110	104
Medium	273	269	264	269	267
High	113	118	123	115	123

Table 2. Shows the number of observations for each group in the sample for each year.

3.3 Data Analysis

After the data was collected, the data was analyzed using the tools; Microsoft Excel and Jamovi. First, the data was prepared for the study by calculating the abnormal returns in order to get an understanding of the sampled companies performance benchmarked against the market, a method supported by MacKinlay (1997). The research expenditure ratio was then calculated using the collected data in order to get the percentage spent on research and development out of the total operating expenses for the sampled companies.

A correlation analysis was then conducted in order to identify the correlation between variables in the study. Furthermore, a linear regression was used in order to evaluate how good of a predictor R&D expenditure ratio and the control variable, market capitalization, are on abnormal returns. The linear regression was also used to determine the strength of this relationship. A one-way ANOVA analysis was used, which according to Burns & Burns

(2008) allows the study to determine if there are any differences between the means of the groups examined. Lastly, another regression analysis was conducted with an added interaction term in order to assess if the relationship between abnormal returns and R&D expenditure ratio is more prominent in the health care sector in the sample.

3.3.1 Abnormal Returns

Abnormal returns are the difference between the actual return and the expected return of a security. The expected return is calculated using a benchmarking index, in order to gain an understanding of whether the security being examined is performing well compared to the market (MacKinlay, 1997). This provides a more nuanced picture of a stock's actual performance and strengthens the results of the study.

According to MacKinlay (1997), the market model calculating returns is specified:

$$R_{it} = a_i + \beta_i \times R_{mt} + \varepsilon_{it}$$

Where,

R_{it} = Returns on security i at period t.

R_{mt} = Returns on the market portfolio m (benchmark) at period t.

β_i = Sensitivity of the return of the asset (slope).

a_i = Adjusted excess return (intercept).

ε_{it} = Zero mean disturbance term.

Mackinlay (1997) further shows that the abnormal return is then given by the following equation:

$$AR_{it} = R_{it} - a_i - \beta_i \times R_{mt}$$

And for simplicity, the expected return of i security at time t is given by:

$$ER_{it} = a_i + \beta_i \times R_{mt}$$

Which in turn gives the simpler formula:

$$AR_{it} = R_{it} - ER_{it}$$

R_{it} is calculated for each company and year using the following formula

$$R_{it} = \frac{(Closing\ Price\ Year\ N - Closing\ Price\ Year\ N{-}1)}{Closing\ Price\ Year\ N{-}1}$$

R_{mt} follows the same principle using the benchmark's closing prices.

$$R_{mt} = \frac{(Closing\ Price\ Year\ N - Closing\ Price\ Year\ N{-}1)}{Closing\ Price\ Year\ N{-}1}$$

The intercept a_i and slope β_i are calculated for each company using Jamovi with a linear regression with R_{it} as the dependent variable and R_{mt} as the covariate. This is also double checked in Excel using the LINEST function.

3.3.2 Research & Development Expenditure Ratio

The percentage spent (R&D Expenditure Ratio) on research and development of total operating expenses for company i during the period t ($RNDP_{it}$) is calculated by simply dividing R&D expenditure for company i during the period t ($RNDEXP_{it}$) by the total operating expenses for company i during the period t (OE_{it}).

$$RNDP_{it} = \frac{RNDEXP_{it}}{OE_{it}}$$

3.3.3 Correlation Analysis

A correlation analysis is used to see if there is a correlation between the sampled variables (Burns & Burns, 2008). In order to see how strong the relationship is and if there is multicollinearity present in the sample between abnormal returns, research and development expenditure ratio and the control variable, market capitalization a correlation analysis was performed.

A correlation matrix was obtained using the correlation matrix function in Jamovi checking for correlation between AR_{it}, $RNDP_{it}$ and CAP_{it}.

3.3.4 Regression Analysis

A regression analysis is used to see how good the independent variables are in predicting the outcome of the dependent variable and to understand the relationship between the variables (Burns & Burns, 2008). A regression analysis was performed in order to predict the sample companies' abnormal returns based on the percentage each company spent on R&D before, during, and after the COVID-19 pandemic.

A regression analysis was run for each year independently across all years (before, during and after the Covid-19 pandemic) with the AR_{it} as the dependent variable and the $RNDP_{it}$ and CAP_{it} as the covariates in Jamovi. These results were also double-checked in Excel using the TOOL-PAK add-in.

In order to determine if R&D expenditure ratio had a larger effect on companies in the healthcare sector during the pandemic, the sectors were converted into binary form where health care = 1 and non-healthcare companies = 0. The binary variable was then multiplied with $RNDP_{it}$ in order to create an interaction term IT_{it}. The regression was then run with AR_{it} as the dependent variable and $RNDP_{it}$, CAP_{it}, $SECTOR_{i}$ and IT_{it} as the covariates in Jamovi.

3.3.5 One-Way ANOVA

A one-way ANOVA is used when you want to compare the means of groups. The test can be used to test hypotheses about differences among group means in order to see if one group's mean is different (Burns & Burns, 2008). In order to determine if there is a difference between companies with low, medium, and high R&D expenditure ratio, a One-way ANOVA test is performed using Jamovi for each year, 2018, 2019, 2020, 2021, and 2022.

3.4 Validity & Reliability

The study strived to achieve a high level of validity and used data from only reputable sources to ensure the data was correct. To improve and avoid issues causing a lower validity and reliability, the authors of this paper sought out the usual pitfalls for these types of study and brought them into consideration. The authors have tried to clearly define the aspects of the study to ensure they align with their intended purposes. Measurement validity applies primarily to quantitative research and essentially means if the collected data really measures what it is intended to explain (Bryman & Bell, 2019). Control variables, potential biases, sampling techniques, and statistical analysis methods were early discussed in relation to the gathering and usage of secondary data.

External validity controls were made to ensure the secondary data was one of transparency and availability to improve the replicability of the study. These controls were made by identifying the most credible source of secondary data available, the Bloomberg Terminal (2023) was deemed the most credible and therefore used to gather the secondary data. According to Bloomberg (2023), Bloomberg Terminal has remained at the cutting edge of innovation and information delivery for over four decades. Due to the limitations of the Bloomberg Terminal licenses at Lund University. Financial Modelling Prep's (FMP) paid API

was deemed of good credibility and therefore used to collect remaining data points, since FMP also offers reliable historical stock and financial data (Financial Modelling Prep, 2023).

Using stock prices as a measurement of company performance does not either come without its own pitfalls, as the stock market performance is the perceived future potential by the market. A company that is losing money can still be seeing higher stock-market returns than a company consistently being profitable if the market sees future potential in the firm. The use of abnormal returns which includes the use of a benchmark index can help researchers take market conditions into account (MacKinlay, 1970).

The external validity of the paper refers to the generalizability of the results and assessing the generalizability of the study findings beyond the specific sample and context used (Burns & Burns, 2008). This includes discussing the relevance of the findings to the broader population or similar settings, as well as potential limitations in generalizability, which increases the external validity, according to authors Bryman & Bell (2019). The authors of this paper used these lessons when discussing the external validity of the findings by addressing the limitations and potential generalizability of the study in order to increase external validity and to decrease potential researcher bias.

A study cannot be externally valid unless it has internal validity. The internal validity extends to which the findings are valid within the parameters of the study (Burns & Burns, 2008). Additionally, research rigor, such as control variables to minimize errors and causal inference, can be taken into account when conducting the analysis and data collection to ensure higher internal validity for the findings (Bryman & Bell, 2019). To increase the internal validity, the authors of the paper have researched and taken this into account when testing and establishing the methods used in the study. This consideration led to the inclusion of control variables in the analysis to address potential confounding factors and may enhance internal validity. This helps isolate the effects of the variables of interest and strengthens the causal inferences that can be drawn (Burns & Burns, 2008). In this study market capitalization (company size) was selected as a control variable.

In the context of studying companies' responses to the COVID-19 pandemic. Biases can influence the findings as they may exclude companies that were unable to adapt or sustain their operations during the crisis. It is important to be aware of potential biases and consider their implications when interpreting the results of the study (Burns & Burns, 2008). As previously discussed, survivor's bias was introduced to the sample, which refers to the phenomenon where the analysis or research is biased toward the entities that have survived or remained active while excluding those that have ceased to exist or dropped out of the sample (Brown et al., 1992).

Reliability helps guide the authors to answer the question of whether the results of the study are repeatable or not. One way to assess a research method's reliability is to evaluate if the obtained data can be consistently obtained in future testing (Bryman & Bell, 2019). Data collected in this study is publicly available as the sampled companies are publicly traded companies. This means that as long as laws stay consistent in the future about the obligation of publicly traded companies to report their financials to the SEC. Through the usage of similar methods for data collection and analysis, this study could be repeatable in the future as new data becomes publicly available. Increasing the potential replicability and reproducibility of the study and allowing for future researchers to build on the shortcomings of prior studies, boosting the reliability of the findings (Bryman & Bell, 2019).

3.5 Limitations

As previously discussed there are limitations to using research and development expenditure in a quantitative research study. As Reeb (2017) argues, managers do not always report expenditures in the same manner, an unavoidable limitation to the study. For example, if an employee is using 70% of his time on research and development and 30% of his time on maintenance, it is difficult for managers to accurately report this, especially in firms with many employees.

Further limitations are that not all companies report their research and development expenditure for competitive reasons (Reeb, 2017), which potentially skews the results of the analysis and might not give a totally accurate representation of all sectors. Some sectors are

also underrepresented in the study, with the majority of the sample being in the healthcare sector, which further limits the insight into some of the sampled market sectors.

