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BIONTECH AND MODERNA: FROM VENTURE CAPITAL TO IPO. FORECASTING PRICE GROWTH AND VOLATILITY.

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INTRODUCTION

The global society's comfortable and well-established certainties have been unpredictably undermined in their foundations by the appearance of the SARS-Cov2 virus. An unknown virus, with potential that cannot be easily categorized and so easily spreadable, has rigorously managed the timing of world population social interaction, without any distinction of latitude or socio-economic profile. The Western world took charge, also on behalf of the less developed societies, of the coronavirus emergency, looking for adequate and effective solutions to the management first and then to the resolution of a problem that, despite being mainly linked to a serious health emergency, it has then determined serious consequences in every area of community life.

Concerns about the management of medical implications have gradually been accompanied by those of an economic and social nature; the world of work has witnessed the maturation of a sudden change. Companies, professional figures of various types and different frameworks, as well as government executives which were responsible for managing correlations and developments in the national and international work structure, have observed the disruptive wave of the new daily life marked by Covid 19. In this sense, aware of the impossibility of being able to restore a balance now violated by the base, the development of vaccines as well as

drugs in the fight against Coronavirus has become the primary objective of every Western country.

Moderna and BioNtech evolution offers multiple ideas for an in-depth analysis of how much the pharmaceutical industry is intended to define the economy and the society interests in the future.

The pandemic has made it necessary to intervene in a targeted and effective way so that the health emergency unpredictability does not lead to the irreversible deterioration of the global socio-economic fabric. The vaccine development against Sars-cov2 in a very short time has offered an effective response to the primary need regarding the virus containment, but the productive strength of both companies has not been exhausted in the development of the two vaccine serums, on the contrary it has in recent months turned towards drugs development able to stem and eradicate the disease. This shows, albeit in a generic way, how much the pharmaceutical sector still has for the next few years the possibility of playing a fundamental role in the society regulation, so it is not impossible to predict how much all this will greatly implement the economic strength of two companies that, more than any other, have been able to quickly achieve a perfect balance between the practical and material needs of the ultimate users of their products and the constant and fast evolution of scientific techniques to achieve the same.

In this perspective it is necessary to consider other lines of research that will certainly be impacted by the new generation of pharmaceuticals that will determine an even greater strengthening of these two avant-garde industries.

In the first chapters, an in-depth analysis of the biotech industry as a whole, will be carried out. Then we will focus on the two most significant biotech companies, namely BioNtech and Moderna, which will take the form of observing the behaviour assumed by companies before, during and after the outbreak of the pandemic. The third chapter is dedicated to the analysis of the venture capitalists, their purposes and how they have developed in the field of biotech start-ups. In conclusion, the final chapter the focus will instead be based on the methodology and data analysis.

1. BIOTECH AND PHARMA INDUSTRY

The choice to analyse the biotechnology industry, also known as biotech, is dictated by the recent challenging event, the Covid 19 pandemic outbreak, that has radically increased the attention to this sector.

Over the past decade we have assisted to a real biotechnological revolution. Biotechnology[1] has always covered an increasing and significant impact in various sectors and disciplines.

The application of biotechnology is currently having an impact in various production sectors, such as in agriculture, in ecology and in the industrial field as well. The most prominent impact is certainly that which occurred in medicine through the creation of more specialised medicine and new diagnostic

[1] Biotechnology consists of the use of biological systems in order to obtain useful products and processes. In 2020, the Organization for Economic Co-operation and Development (OECD) developed definition of biotechnology which is mostly and commonly accepted by everyone. As claimed by the OECD, biotechnology is "*the application of science and technology to living organism, as well as products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services*". Moreover, the development of biotechnology occurs when researchers discovered that the regulation of the life of a cell and of an organism lies in the genes contained in the cells. All of this have determined the possibility of modifying living beings by obtaining important goals to improve their life. In addition, biotechnology can lead to industrial activities based on science and knowledge rather than matter.

methodologies. For over a decade, the biotechnology industry has been dominated, or almost, by genetic engineering thanks to the recombinant DNA technology. In the medical sector the use of biotechnology can be seen as a way to fight, silence or wholly eliminate human diseases. Biotechnology has the potential to produce an increased number of more-effective drugs and bring about radical changes in the healthcare.

The increasingly drugs development able to address in a targeted way the resolution of problems until a few decades ago considered second-degree or simply ignored, has consequently generated numerous benefits, guaranteeing a good expectation of life to a multitude of people, or determining a positive outcome where the sick conditions in previous times could have been fatal.

Big steps in the biopharmaceutical research, approved by many smaller steps, have allowed the reductions in mortality. Nowadays citizens can expect to live up to 30 years longer than they did a century ago.