The study is also using stock prices in order to measure performance. As stock prices are a measurement of market expectations, they might not fully represent how a company is performing at the moment but rather how they are expected to perform in the future. These expectations can be influenced by various external noises that are not considered in the study, which can also influence the results. The sample is limited to U.S. companies listed on U.S. stock exchanges. The selection criteria also introduce bias, as previously discussed.

4. Results & Discussion

In this chapter, the results of the empirical data collection are presented in order to answer the research question. The findings of this study are divided into three parts based on the hypothesis. Firstly the results from the regression analysis and correlation analysis are presented. Secondly the results of the One-way ANOVA are presented, and thirdly the results of the regression analysis including the interaction term for the healthcare sector are presented.

4.1 Research & Development Relationship

The paper's first hypothesis: *There is a positive relationship between abnormal returns and research and development expenditure ratio before, during, and after the COVID-19 pandemic and abnormal returns.*

Year	Variable	Estimate	Std, Error	t-value	p-value	R	R^2	Adjusted R^2	F	p-value for F
2018	Intercept	0,132	0,051	2,608	0,009	0,091	0,008	0,004	2,060	0,128
	R&D Expenditure Ratio 2018	-0,211	0,105	-2,010	0,045					
	Market Cap 2018	2,00E-11	5,38E-12	0,373	0,709					
2019	Intercept	-0,150	0,122	-1,230	0,219	0,091	0,008	0,004	2,060	0,129
	R&D Expenditure Ratio 2019	0,028	0,254	0,111	0,912					
	Market Cap 2019	2,03E-11	1,01E-11	2,013	0,045					
2020	Intercept	0,186	0,144	1,290	0,198	0,096	0,009	0,005	2,260	0,105
	R&D Expenditure Ratio 2020	0,308	0,305	1,010	0,314					
	Market Cap 2020	4,08E-11	2,26E-11	1,810	0,071					
2021	Intercept	-0,365	0,128	-2,850	0,005	0,259	0,067	0,063	17,700	<0,001
	R&D Expenditure Ratio 2021	-0,258	0,257	-1,000	0,316					
	Market Cap 2021	1,89E-10	3,26E-11	5,8	<0,001					
2022	Intercept	-0,063	0,044	-1,434	0,152	0,061	0,004	0,000	0,911	0,403
	R&D Expenditure Ratio 2022	0,116	0,088	1,313	0,190					
	Market Cap 2022	-3,67E-12	2,09E-11	-0,176	0,861					

Table 3. Shows the results of the annual regression analyses.

Table 3 presents the results of the annual regression analyses conducted on abnormal returns on R&D expenditure ratio and the control variable, market capitalization (market cap). It shows the results before (2018), during (2019, 2020, and 2021), and after (2022) the COVID-19 pandemic. The coefficient is the estimated change in abnormal returns for a one-unit increase in the corresponding variable with all other variables constant. The standard errors (SE) are presented in the parentheses below the coefficients. The p-values test the null-hypothesis that the coefficients are zero. The t-value is the ratio of the coefficient to its standard error, indicating the statistical significance. R-squared represents the proportion of the variance in abnormal returns that are explained by R&D expenditure ratio and market

capitalization. Adjusted R-squared adjusts the R-squared value based on the number of predictions in the model, and the F-statistic tests the overall significance of the model.

Correlation Matrix

Correlation Matrix

		Abnormal Returns	R&D Exp Ratio	Cap
Abnormal Returns 2018	Pearson's r	—		
	p-value	—		
R&D Exp Ratio 2018	Pearson's r	-0.090 *	—	
	p-value	0.046	—	
Cap 2018	Pearson's r	0.013	0.038	—
	p-value	0.767	0.398	—
Abnormal Returns 2019	Pearson's r	—		
	p-value	—		
R&D Exp Ratio 2019	Pearson's r	0.013	—	
	p-value	0.773	—	
CAP 2019	Pearson's r	0.091 *	0.074	—
	p-value	0.043	0.101	—
Abnormal Returns 2020	Pearson's r	—		
	p-value	—		
R&D Exp Ratio 2020	Pearson's r	0.050	—	
	p-value	0.263	—	
Cap 2020	Pearson's r	0.084	0.061	—
	p-value	0.062	0.177	—
Abnormal Returns 2021	Pearson's r	—		
	p-value	—		
R&D Exp Ratio 2021	Pearson's r	-0.057	—	
	p-value	0.208	—	
CAP 2021	Pearson's r	0.256 ***	-0.051	—
	p-value	< .001	0.257	—
Abnormal Returns 2022	Pearson's r	—		
	p-value	—		
R&D Exp Ratio 2022	Pearson's r	0.060	—	
	p-value	0.181	—	
Cap 2022	Pearson's r	-0.014	-0.101 *	—
	p-value	0.757	0.024	—

Note. * p < .05, ** p < .01, *** p < .001

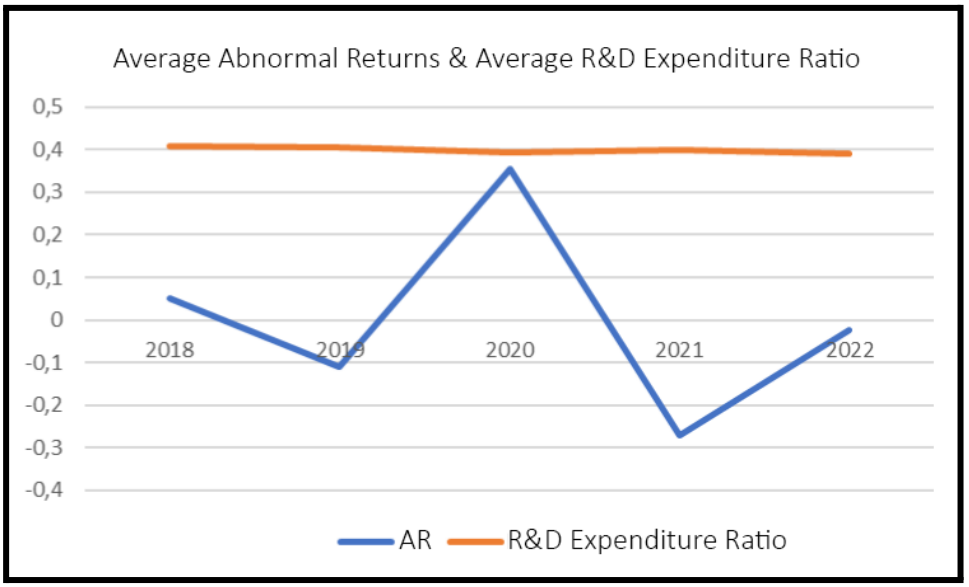
Table 4. Shows the Correlation Matrix for Abnormal Returns, R&D Expenditure Ratio & Market Cap for each year.

The results presented in Table 4 suggest that the relationship between R&D expenditure ratio, market capitalization, and abnormal returns varies year by year. In 2018, R&D expenditure ratio had a statistically significant relationship with abnormal returns and market cap had a statistically significant relationship in 2019 and 2021. In the other years examined in this study, neither variable was statistically significant for abnormal returns. This can also be seen

in Table 4, the Correlation Matrix, that there is a statistically significant negative correlation in 2018 between Abnormal Returns and R&D Expenditure Ratio. Table 4 also shows a positive correlation in 2019 and 2021 between abnormal returns and market capitalization. Furthermore, table 4 shows statistically significant negative correlation between R&D expenditure ratio and market capitalization in 2022 suggesting some collinearity in the sample. The overall explanatory power of the regression analysis, as seen by the R-squared and adjusted R-squared values, is relatively low in all years, suggesting that the model's overall fit could be improved.

YEAR	Average Abnormal Returns	Average R&D Expenditure Ratio
2018	0,051	0,409
2019	-0,111	0,405
2020	0,356	0,393
2021	-0,272	0,398
2022	-0,023	0,389

Table 5. Shows the average abnormal returns and R&D expenditure ratio for 2018-2022.



Graph 1. Visualizes the average abnormal returns and the average R&D expenditure ratio for 2018-2022.

Graph 1 visualizes Table 5 in order to provide a visual overview of the average abnormal returns and average R&D expenditure ratio, for each of the years examined in the study.

4.1.1 Before COVID-19

We could identify the following when analyzing SMC companies' investments in innovation before the COVID-19 pandemic crisis during the year 2018. In 2018, the R&D expenditure ratio had a significant negative relationship with abnormal returns (p=0.045). Market cap had no significant relationship with abnormal returns (p=0.709). Lastly, the overall model was not statistically significant (p=0.128).

The regression analysis findings in 2018 show that investments made into innovation had a significant negative relationship with abnormal returns, with a coefficient of -0.211, meaning that a 1% increase in R&D investments would decrease abnormal returns of 0.211 units. According to Rajapathirana & Hui (2018), an increase in innovation capabilities should generate higher performance. However, the results find that an increase in R&D spending does not translate to higher performance. The findings also found no statistically significant relationship between market capitalization (company size) in 2018, suggesting that the size of the company did not affect its market performance before the pandemic.

The study does not take into account how the money is spent, it shows that in 2018, R&D investments were not an easy way to increase innovation and enhance the company's performance. Since innovation can be seen as both tangible and intangible. Innovation can be used to create long-term economic growth, which might not reflect the short-term cost of investment (Rubera & Kirca, 2012). This leaves room for these increased efforts towards innovation to not directly impact economic performance due to their inherent states as both tangible and intangible (Rubera & Kirca, 2012; Porter, 1990).

However, the potential upside and downside of these investments should be, in accordance with the efficient market hypothesis by Fama (1970), immediately reflected upon in the stock prices, which would eliminate the lag of the investments. The meta-analytic review by Damanpour (2014) bolsters these findings by shedding light on the possibility that innovation might also affect other aspects of a company than solely economic performance, perhaps instead strengthening their adaptability instead of creating short-term economic gain.

The findings would indicate that in 2018, spending more money on innovation would decrease the company's market performance providing valuable insight to managers of the risk of over-investing in innovation, as also mentioned by authors Chen et al., (2019). This decrease doesn't necessarily mean that the company is investing poorly since authors Miocevic et al., (2021) and Ombi (2018) shed light on the fact that innovation can still strengthen performance, for example, increase a company's resource base, which in turn might make the investment more profitable in the long term. Although this decrease in market performance and instead long-term profitability should be reflected directly in stock pricing, according to the effect of the efficient market hypothesis since all company actions should immediately affect stock pricing (Fama, 1970).

The results showed that investments made into innovation, in terms of R&D, had a statistically significant negative relationship with abnormal returns, meaning that an increase in R&D investments would result in lower market performance in 2018. However, it is worth noting that the limitations of the model introduce a degree of uncertainty around these findings. Therefore these negative performances caused by innovation investments add insight and contrast to the notion that innovation efforts should lead to increased economic performance, discussed by Whelan & Fink (2016) and Shin et al., (2022). It's also worth mentioning that these innovation investments could be made in both tangibles and intangibles (Rubera & Kirca, 2012), which in turn might make it more difficult for the market to directly observe and account for these investments in relation to stock pricing according to the efficient market hypothesis.

4.1.2 Entering COVID-19

We could identify the following when analyzing SMCs investments in innovation entering the COVID-19 pandemic crisis during the year 2019. In 2019, the market cap did have a statistically significant positive relationship with abnormal returns ($p<0.001$), while R&D expenditure ratio did not have a statistically significant relationship with abnormal returns at the $p<0.05$ level and the overall model was not statistically significant ($p=0.129$).

In 2019 the results found that there is no statistically significant relationship between investments made into R&D and abnormal returns. According to Ratten (2020) and Ratten & Jones (2021), innovation is very important during crises to achieve company success, but the findings show that at least increasing investments in innovation does not automatically equal greater economic performance.

The findings also highlight the importance of implementing and utilizing a robust risk assessment strategy and approach, as also found and discussed by authors H, Berglund (2007) and Shaik & Dhir (2021). The authors promote the managerial and organizational need for current and structured risk management strategies to preserve the company's economic growth, seemingly supported by the study's findings. Furthermore, a statistically significant relationship was found that indicates that a larger market capitalization allowed for larger abnormal returns, although a very weak relationship, than the abnormal returns of companies with a smaller market capitalization. This is probably due to the companies with larger market capitalization having bigger availability and access to resources than their smaller counterparts. This strengthens the argument that conserving resources during prolonged crises is desirable for SMCs, as Prorokowski (2014) argues. This can also be seen to be accurate when looking at the findings from 2019, where the companies with a smaller market capitalization, who have more limited access to funds, performed worse in 2019 than those with a higher market capitalization.

4.1.3 During COVID-19

In 2020, R&D expenditure ratio had no statistically significant relationship with abnormal returns ($p=0.314$) and market capitalization had no statistically significant impact on abnormal returns ($p=0.071$). Furthermore, the overall model was not statistically significant ($p=0.105$). We could identify the following when analyzing SMC companies' investments in innovation during the COVID-19 pandemic crisis during the year 2020:

The findings indicate that rolling back expenses and innovation investments, and possibly instead, focus on observing the market for the next accurate step might have been the best approach for SMCs entering the pandemic. Doing this would allow the companies to preserve

resources and avoid expenditures on failed innovations, a vital aspect of risk and crisis management (Chen et al., 2019). These findings could be seen across all the included sectors. They could provide valuable additions to the EU study by Marques Santos et al., (2021), which promotes increased innovation efforts to survive crises.

In 2020 the results found that there is no statistically significant relationship between investment expenditure ratio, market capitalization and abnormal returns. According to Seggra-Ciprés (2018), innovation is imperative during crises. However, the findings show that at least increasing investment expenditure ratio does not automatically equal greater economic performance when looking at abnormal returns.

4.1.4 Exiting COVID-19

We could identify the following when analyzing SMC companies' investments in innovation exiting the COVID-19 crisis during the year 2021. In 2021, the market cap also had a statistically significant positive relationship with abnormal returns ($p<0.001$), while R&D expenditure ratio still did not have a statistically significant relationship with abnormal returns ($p=0.316$). The overall model was statistically significant ($p<0.001$).

In 2021 the results indicated that innovation investments don't have a statistically significant impact on abnormal returns. The findings indicate that, instead, rolling back expenses and observing the market for the next accurate step might have been the best approach for SMCs exiting the pandemic. Doing this would allow the companies to have preserved their limited resources and avoid expenditures on failed innovations, a vital aspect of risk and crisis management (Chen et al., 2019). These findings could be seen across all the included sectors, which adds context to the EU report from Marques Santos et al., (2021), which promotes innovation efforts in order to survive crises.

As discussed by H, Berglund (2007) and Shaik & Dhir (2021) it is important to implement and utilize a robust risk assessment strategy and approach. They further promote the managerial and organizational need for current and structured risk management strategies to be used to preserve the company's economic growth. Drawing on the above-mentioned

insights mentioned by the authors and the study's findings, SMCs could enhance their risk management capabilities and more effectively respond to extreme or more dynamic challenges and uncertainties that may impact their economic performance during a crisis. This would allow companies to manage and allocate resources more successfully in order to reach a desired level of economic performance.

4.1.5 After COVID-19

The data from 2022, after COVID-19, indicated that there was no statistically significant relationship between R&D expenditure ratio and abnormal returns at the $p<0.05$ level, nor between market capitalization and abnormal returns. The model had no statistical significance ($p=0.403$). This suggests that, within the scope of the study, the amount of R&D investment and the market capitalization of the companies did not significantly impact abnormal returns. These findings may imply that other factors, beyond R&D expenditure ratio and market capitalization, are more dominant in driving abnormal returns in the examined context.

4.1.6 Primary findings

Looking at the companies that increased their innovation efforts during the duration of the pandemic to remain ahead of the competition, it could be identified that they instead gained no extra economic benefits from these increases in innovation investments compared to their competitors, who instead used a more sparing investment approach. The results even found a negative, statistically significant relationship in 2018.

Additionally, the size of the sampled companies did only show a very small statistically significant effect in 2019 and 2021. It did not appear to significantly affect the results in the other examined years. As size grants different company strengths, companies can utilize these different strengths to stay competitive and maintain market positioning (Santoro et al., 2021). Arguably then, is the fact that companies regardless of size who chose to be more careful with their spending and investments in innovation, could probably weather the COVID-19 pandemic crisis better than their more investment-heavy counterparts. A finding that could be seen also supported by authors A, Berglund (2007), Danneels (2004) and Dillerup et al., (2018) who argue that a more balanced and effective approach to leveraging investments in

innovation can lead to higher long-term success. A finding that could potentially help SMCs to avoid harsher economic consequences from overly ambitious innovation efforts and investments.

Furthermore, the findings adds valuable input to the idea of innovation as the holy grail of economic growth and performance, as depicted by Rajapathirana & Hui (2018) and the typical view that innovation is one of the primary tools for solving a crisis (Filippetti, 2011) when looking at economic performance amongst SMCs.

Finally, it is important to consider the context of the study conducted, as the COVID-19 pandemic presented unique challenges unlike previous economic crises like the 1997 and 2008 economic crises and also had a significant impact on global markets and overall potential economic performance (Worldbank, 2022). The role of investments in R&D during the COVID-19 pandemic can be inferred that companies prioritizing R&D were instead potentially making strategic investments to enhance their long-term competitiveness. However, the results of the study show that this was not reflected in the market. Therefore, further research is needed to understand how investing in innovation has evolved in response to the pandemic and its aftermath, as there seem to be other factors beyond R&D expenditure ratio and market capitalization that play a more significant role in driving abnormal returns in the sample.

4.2 Level of R&D Expenditure Ratio

The paper's second hypothesis: *The group of companies with high research and development expenditure ratio will generate higher abnormal returns than the other groups with low and medium research and development expenditure ratio during times of crisis.*

Year	R&D Expenditure Ratio	Sample Size (N)	Mean	Standard Deviation (SD)	Standard Error (SE)
2018	Low	108	0,043	0,370	0,036
	Medium	273	0,071	0,684	0,041
	High	113	-0,003	0,558	0,053
2019	Low	107	-0,030	0,739	0,072
	Medium	269	-0,162	0,859	0,052
	High	118	-0,068	2,621	0,241
2020	Low	107	0,231	1,070	0,104
	Medium	264	0,389	1,570	0,097
	High	123	0,400	2,320	0,209
2021	Low	110	-0,197	0,719	0,069
	Medium	269	-0,248	1,918	0,117
	High	115	-0,409	0,967	0,090
2022	Low	104	-0,012	0,286	0,028
	Medium	267	-0,050	0,622	0,038
	High	123	0,036	0,331	0,030

Table 6. Shows the descriptive statistics for the three groups of R&D expenditure ratio (low, medium and high) for the years 2018 to 2022.