They play an important role in maintaining public health and being called upon to ensure a fair distribution of the resources available to the whole community. Besides, the ultimate goal of both biotech and pharma companies is the same. In fact, they are both interested in the improvement of the human life quality through the creation, production, and sale of new life-improving drugs. Nevertheless, there are some distinctions between the two industries that should be analysed. Traditionally, the pharmaceutical companies own portfolios of

chemically designed entities, that cover various therapeutic areas and offer enduring financial returns. Moreover, these companies invest into R&D in order to develop their pipeline or to optimize their portfolio and then they use their lobbying and marketing competences to ensure commercial success.

On the contrary, biotech companies focus on a product where they develop therapies by manipulating living organisms. Biotechs involve a very high added value of products, does not require raw materials, but requires personnel with high and advanced scientific qualification. In addition, these companies invest in research without benefiting from any major earnings for years, but they rely mostly on fundraising.

1.1 The evolution of the biotech industry

Of course, the main health care system segment is the pharmaceutical industry, which deals with the production and marketing of pharmaceuticals, biological products, and medical devices, used for the diagnosis and for human diseases treatment. The advances in both science and technology have permitted to enter in a new era for the medicine's development. Not by chance, the industry has truly contributed to improve patients' well-beings.

A more in-depth analysis defines this industry characteristics. The pharmaceutical industry stands out for a high degree of complexity and articulation, for the considerable business risks to which it is subject, deriving above all from the R&D activity and for the singular margins enjoyed above all by large pharmaceutical companies, the so-called Big Pharma[2]. The origins of this industry are dated between the end of the nineteenth and the beginning of the twentieth

[2] Big Pharma are large pharmaceutical companies considered especially as a politically influential group. They are companies with billions of revenues that operate in the production, marketing and distribution of drugs and medicines all over the world. These large pharmaceutical companies use their profit to manage a work that concerns not only generic drugs but also advanced therapies. These companies used to make a much larger profit from their products than other large public companies. This is important because it indicates their potential while supporting the development and commercialization of competitive and innovative drugs.

century in conjunction with the birth of some of the most important pharmaceutical companies such as Roche and Sandoz. In fact, Switzerland, Germany, and finally Italy[3] were the first countries where some of the most important pharmaceutical companies of the time were born, followed by the United Kingdom, the United States, Belgium, and the Netherlands. Some key discoveries between the twenties and thirties gave a strong incentive to the development of this sector. During the mid-eighties there was also the appearance of a new type of player: the biotech companies.

Most pharmaceutical companies are public corporations, so they are constantly monitored by investors who expect growth and a substantial return-on-investment. Many decisions taken inside the firm are strategically driven by the potential to increase revenues. This usually involves reducing risk by staying within the firm's core competences. Pharmaceutical companies must therefore raise their pipelines in order to make up for future revenue decreases.

[3] Examples of the first most important Italian pharmaceutical companies were Menarini (1886), Zambon (1906), Angelini (1919), Recordati (1926), Molteni (1934), Chiesi (1935), Italfarmaco (1938) and Dompè (1940).

This is the context where biotech start-ups start to emerge. In this view, biotechs are supported by venture capital[4] and oriented to the exploitation of the multiple opportunities deriving from molecular biology and genetic engineering. In recent years there has been a change in the corporate structure of companies in the sector, many are start-ups, and, as a result, their approach to product development has also changed. There must be a culture that fosters the support of investors specialized in R&D processes. In fact, biotech companies have always invested in R&D, and more in detail we will see that BioNtech and Moderna invested into R&D to develop their pipeline and to optimize their portfolio as well.

[4] Venture capital (VC), called also risk capital, is a form of private equity and a type of financing that investors provide to startup companies and SMEs that are considered to have long-term growth potential. Venture capital comes from well-off investors, investment banks, and any other financial institutions. However, it does not always take a monetary form, but it can be provided in the form of technical as well as managerial expertise. Venture capital is typically assigned to small companies with outstanding growth potential, or to companies that have grown rapidly and look poised to continue to expand. Nevertheless, it is risky for investors who put up funds, the potential for above-average returns is an attractive payoff.