The paper's second hypothesis aimed to look into how companies with high R&D expenditure ratios during a crisis performed with the assumption that these types of companies would outperform companies with lower R&D expenditure ratio. This was done by dividing them into three expenditure ratio groups in order to isolate if different expenditure ratios yielded different economic outcomes.

Source of Variation	F-Statistic	Df1	Df2	p-value
R&D Expenditure Ratio Groups 2018	0.615	2	267	0.541
R&D Expenditure Ratio Groups 2019	1.13	2	210	0.324
R&D Expenditure Ratio Groups 2020	0.689	2	246	0.503
R&D Expenditure Ratio Groups 2021	1.77	2	299	0.172
R& Expenditure Ratio Groups 2022	1.68	2	298	0.189

Table 7. Shows the results of the One-way ANOVA for each year.

The results of the one-way ANOVA test shown in Table 7, suggest that there is no statistically significant difference in abnormal returns across the three levels of R&D expenditure ratio in the sample. For all the observed years, the p-values indicated no statistical significance above the 0.05 significance level. The findings for each year consistently indicate that there are no statistical differences between the low, medium, and high R&D expenditure ratio groups with abnormal returns. The results suggest that companies with high R&D expenditure ratio would not perform better than those with lower R&D expenditure ratio during the COVID-19 pandemic.

4.2.1 Primary Findings

A similar result, as found in hypothesis 1, could be identified when analyzing the result from the three different R&D expenditure ratio groups. The findings across all expenditure ratio groups do not support the hypothesis that companies with high R&D expenditure ratio during a crisis would outperform companies with lower R&D expenditure ratio, as suggested by Marques Santos et al., (2021) and Damanpour (2014). In each of the years analyzed (2019, 2020, 2021, and 2022), R&D expenditure ratio showed no statistically significant relationship with abnormal returns. The findings suggest that the relationship between R&D expenditure ratio and financial performance is more complex and that other factors influence the results.

Furthermore, the overall model was not statistically significant, indicating that the combined effect over the years of R&D expenditure ratio did not significantly impact abnormal returns.

These results suggest that the assumption underlying the hypothesis, which posited that companies with high R&D expenditure ratio would perform better during a crisis, did not hold true during the pandemic. Giving managers the perspective that monetary investments in innovation do not translate to the academic advice to innovate in order to weather a crisis which is argued by authors Pece et al., (2015) and also the EU report from Marques Santos et al., (2021).

Furthermore, the analysis of data from the COVID-19 years does not support the notion that companies with high R&D expenditure ratio outperformed those with lower R&D expenditure ratio during the crisis. The findings suggest that the benefits of R&D investments may be more nuanced and context-dependent than previously assumed, especially in times of unprecedented challenges, as discussed by authors A, Berglund, (2007), Danneels (2004) and Chen et al., (2019). The ability to adapt, manage risks, and swiftly respond to changing market conditions might emerge as critical factors for success during the COVID-19 pandemic. To gain deeper insights into these relationships, further research might be needed to explore the complex dynamics between R&D expenditure ratio, company performance, and crisis situations.

4.3 The Healthcare Sector & Level of R&D Expenditure Ratio

The paper's third hypothesis: *The healthcare sector's performance is more dependent on research and development expenditure ratio than the rest of the sample.*

Year	Variable	Estimate	Std. Error	t-value	p-value	R	R^2	Adjusted R^2	F	p-value for F
2018	Intercept	0,003	0,093	0,035	0,972	0,124	0,015	0,007	1,910	0,107
	R&D Expenditure Ratio 2018	0,149	0,386	0,387	0,699					
	Market Cap 2018	1,92e−12	5,37e−12	0,357	0,721					
	Interaction Term 2018 (R&D exp r * Healthcare)	-0,489	0,406	-1,204	0,229					
	Sector (Healthcare=1, Other Sectors=0)	0,211	0,116	1,827	0,068					
2019	Intercept	0,026	0,227	0,116	0,908	0,105	0,011	0,003	1,360	0,248
	R&D Expenditure Ratio 2019	-1,082	1,006	-1,075	0,283					
	Market Cap 2019	2,00E-11	1,01E-11	1,988	0,047					
	Interaction Term 2019 (R&D exp r * Healthcare)	1,165	1,052	1,108	0,268					
	Sector (Healthcare=1, Other Sectors=0)	-0,193	0,281	-0,685	0,493					
2020	Intercept	0,019	0,192	0,101	0,920	0,137	0,019	0,011	2,310	0,057
	R&D Expenditure Ratio 2020	0,334	0,306	1,093	0,275					
	Market Cap 2020	4,08E-11	2,26E-11	1,806	0,072					
	Interaction Term 2020 (R&D exp r * Healthcare)	0,656	0,367	1,787	0,075					
	Sector (Healthcare=1, Other Sectors=0)	-0,094	0,247	-0,382	0,702					
2021	Intercept	-0,391	0,227	-1,724	0,085	0,262	0,069	0,061	9,000	<,001
	R&D Expenditure Ratio 2021	-0,575	1,011	-0,569	0,570					
	Market Cap 2021	1,91E-10	3,27E-11	5,842	<,001					
	Interaction Term 2021 (R&D exp r * Healthcare)	0,217	1,058	0,205	0,838					
	Sector (Healthcare=1, Other Sectors=0)	0,100	0,278	0,359	0,720					
2022	Intercept	0,021	0,077	0,269	0,788	0,086	0,007	-0,001	0,908	0,459
	R&D Expenditure Ratio 2022	-0,204	0,337	-0,607	0,544					
	Market Cap 2022	-5,76e−12	2,10E-11	-0,274	0,785					
	Interaction Term 2022 (R&D exp r * Healthcare)	0,391	0,352	1,110	0,268					
	Sector (Healthcare=1, Other Sectors=0)	-0,125	0,093	-1,340	0,181					

*Table 8. Shows the results of the linear regression using the interaction term R&D expenditure ratio * the sector (binary 1 or 0).*

The analysis conducted on the dataset, as shown in the above table 8, aimed to evaluate the relationship between R&D expenditure ratio and company performance during the COVID-19 years across various industries. The point of interest was to determine if the healthcare sector demonstrated a higher dependence on R&D investments compared to the other sectors since the crisis was one of public health origin rather than purely economical, like the 1997 and 2008 crisis.

To account for this, the data was carefully scrutinized and specifically analyzed to try and identify and validate any significant differences in the healthcare sector compared to the rest

of the sectors in the data sample. The analysis of the data from the sample was found not to support the notion that the healthcare sector is more dependent on R&D expenditure ratio compared to other sectors. Marques Santos et al., (2021) state that sectors with heavier innovation needs will be more negatively affected than less innovation-heavy sectors. This, however, does not translate to investments in innovation in the sampled companies.

The results of the analysis failed to reject the hypothesis that the healthcare sector is more dependent on R&D expenditure ratio than the other sectors in the sample. This implies that the data did not provide sufficient evidence to support the claim that the healthcare sector exhibits a greater reliance on R&D investments compared to other sectors, such as technology, manufacturing, or services. Authors Perel (2002) and Țîțu et al., (2015) argue that companies with greater innovation efforts should perform better than companies with lower innovation efforts.

4.3.1 Primary Findings

The healthcare sector is often regarded as a critical domain for innovation due to its direct impact on public health and well-being. Given the sector's unique characteristics and the importance of advancements in medical technology and treatments, it is commonly assumed, as also depicted in the EU report from Marques Santos et al., (2021), that the healthcare industry would be more dependent on investments in innovation. The data in this study does not support the hypothesis that the healthcare sector specifically would be more dependent on innovation investments than other sectors. But in the face of a global pandemic, the possibility to share knowledge and resources might have aided the healthcare sector more than other sectors, as also discussed by Ombi (2018), who sheds light on the need for external support for SMCs in crisis to reach a desired economic performance. A potential cause to the finding that the healthcare sector did not experience any significant needs than other sectors.

The healthcare sector, however, was also the sector with the highest number of challenges during the crisis, according to the EU-supported report by the authors Marques Santos et al., (2021). In the report, they proclaimed that sectors with heavy investments in R&D and face-to-face interactions would be impacted the most by the pandemic. The data in this study

does not support the hypothesis that the healthcare sector specifically would be more dependent on R&D investments than other sectors. By recognizing the need to share knowledge of the healthcare sector to save lives instead of pure profit focus, the sector could possibly have utilized knowledge sharing similar to open innovation as Chesbrough (2003) recommended to ensure desirable economic performance.

Furthermore, the healthcare sector encompasses a wide range of organizations, including pharmaceutical companies, medical device manufacturers, healthcare providers, and biotechnology firms. Each of these sub-sectors may have higher variation degrees of reliance on R&D investments than other sectors, influencing the result. For instance, pharmaceutical companies often allocate significant resources towards innovation, such as research and clinical trials. While healthcare providers instead prioritizes investing in innovation to increase their potential operational efficiency and patient care rather than extensive and expensive R&D activities.

5. Conclusion

This final chapter presents the conclusion of the research and looks into whether the intended aim was met and the research question was answered. Research purpose and objective follows. Finally the chapter will also address the theoretical and managerial contributions, as well as reflect on the study limitations and discuss future research.

5.1 Research Aim

Companies faced unique challenges due to the pandemic's extraordinary disruptions to successfully navigate these challenging times, SMCs had to modify their innovation strategies and processes(Albertoni & Wise, 2021; Marques Santos et al., 2021). This study aimed to contribute to the existing body of knowledge on the relationship between innovation and performance in SMCs and provide insights into the unique challenges and opportunities faced during the COVID-19 pandemic. The study also aimed to offer practical implications for firms aiming to enhance their innovation strategies and overall performance in turbulent times. Innovation may not always be as beneficial as it is frequently portrayed to be, and it may even negatively impact a company's financial performance if implemented incorrectly (Beck et al., 2016; Nechaev et al., 2017; Namky, 2022).

The study sought to provide a more comprehensive understanding of the relationship between innovation investments and performance in SMCs across different U.S. industries and how this relationship was affected by COVID-19. The authors of the paper aimed to identify whether an optimal level of innovation exists and whether being highly innovative was universally desirable across all sectors during times of crisis. The study utilized the following research question; **"***Is there a relationship between innovation and abnormal returns in SMCs across different industries publicly traded on U.S. exchanges before, during, and after the COVID-19 pandemic, and was there an optimal level of innovation related to performance?"* to create and test the paper's hypotheses and add to the above-mentioned body of knowledge.

5.2 Research Purpose & Objective

This study aimed to analyze how investments made into innovation could affect the economic performance of U.S. SMCs with less than $2B market cap listed on U.S. markets before, during, and after the COVID-19 pandemic. The study aimed to gain insights into how these innovation investments influenced the companies' performance in the face of the unique and unprecedented challenges brought about by the pandemic. The study was conducted by utilizing historical stock closing prices and financial statements of 500 companies that matched the selection criteria and met the control points. In the study, there were three hypotheses developed that the methodology aimed to answer. The study aimed to investigate these three hypotheses by analyzing the data collected. The results were then discussed using relevant theory and were compared to previous research on investments in innovation and company performance.

H1: *There is a positive relationship between abnormal returns and research and development expenditure ratio before, during, and after the Covid-19 pandemic and abnormal returns.* This hypothesis tested how good of a predictor R&D expenditure is for abnormal returns. The testing of this hypothesis showed that the sampled companies gained no extra economic benefits or downsides from higher investments in innovation during the crisis. However, as the higher investments did not yield any statistically significant increase in abnormal returns the money could be better spent elsewhere.

H2: *The group of companies with high research and development expenditure ratio will generate higher abnormal returns than the other groups with low and medium research and development expenditure ratio during times of crisis.* This hypothesis was tested by dividing the company sample into 3 groups based on their R&D expenditure ratio to see if there is any difference between the group's abnormal returns during the challenging period of the COVID-19 pandemic. The testing of this hypothesis showed that there were no differences between the 3 groups (low, medium and high levels of R&D expenditure ratio). Suggesting that the group with higher expenditure did not perform better than the other sampled groups during the crises.

H3: *The healthcare sector's performance is more dependent on research and development expenditure ratio than the rest of the sample.* This hypothesis tested whether the healthcare sector, due to its inherent reliance on innovation and R&D, would experience greater performance benefits from increased investments in R&D compared to other sectors. The testing of this hypothesis showed that the sector did not experience any statistically significant benefits from increasing their innovation investments compared to the other sampled sectors.

The study used statistical analysis and relevant theories to examine the connection between innovation investments and economic performance. The analysis's conclusions were then contrasted with those of earlier studies on innovation and company economic performance, allowing for a thorough discussion of the findings and their congruence with pre-existing theoretical viewpoints. The study sought to further the understanding of how innovation investments may affect the success of small and medium-sized U.S. businesses, particularly in light of the COVID-19 pandemic, by addressing the above-mentioned hypotheses.

5.3 Practical Implications & Theoretical Contributions

The study results have significant ramifications for both theoretical comprehension and decision-making in innovation management strategies and investment. The findings cast doubt on the idea that greater investments in research and development (R&D) should result in greater innovation capabilities, which should inevitably result in better market performance for SMCs. The results do not support the notion that higher investments in innovation lead to significantly different performance outcomes within the sampled companies.

Theoretically, this study adds to the field by expanding the body of knowledge about the relationship between R&D expenditures, innovation capacity, and financial performance. According to the findings, there is no statistically significant link between abnormal returns and the amount of R&D done before, during, or after the COVID-19 pandemic. However, a statistically significant negative link was found in 2018; this finding suggests that the effect of innovation investments on market performance may change with time. Suggesting that investments made into innovation do not necessarily translate to better market performance.

Elegantly supported by the late Steve Jobs (1998), who said, "*Innovation has nothing to do with how many R&D dollars you have. When Apple came up with the Mac, IBM was spending at least 100 times more on R&D. It's not about money. It's about the people you have, how you're led, and how much you get it."*.

Furthermore, the results suggest that there are no statistically significant differences between the low, medium, and high R&D expenditure ratio groups within the sample. Considering the findings' practical ramifications, SMCs should carefully assess how they should both increase their R&D investments and distribute their innovation efforts in dynamic or competitive markets.

Finally, since the crisis, COVID-19 was primarily one of public health. The authors of the paper were interested to see if innovation investment made into R&D in the healthcare sector differed from other sectors, due to this sector being extra important in this crisis. The findings for the healthcare sector did not reveal a statistical significance from the other sectors. The finding shows that the healthcare sector would not benefit more from increased R&D investments compared to other sectors. The data examined in the study did not find any statistically significant support of the notion that the healthcare sector would benefit to a greater extent than other sectors from a higher R&D expenditure ratio. This suggests that managers in the healthcare sector should not solely rely on increased investment in innovation as a means to achieve better market economic performance in a crisis. The study's results also indicate that there is no inherent risk for managers to over-invest in innovation but no inherent benefit of spending more. However, it's important to remember that the external support that was given to this sector might influence the findings.

The practical implications of this study extend to managers, policymakers, and industry stakeholders who can benefit from the insights provided. Furthering the understanding of the complex relationship between innovation investments, market performance, and the specific context of crises, such as the COVID-19 pandemic. This can help inform and improve companies' decision-making processes regarding innovation strategies during challenging times.

5.4 Limitations & Future Research

The paper discusses the flaws of using R&D expenditure ratio as a metric for innovation and how abnormal returns can be used to mitigate some of these flaws. It further discusses how the sample criteria have introduced bias to the sample and why this criterion was set in place. Only companies that were still trading as of 2023, with complete historical stock prices and financial statements, are included in the sample. The study does, for example, not include companies that delisted, merged, or went bankrupt during the sampled period. It also discusses the flaws of the performed statistical analysis and why it is important to interpret the results of the analysis with caution.

The result discussion presents how theory and previous studies made within the context of innovation and performance compare to the findings in this paper and find contributions to the managerial perspective. However, these could be due to the previously discussed skewness of the sampled companies promoting the need for additional research or varying sample sizes and markets. The paper also acknowledges potential limitations in the statistical analysis performed. It emphasizes the importance of interpreting the results with caution, recognizing the potential for confounding variables and other factors that may influence the relationship between innovation investments in R&D and economic performance.

Innovation moves companies forward regardless of increased market performance or not, and has taken us to where we are today. It would be encouraged for further research on this topic to increase the sample size, include other markets than the U.S. and to improve on the statistical models used in examining the relationship. Another potential direction for future research is improving the statistical models used in examining the relationship between innovation and performance. This could involve utilizing more advanced econometric techniques or exploring alternative methodologies to better understand the relationship.

Finally, investigating the relationship between innovation and performance in conjunction with other mediators or factors could provide additional insights. Exploring the moderating role of organizational culture or the influence of external factors such as industry and market

dynamics influence on the innovation-performance relationship, could contribute to a more comprehensive understanding of the topic.

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7. Appendix

Appendix A

```
import requests
import pandas as pd
import time

def get_stock_price(ticker, api_key, date):
                                                                    url                 =
f"https://financialmodelingprep.com/api/v3/historical-price-full/{ticker}?from={dat
e}&to={date}&apikey={api_key}"
    try:
        response = requests.get(url, timeout=10)
        response.raise_for_status()
    except requests.exceptions.RequestException as e:
        print(f"Error fetching data for {ticker}: {e}")
        return None

    data = response.json()
    if "historical" in data and len(data["historical"]) > 0:
        return data["historical"][0]["close"]
    return None

api_key = 'API-KEY'  # Replace with your Financial Modeling Prep API key
tickers = ["TICKER",]
dates = [
    ('2017-12-29', 'Last Trading Day of 2017'),
    ('2018-12-31', 'Last Trading Day of 2018'),
    ('2019-12-31', 'Last Trading Day of 2019'),
    ('2020-12-31', 'Last Trading Day of 2020'),
    ('2021-12-31', 'Last Trading Day of 2021'),
    ('2022-12-30', 'Last Trading Day of 2022'),
]

data = []

for i, ticker in enumerate(tickers):
    row = {'Ticker': ticker}
    for date, label in dates:
        row[label] = get_stock_price(ticker, api_key, date)
        time.sleep(1)  # Introduce a delay of 1 second between requests

    data.append(row)
    progress = (i + 1) / len(tickers) * 100
    print(f"Progress: {progress:.2f}%")  # Print progress update

df = pd.DataFrame(data)
df.to_excel("stock_pricess.xlsx", index=False, engine='openpyxl')
```

Appendix A. Shows the code co-written with GPT-4 that collects stock closing prices for each year used in the study.