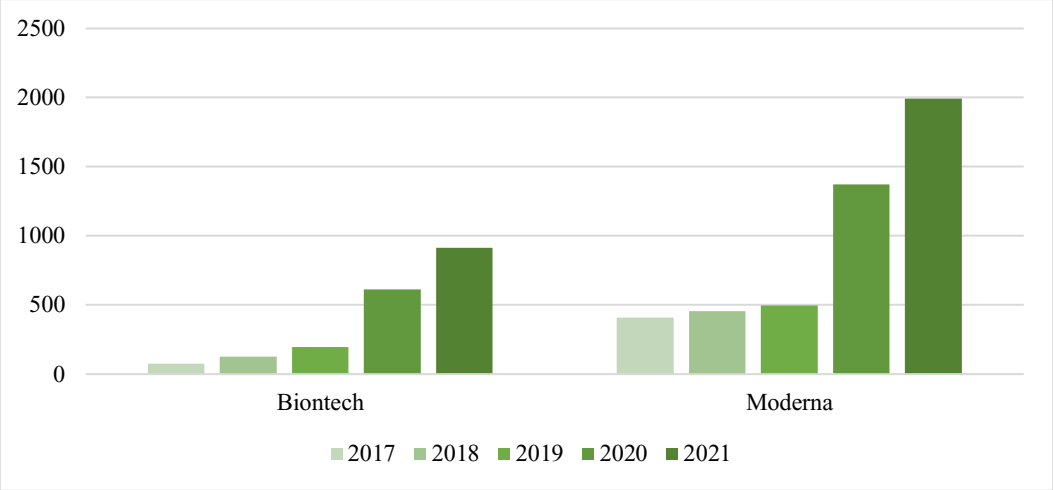

FIGURE 1: Moderna's and BioNtech's investment in R&D from 2017 to 2021 in million U.S dollars, Crunchbase database.

Figure 1 illustrated above shows that, since 2017, Moderna has invested more in research and development than BioNtech. What clearly emerges from this illustration is that between 2020 and 2021 the investments in R&D from both companies, have been significantly higher than in the past.

All of this does not exclude the fact that, even in previous years, these two companies have invested part of their profit for R&D. BioNtech and Moderna invested massively in research and development probably to become more robust. Targeted investments in R&D allow these companies to gain a competitive advantage in the long run.

Understanding the strengths of the system, in which the innovative process of biotech companies takes place, is therefore essential to formulate support policies

that can promote the sector consolidation and make it ready to face the challenges related to the growing competition in international markets. In this scenario, in order to support growth and overall development, the biotech sector certainly plays a strategic role. It has a highly competitive potential since it represents one of the sectors with the highest intensity of research and innovation and with a high rate of qualified employment.

Biotech firms are typically small, often upstart companies, that employ scientists and engineers, by advancing their research in order to license or sold it to multinational pharmaceutical firms. This happens because multinational pharmaceutical firms are commonly known to have a better capability at bringing products through clinical trials, obtaining regulatory approval, and finally by introducing these medical products to the market.

Since its beginning, this sector has had an economic growth but, it is with the outbreak of Covid 19 pandemic, that it has become the flagship of the industry. The companies that constitute the biotech industry can be divided in two wide categories, those that are privately held and those that are publicly held, that is in which shares are freely traded. According to the National Institute of Allergy and

Infectious Diseases (NIH), overall, in 2020 the worldwide biotech industry has represented about 1,5-2 percent of the gross domestic product (GDP)[5].

[5] Gross domestic product or GDP is a measure of the size and health of a country's economy over a period of time. Usually, the GDP is typically calculated on an annual basis, it is sometimes calculated on a quarterly basis as well. GDP provides an economic snapshot of a country, used to estimate the size of an economy and growth rate actually it can be used to compare the size of different economies at a different point in time.

1.2 The primacy of the biotech sector

The lockdown, imposed at the beginning of the 2020 by national governments on the world's population, with the aim of generating a contraction in the contagion curve, has determined for the global economy one of the worst crises since the Second World War.

The evolution of this crisis must necessarily pass through the observation that since the beginning of 2020, the epidemic impact, has gone from being a localized supply shock focused on China, to a violent shock in demand, which has damaged consumption and investment worldwide.

In this context, governments have been forced to implement a shutdown of the economic activities. They were able to introduce health and containment policies with the aim to respond to the virus outbreak.

The pandemic has spread all over the world, affecting not only the health system but also compromising the socio-economic one. The reality is that the Covid 19 has significantly affected both the lifestyle and the economy. Of course, understanding the pandemic impact on economic activity as well as the effectiveness and economic impact of health and containment policies has been one of the most challenging factors faced by worldwide policymakers.

For many traditional companies, the health emergency had a negative impact. In a context of great uncertainty regarding the emergency duration, the concern of

companies called to face the effects of the pandemic on the business and to put in place all possible strategies in order to preserve economic sustainability, is growing. To further confirm this, an indication from the International Monetary Fund[6] notes that, in the two-month period March-April 2020 compared to the same period of 2019, the worldwide GDP of the industrial sector as a whole, which is the amount of money a country makes in trade and their economic output, has suffered a net halving by showing a negative percentage of -3,03%.

FIGURE 2: World Gross domestic product, constant prices, percent change. International Monetary Fund, April 2020, World Economic Outlook Database.

[6] The International Monetary Fund (IMF) is an international organization that provides financial assistance and advice to member countries. It is composed by 189 member countries that work together to try to stabilise the global economy.