Appendix B

```
import requests
import pandas as pd
import time

def get_market_cap(ticker, api_key, year):
                                                                    url                 =
f"https://financialmodelingprep.com/api/v3/historical-market-capitalization/{ticker
}?apikey={api_key}"
    try:
        response = requests.get(url, timeout=10)
        response.raise_for_status()
    except requests.exceptions.RequestException as e:
        print(f"Error fetching data for {ticker}: {e}")
        return None

    data = response.json()

    for record in data:
        record_date = record['date']
         if str(year) in record_date:  # Check if the year matches the year in the
record's date
             if '-12-31' in record_date or '-12-30' in record_date or '-12-29' in
record_date:
                 return record.get("marketCap", None)
    return None

api_key = 'API-KEY'  # Replace with your Financial Modeling Prep API key
tickers = ["TICKER",]  # Trimmed for brevity, add your tickers here
years = [2018, 2019, 2020, 2021, 2022]

data = []

for i, ticker in enumerate(tickers):
    row = {'Ticker': ticker}
    for year in years:
        row[str(year)] = get_market_cap(ticker, api_key, year)
        time.sleep(1)  # Introduce a delay of 1 second between requests
    data.append(row)
    progress = (i + 1) / len(tickers) * 100
    print(f"Progress: {progress:.2f}%")  # Print progress update

df = pd.DataFrame(data)
df.to_excel("market_cap_per_year.xlsx", index=False, engine='openpyxl')
```

Appendix B. Shows the code co-written with GPT-4 that collects the market cap for each company at the last trading day of each year used in the study.

Appendix C

TICKER	COMPANY NAME	SECTOR
ABEO	Abeona Therapeutics Inc.	Health Care
ABIO	ARCA biopharma, Inc.	Health Care
ABUS	Arbutus Biopharma Corporation	Health Care
ACER	Acer Therapeutics Inc.	Health Care
ACET	Adicet Bio, Inc.	Health Care
ACHV	Achieve Life Sciences, Inc.	Health Care
ACOR	Acorda Therapeutics, Inc.	Health Care
ACRS	Aclaris Therapeutics, Inc.	Health Care
ACRX	AcelRx Pharmaceuticals, Inc.	Health Care
ACST	Acasti Pharma Inc.	Health Care
ADMA	ADMA Biologics, Inc.	Health Care
ADMP	Adamis Pharmaceuticals Corporation	Health Care
ADVM	Adverum Biotechnologies, Inc.	Health Care
ADXS	Advaxis, Inc.	Health Care
AGFS	AgroFresh Solutions, Inc.	Materials
AGLE	Aeglea BioTherapeutics, Inc.	Health Care
AGRX	Agile Therapeutics, Inc.	Health Care
AGS	PlayAGS, Inc.	Consumer Discretionary
AIM	AIM ImmunoTech Inc.	Health Care
AIMC	Altra Industrial Motion Corp.	Industrials
AIN	Albany International Corp.	Industrials
AKBA	Akebia Therapeutics, Inc.	Health Care
ALDX	Aldeyra Therapeutics, Inc.	Health Care
ALIM	Alimera Sciences, Inc.	Health Care
ALPN	Alpine Immune Sciences, Inc.	Health Care
ALRN	Aileron Therapeutics Inc.	Health Care
ALT	Altimmune, Inc.	Health Care
AMOT	Allied Motion Technologies, Inc.	Industrials
AMPE	Ampio Pharmaceuticals, Inc.	Health Care
AMPH	Amphastar Pharmaceuticals, Inc.	Health Care
AMRS	Amyris, Inc.	Materials
AMSC	American Superconductor Corporation	Industrials
AMTX	Aemetis, Inc.	Energy
ANAB	AnaptysBio, Inc.	Health Care
ANGO	AngioDynamics, Inc.	Health Care
ANIK	Anika Therapeutics, Inc.	Health Care
ANIP	ANI Pharmaceuticals, Inc.	Health Care
ANIX	Anixa Biosciences, Inc.	Health Care
AORT	Antibe Therapeutics Inc.	Health Care
APDN	Applied DNA Sciences, Inc.	Health Care
APEN	Apollo Endosurgery, Inc.	Health Care
APLS	Apellis Pharmaceuticals, Inc.	Health Care
APVO	Aptevo Therapeutics Inc.	Health Care
AQB	AquaBounty Technologies, Inc.	Health Care

TICKER	COMPANY NAME	SECTOR
AQMS	Aqua Metals, Inc.	Industrials
ARAV	Aravive, Inc.	Health Care
ARAY	Accuray Incorporated	Health Care
ARCT	Arcturus Therapeutics Holdings Inc.	Health Care
ARDX	Ardelyx, Inc.	Health Care
ARMP	Armata Pharmaceuticals, Inc.	Health Care
ARTW	Art's-Way Manufacturing Co., Inc.	Industrials
ARWR	Arrowhead Pharmaceuticals, Inc.	Health Care
ASAP	ASAP Semiconductor Holdings, Inc.	Consumer Discretionary
ASMB	Assembly Biosciences, Inc.	Health Care
ASPN	Aspen Aerogels, Inc.	Materials
ASTE	Astec Industries, Inc.	Industrials
ASUR	Asure Software Inc.	Industrials
ASXC	Asensus Surgical, Inc.	Health Care
ATEC	Alphatec Holdings, Inc.	Health Care
ATEX	Anterix Inc.	Communication Services
ATHX	Athersys, Inc.	Health Care
ATNM	Actinium Pharmaceuticals, Inc.	Health Care
ATNX	Athenex, Inc.	Health Care
ATOS	Atossa Therapeutics, Inc.	Health Care
ATRC	AtriCure, Inc.	Health Care
ATRI	Atrion Corporation	Health Care
ATXI	Avenue Therapeutics, Inc.	Health Care
AUPH	Aurinia Pharmaceuticals Inc.	Health Care
AVAV	AeroVironment, Inc.	Industrials
AVD	American Vanguard Corporation	Materials
AVGR	Avinger, Inc.	Health Care
AVTA	Avantogen Oncology, Inc.	Financials
AVTX	AVITA Therapeutics, Inc.	Health Care
AWH	Aspira Women's Health Inc.	Health Care
AXDX	Accelerate Diagnostics, Inc.	Health Care
AXGN	Axogen, Inc.	Health Care
AXSM	Axsome Therapeutics, Inc.	Health Care
AYTU	Aytu BioScience, Inc.	Health Care
BAND	Bandwidth Inc.	Communication Services
BCLI	BrainStorm Cell Therapeutics Inc.	Health Care
BCRX	BioCryst Pharmaceuticals, Inc.	Health Care
BIOC	Biocept, Inc.	Health Care
BIOL	BIOLASE, Inc.	Health Care
BLCM	Bellicum Pharmaceuticals, Inc.	Health Care
BLFS	BioLife Solutions, Inc.	Health Care
BMRA	Biomerica, Inc.	Health Care
BPTH	Bio-Path Holdings, Inc.	Health Care
BTAI	BioXcel Therapeutics, Inc.	Health Care

Appendix C. Shows the ticker, full name and sector of the companies used in the study.

TICKER	COMPANY NAME	SECTOR
BW	Babcock & Wilcox Enterprises, Inc.	Industrials
BYSI	BeyondSpring Inc.	Health Care
CALA	Calithera Biosciences, Inc.	Health Care
CAPR	Capricor Therapeutics, Inc.	Health Care
CARA	Cara Therapeutics, Inc.	Health Care
CARM	Carmax Mining Corp.	Health Care
CATX	Catabasis Pharmaceuticals, Inc.	Health Care
CBAY	CymaBay Therapeutics, Inc.	Health Care
CBIO	Catalyst Biosciences, Inc.	Health Care
CCLD	Creative Learning Corporation	Health Care
CDLX	Cardlytics, Inc.	Communication Services
CDNA	CareDx, Inc.	Health Care
CDTX	Cidara Therapeutics, Inc.	Health Care
CDXC	ChromaDex Corporation	Health Care
CDXS	Codexis, Inc.	Health Care
CELC	Celcuity Inc.	Health Care
CEMI	Chembio Diagnostics, Inc.	Health Care
CERS	Cerus Corporation	Health Care
CFMS	Conformis, Inc.	Health Care
CFRX	ContraFect Corporation	Health Care
CGRN	Capstone Green Energy Corporation	Industrials
CHRS	Coherus BioSciences, Inc.	Health Care
CKPT	Checkpoint Therapeutics, Inc.	Health Care
CLDX	Celldex Therapeutics, Inc.	Health Care
CLRB	Cellectar Biosciences, Inc.	Health Care
CLSD	Clearside Biomedical, Inc.	Health Care
CLXT	Calyxt, Inc.	Health Care
CMCO	Columbus McKinnon Corporation	Industrials
CMRX	Chimerix, Inc.	Health Care
CNMD	CONMED Corporation	Health Care
COCP	Cocrystal Pharma, Inc.	Health Care
CODX	Co-Diagnostics, Inc.	Health Care
COGT	Cogent Biosciences, Inc.	Health Care
COLL	Collegium Pharmaceutical, Inc.	Health Care
CPIX	Cumberland Pharmaceuticals Inc.	Health Care
CPRX	Catalyst Pharmaceuticals, Inc.	Health Care
CPSI	Computer Programs and Systems, Inc.	Health Care
CRBP	Corbus Pharmaceuticals Holdings, Inc.	Health Care
CRDF	Cardiff Oncology, Inc.	Health Care
CRIS	Curis, Inc.	Health Care
CRMD	CorMedix Inc.	Health Care
CRVS	Corvus Pharmaceuticals, Inc.	Health Care
CSBR	Champions Oncology, Inc.	Health Care
CSGS	CSG Systems International, Inc.	Industrials

TICKER	COMPANY NAME	SECTOR
CSII	Cardiovascular Systems, Inc.	Health Care
CTIC	CTI BioPharma Corp.	Health Care
CTMX	CytomX Therapeutics, Inc.	Health Care
CTSO	Cytosorbents Corporation	Health Care
CTXR	Citius Pharmaceuticals, Inc.	Health Care
CUE	Cue Biopharma, Inc.	Health Care
CUTR	Cutera, Inc.	Health Care
CVM	Cel-Sci Corporation	Health Care
CWBR	CooTek (Cayman) Inc.	Health Care
CYAN	Cyanotech Corporation	Consumer Staples
CYCC	Cyclacel Pharmaceuticals, Inc.	Health Care
CYRX	Cryoport, Inc.	Health Care
DCPH	Deciphera Pharmaceuticals, Inc.	Health Care
DDD	3D Systems Corporation	Industrials
DFFN	Diffusion Pharmaceuticals Inc.	Health Care
DHX	DHI Group, Inc.	Communication Services
DNLI	Denali Therapeutics Inc.	Health Care
DRIO	DarioHealth Corp.	Health Care
DRQ	Dril-Quip, Inc.	Energy
DRRX	DURECT Corporation	Health Care
DVAX	Dynavax Technologies Corporation	Health Care
EDIT	Editas Medicine, Inc.	Health Care
EFOI	Energy Focus, Inc.	Industrials
EGRX	Eagle Pharmaceuticals, Inc.	Health Care
EIGR	Eiger BioPharmaceuticals, Inc.	Health Care
EKSO	Ekso Bionics Holdings, Inc.	Health Care
ELDN	Eledon Pharmaceuticals, Inc.	Health Care
ELMD	Electromed, Inc.	Health Care
ELOX	Eloxx Pharmaceuticals, Inc.	Health Care
EML	Eastern Company	Industrials
EMMA	Emmaus Life Sciences, Inc.	Health Care
ENTA	Enanta Pharmaceuticals, Inc.	Health Care
ENZ	Enzo Biochem, Inc.	Health Care
EOLS	Evolus, Inc.	Health Care
EPIX	ESSA Pharma Inc.	Health Care
ERII	Energy Recovery, Inc.	Industrials
ESPR	Esperion Therapeutics, Inc.	Health Care
EVLO	Evelo Biosciences, Inc.	Health Care
EVOK	Evoke Pharma, Inc.	Health Care
EVRI	Everi Holdings Inc.	Consumer Discretionary
EYEN	Eyenovia, Inc.	Health Care
EYPT	EyePoint Pharmaceuticals, Inc.	Health Care
FATE	Fate Therapeutics, Inc.	Health Care
FBIO	Fortress Biotech, Inc.	Health Care

Appendix C. Shows the ticker, full name and sector of the companies used in the study.

TICKER	COMPANY NAME	SECTOR
FBRX	Forte Biosciences, Inc.	Health Care
FCEL	FuelCell Energy, Inc.	Industrials
FF	FutureFuel Corp.	Materials
FIXX	Homology Medicines, Inc.	Health Care
FLGT	Fulgent Genetics, Inc.	Health Care
FLNT	Fluent, Inc.	Communication Services
FLWS	1-800-FLOWERS.COM, Inc.	Consumer Discretionary
FONR	Fonar Corporation	Health Care
FOXF	Fox Factory Holding Corp.	Consumer Discretionary
FRTX	Forte Biosciences, Inc.	Health Care
FSI	Flexible Solutions International Inc.	Materials
FTEK	Fuel Tech, Inc.	Industrials
FTK	Flotek Industries, Inc.	Materials
FUV	Arcimoto, Inc.	Consumer Discretionary
FWBI	First Western Financial, Inc.	Health Care
GALT	Galectin Therapeutics Inc.	Health Care
GENC	Gencor Industries Inc.	Industrials
GEOS	Geospace Technologies Corporation	Energy
GERN	Geron Corporation	Health Care
GEVO	Gevo, Inc.	Energy
GKOS	Glaukos Corporation	Health Care
GLYC	GlycoMimetics, Inc.	Health Care
GNPX	Genprex, Inc.	Health Care
GOGO	Gogo Inc.	Communication Services
GOLF	Acushnet Holdings Corp.	Consumer Discretionary
GPRO	GoPro, Inc.	Consumer Discretionary
GTHX	G1 Therapeutics, Inc.	Health Care
HAYN	Haynes International, Inc.	Materials
HBIO	Harvard Bioscience, Inc.	Health Care
HROW	Harrow Health, Inc.	Health Care
HSDT	Helius Medical Technologies, Inc.	Health Care
HSKA	Heska Corporation	Health Care
HSTM	HealthStream, Inc.	Health Care
HSTO	Histogen Inc.	Health Care
IBIO	iBio, Inc.	Health Care
IBRX	ImmunoBiotics Inc.	Health Care
ICAD	iCAD, Inc.	Health Care
ICCC	ImmuCell Corporation	Health Care
IDXG	Interpace Biosciences, Inc.	Health Care
IMAX	IMAX Corporation	Communication Services
IMGN	ImmunoGen, Inc.	Health Care
IMNN	Immunome, Inc.	Health Care
IMUX	Immunic, Inc.	Health Care
INFI	Infinity Pharmaceuticals, Inc.	Health Care

TICKER	COMPANY NAME	SECTOR
INO	Inovio Pharmaceuticals, Inc.	Health Care
INSP	Inspire Medical Systems, Inc.	Health Care
IOSP	Innospec Inc.	Materials
IOVA	Iovance Biotherapeutics, Inc.	Health Care
IRBT	iRobot Corporation	Consumer Discretionary
IRDM	Iridium Communications Inc.	Communication Services
IRMD	IRadimed Corporation	Health Care
IRTC	iRhythm Technologies, Inc.	Health Care
ISEE	IVERIC bio, Inc.	Health Care
ISSC	Innovative Solutions and Support, Inc.	Industrials
ITCI	Intra-Cellular Therapies Inc.	Health Care
ITRM	Iterum Therapeutics plc	Health Care
JAGX	Jaguar Health, Inc.	Health Care
JNCE	Jounce Therapeutics, Inc.	Health Care
JOUT	Johnson Outdoors Inc.	Consumer Discretionary
KAI	Kadant Inc.	Industrials
KALA	Kala Pharmaceuticals, Inc.	Health Care
KALV	KalVista Pharmaceuticals, Inc.	Health Care
KIDS	OrthoPediatrics Corp.	Health Care
KNSA	Kiniksa Pharmaceuticals, Ltd.	Health Care
KPRX	KemPharm, Inc.	Health Care
KPTI	Karyopharm Therapeutics Inc.	Health Care
KRYS	Krystal Biotech, Inc.	Health Care
KTOS	Kratos Defense & Security Solutions, Inc.	Industrials
KURA	Kura Oncology, Inc.	Health Care
LAB	Labrador Gold Corp.	Health Care
LCTX	Lineage Cell Therapeutics, Inc.	Health Care
LFCR	LifeCores Biomedical Inc.	Consumer Staples
LGMK	L&G Acquisition Corp.	Health Care
LIFE	aTyr Pharma, Inc.	Health Care
LMAT	LeMaitre Vascular, Inc.	Health Care
LNN	Lindsay Corporation	Industrials
LNTH	Lantheus Holdings, Inc.	Health Care
LOOP	Loop Industries, Inc.	Materials
LPRO	Open Lending Corporation	Financials
LPTX	Leap Therapeutics, Inc.	Health Care
LRMR	Larimar Therapeutics, Inc.	Health Care
LSTA	LSTA Holdings, Inc.	Health Care
LTBR	Lightbridge Corporation	Energy
LUMO	Lumos Pharma, Inc.	Health Care
LVO	Alussa Energy Acquisition Corp.	Communication Services
LXRX	Lexicon Pharmaceuticals, Inc.	Health Care
MATV	Matlin & Partners Acquisition Corporation	Materials
MBIO	Mustang Bio, Inc.	Health Care

Appendix C. Shows the ticker, full name and sector of the companies used in the study.

TICKER	COMPANY NAME	SECTOR
SIEN	Sientra, Inc.	Health Care
SINT	SiNtx Technologies, Inc.	Health Care
SIOX	Sio Gene Therapies Inc.	Health Care
SLDB	Solid Biosciences Inc.	Health Care
SLNO	Soleno Therapeutics, Inc.	Health Care
SLP	Simulations Plus, Inc.	Health Care
SLRX	Salarius Pharmaceuticals, Inc.	Health Care
SLS	SELLAS Life Sciences Group, Inc.	Health Care
SNBR	Sleep Number Corporation	Consumer Discretionary
SNDX	Syndax Pharmaceuticals, Inc.	Health Care
SNES	SenesTech, Inc.	Health Care
SNGX	Soligenix, Inc.	Health Care
SNOA	Sonoma Pharmaceuticals, Inc.	Health Care
SPOK	Spok Holdings, Inc.	Communication Services
SPPI	Spectrum Pharmaceuticals, Inc.	Health Care
SPRO	Spero Therapeutics, Inc.	Health Care
SPWR	SunPower Corporation	Industrials
SRGA	Surgalign Holdings, Inc.	Health Care
SRI	Stoneridge, Inc.	Consumer Discretionary
SRRK	Scholar Rock Holding Corporation	Health Care
SRTS	Sensus Healthcare, Inc.	Health Care
SSKN	STRATA Skin Sciences, Inc.	Health Care
SSTK	Shutterstock, Inc.	Communication Services
STAA	Staar Surgical Company	Health Care
STRM	Streamline Health Solutions, Inc.	Health Care
SURF	Surface Oncology, Inc.	Health Care
SVRA	Savara Inc.	Health Care
SWBI	Smith & Wesson Brands, Inc.	Consumer Discretionary
SYBX	Synlogic, Inc.	Health Care
SYRS	Syros Pharmaceuticals, Inc.	Health Care
TARA	ArTara Therapeutics, Inc.	Health Care
TCMD	Tactile Systems Technology, Inc.	Health Care
TCON	TRACON Pharmaceuticals, Inc.	Health Care
TCRT	Tucows Inc.	Health Care
TENX	Tenax Therapeutics, Inc.	Health Care
TG	Tredegar Corporation	Materials
TGEN	Tecogen Inc.	Industrials
TGTX	TG Therapeutics, Inc.	Health Care
THMO	ThermoGenesis Holdings, Inc.	Health Care
THRM	Gentherm Incorporated	Consumer Discretionary
TIKK	Tel-Instrument Electronics Corp.	Industrials
TMBR	Timber Pharmaceuticals, Inc.	Health Care
TNC	Tennant Company	Industrials
TNDM	Tandem Diabetes Care, Inc.	Health Care

TICKER	COMPANY NAME	SECTOR
NTRA	Natera, Inc.	Health Care
NURO	Neurometrix, Inc.	Health Care
NUWE	Nuwellis, Inc.	Health Care
NVAX	Novavax, Inc.	Health Care
NVTA	Invitae Corporation	Health Care
NXGN	NextGen Healthcare, Inc.	Health Care
NXTP	NextPoint Acquisition Corp.	Communication Services
OCGN	Ocugen, Inc.	Health Care
OCUL	Ocular Therapeutix, Inc.	Health Care
OCX	OncoCyte Corporation	Health Care
OEC	Orion Engineered Carbons S.A.	Materials
OESX	Orion Energy Systems, Inc.	Industrials
OFIX	Orthofix Medical Inc.	Health Care
OFLX	Omega Flex, Inc.	Industrials
OGEN	Oragenics, Inc.	Health Care
OMCL	Omnicell, Inc.	Health Care
OMER	Omeros Corporation	Health Care
ONCS	Oncosec Medical Incorporated	Health Care
ONCT	Oncternal Therapeutics, Inc.	Health Care
ONTX	Onconova Therapeutics, Inc.	Health Care
ONVO	Organovo Holdings, Inc.	Health Care
OOMA	Ooma, Inc.	Communication Services
OPGN	OpGen, Inc.	Health Care
OPTN	OptiNose, Inc.	Health Care
OPTT	Ocean Power Technologies, Inc.	Industrials
ORGO	Organogenesis Holdings Inc.	Health Care
ORGS	Orgenesis Inc.	Health Care
OSTK	Overstock.com, Inc.	Consumer Discretionary
OSUR	OraSure Technologies, Inc.	Health Care
OTLK	Outlook Therapeutics, Inc.	Health Care
OVID	Ovid Therapeutics Inc.	Health Care
PACB	Pacific Biosciences of California, Inc.	Health Care
PALI	Palisade Bio, Inc.	Health Care
PAVM	PAVmed Inc.	Health Care
PBI	Pitney Bowes Inc.	Industrials
PBYI	Puma Biotechnology, Inc.	Health Care
PCRX	Pacira BioSciences, Inc.	Health Care
PDEX	Pro-Dex, Inc.	Health Care
PDSB	PDS Biotechnology Corporation	Health Care
PESI	Perma-Fix Environmental Services, Inc.	Industrials
PFIE	Profire Energy, Inc.	Energy
PHIO	Phio Pharmaceuticals Corp.	Health Care
PIRS	Pieris Pharmaceuticals, Inc.	Health Care
PIXY	ShiftPixy, Inc.	Industrials

Appendix C. Shows the ticker, full name and sector of the companies used in the study.

TICKER	COMPANY NAME	SECTOR
MBOT	Microbot Medical Inc.	Health Care
MBRX	Moleculin Biotech, Inc.	Health Care
MCHX	Marchex, Inc.	Communication Services
MCRB	Seres Therapeutics, Inc.	Health Care
MDGL	Madrigal Pharmaceuticals, Inc.	Health Care
MDXG	MiMedx Group, Inc.	Health Care
MEIP	MEI Pharma, Inc.	Health Care
MG	Mistras Group, Inc.	Industrials
MGNI	Magnite, Inc.	Communication Services
MGNX	MacroGenics, Inc.	Health Care
MIND	MIND Technology, Inc.	Energy
MLAB	Mesa Laboratories, Inc.	Health Care
MLSS	Milestone Scientific Inc.	Health Care
MNKD	MannKind Corporation	Health Care
MNOV	Medicinova, Inc.	Health Care
MNTX	Manitex International, Inc.	Industrials
MODG	Model Group Inc.	Consumer Discretionary
MPAA	Motorcar Parts of America, Inc.	Consumer Discretionary
MRCY	Mercury Systems, Inc.	Industrials
MRKR	Marker Therapeutics, Inc.	Health Care
MRNS	Marinus Pharmaceuticals, Inc.	Health Care
MRSN	Mersana Therapeutics, Inc.	Health Care
MRTX	Mirati Therapeutics, Inc.	Health Care
MTEM	Molecular Templates, Inc.	Health Care
MTRN	Materion Corporation	Materials
MYO	Myomo, Inc.	Health Care
NAOV	NanoVibronix, Inc.	Health Care
NAVB	Navidea Biopharmaceuticals, Inc.	Health Care
NBSE	NeuBase Therapeutics, Inc.	Health Care
NBY	Novabay Pharmaceuticals, Inc.	Health Care
NDRA	ENDRA Life Sciences Inc.	Health Care
NEO	NeoGenomics, Inc.	Health Care
NEPT	Neptune Wellness Solutions Inc.	Consumer Staples
NERV	Minerva Neurosciences, Inc.	Health Care
NH	NantHealth, Inc.	Health Care
NHWK	Nighthawk Interactive Corp.	Health Care
NLTX	Neoleukin Therapeutics, Inc.	Health Care
NMTR	9 Meters Biopharma, Inc.	Health Care
NNVC	NanoViricides, Inc.	Health Care
NOVN	Novan, Inc.	Health Care
NRBO	NeuroBo Pharmaceuticals, Inc.	Health Care
NSTG	NanoString Technologies, Inc.	Health Care
NTIC	Northern Technologies International Corporation	Materials
NTLA	Intellia Therapeutics, Inc.	Health Care

TICKER	COMPANY NAME	SECTOR
TNXP	Tonix Pharmaceuticals Holding Corp.	Health Care
TPST	Tempest Therapeutics Inc.	Health Care
TRHC	Tabula Rasa HealthCare, Inc.	Health Care
TRUE	TrueCar, Inc.	Communication Services
TRUP	Trupanion, Inc.	Financials
TRVN	Trevena, Inc.	Health Care
TTGT	TechTarget, Inc.	Communication Services
TTNP	Titan Pharmaceuticals, Inc.	Health Care
TTOO	T2 Biosystems, Inc.	Health Care
TVTX	Travere Therapeutics, Inc.	Health Care
TWI	Titan International, Inc.	Industrials
TZOO	Travelzoo	Communication Services
UBX	Unity Biotechnology, Inc.	Health Care
UEIC	Universal Electronics Inc.	Consumer Discretionary
UG	United-Guardian, Inc.	Consumer Staples
ULBI	Ultralife Corporation	Industrials
URGN	UroGen Pharma Ltd.	Health Care
UTMD	Utah Medical Products, Inc.	Health Care
VANI	Vivos Therapeutics, Inc.	Health Care
VBIV	VBI Vaccines Inc.	Health Care
VCEL	Vericel Corporation	Health Care
VCYT	Veracyte, Inc.	Health Care
VERO	Venus Concept Inc.	Health Care
VERU	Veru Inc.	Consumer Staples
VICR	Vicor Corporation	Industrials
VIRX	Viracta Therapeutics, Inc.	Health Care
VIVO	Meridian Bioscience, Inc.	Health Care
VKTX	Viking Therapeutics, Inc.	Health Care
VNDA	Vanda Pharmaceuticals Inc.	Health Care
VRAY	ViewRay, Inc.	Health Care
VRDN	Viridian Therapeutics, Inc.	Health Care
VREX	Varex Imaging Corporation	Health Care
VSTM	Verastem, Inc.	Health Care
VSTO	Vista Outdoor Inc.	Consumer Discretionary
VTGN	VistaGen Therapeutics, Inc.	Health Care
VTSI	VirTra, Inc.	Industrials
VTVT	vTv Therapeutics Inc.	Health Care
VUZI	Vuzix Corporation	Consumer Discretionary
VXRT	Vaxart, Inc.	Health Care
VYGR	Voyager Therapeutics, Inc.	Health Care
VYNE	VYNE Therapeutics Inc.	Health Care
WATT	Energous Corporation	Industrials
WVE	Wave Life Sciences Ltd.	Health Care
XBIO	Xenetic Biosciences, Inc.	Health Care
XBIT	XBiotech Inc.	Health Care
XENE	Xenon Pharmaceuticals Inc.	Health Care
XFOR	X4 Pharmaceuticals, Inc.	Health Care
XOMA	XOMA Corporation	Health Care
XTNT	Xtant Medical Holdings, Inc.	Health Care
XXII	22nd Century Group, Inc.	Consumer Staples
YTEN	Yield10 Bioscience, Inc.	Health Care
ZOM	Zomedica Corp.	Health Care
ZYME	Zymeworks Inc.	Health Care
ZYNE	Zynerba Pharmaceuticals, Inc.	Health Care

Appendix C. Shows the ticker, full name and sector of the companies used in the study.