As described in the Figure 2, almost all the main industrial groupings have recorded a negative result in 2020. The health state of the industry is an important symptom from which to start to give new impulses to the economy. In general, it is necessary that institutions and companies find solid and concrete agreements in a very short time to give new impulse to the country's industrial sector.

In such a complex economic situation in the first instance, but also political and social, the only positive data is recorded in relation to the biotech and pharma industries. Moreover, the pharma industries have registered data that were totally in contrast to what was recorded in other production areas. The biotech and pharmaceutical industry represent a key asset for the world economy, as well as driving the medical progress by researching, developing and bringing new medicines. The biotech sector has experienced the longest upward market in the history, and this is the reason why the Covid 19 pandemic effect on the biotech market during the first quarter of 2020, unlike most industries, was relatively minor. It is in this challenging situation that the private and public biotech fundings, including global venture capital, investments, deals, and IPOs[7], reached all-time

[7] An initial public offering (IPO) refers to the process of offering shares of a private corporation to the public in a new stock issuance. Companies must meet requirements by exchanges and the Securities and Exchange Commission (SEC) to hold an IPO. Before an IPO, a company is considered private. An IPO is a big step for a company as it provides the company with access to raising a lot of money. This gives the company a greater ability to grow and expand. The increased

increase in 2020. In addition to that, biotech is outperforming its sister industry, pharmaceuticals, as well as many household-name consumer-goods and technology companies. Despite a brief downturn at the start of 2020, which is totally normal considering that even the biotechs found themselves with a situation never experienced before, the biotech companies' average growth recovered quite good.

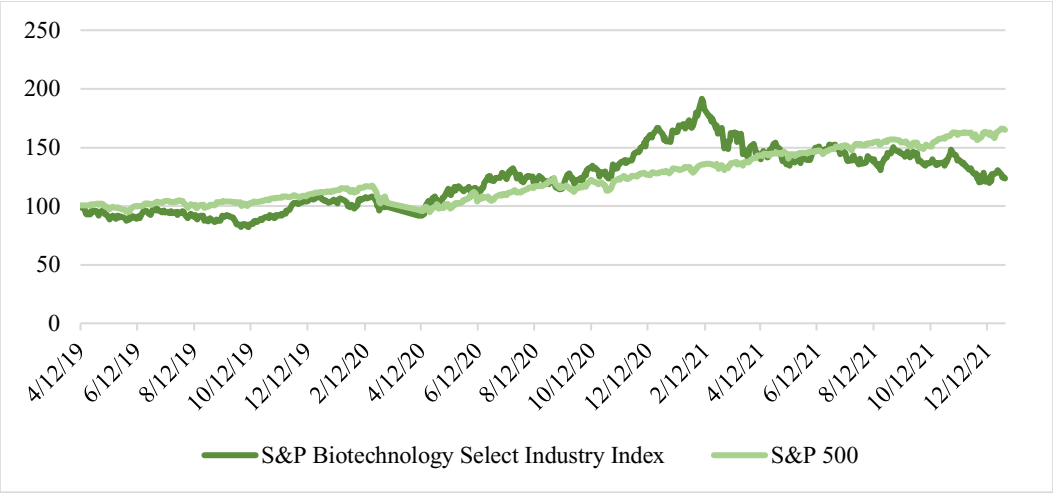

FIGURE 3: Comparison between S&P Biotechnology Select Industry Index and S&P 500, S&P Dow Jones Indices a division of S&P Global.

transparency and share listing credibility can also be a factor in helping it obtain better terms when seeking borrowed funds as well.

Above, Figure 3 illustrates the S&P Biotechnology Select Industry Index[8] trend compared with S&P 500. Except for the first months of 2020, the S&P 500 has an increasing trend over the next year. The S&P Biotechnology Select Industry Index reach the highest point at the beginning of the 2021 which is then followed by a subsequent downward. According to McKinsey[9] between January 2020 and January 2021, the European and US biotechs' average share price increased at more than twice the rate of the S&P 500[10]. This is relevant because biotech companies

[8] S&P Biotechnology Select Industry Index is a leading biotechnology index. It was launched in January 2006 and has a long back-test history, with a first value date of Dec. 17, 1999. It is designed to measure the performance of U.S. biotechnology stocks. The index uses a transparent, rules-based selection process, starting with constituents of the S&P total market index. In other words, it represents the biotechnology sub-industry portion.

[9] Compare with "*What's ahead for biotech: another wave or low tide?*" April 30, 2021, by Laura Cancherini, Joseph Lydon, Jorge Santos da Silva, and Alexandra Zemp.

[10] The S&P 500 is a stock market index that tracks the stocks of 500 large-cap U.S. It represents the stock market's performance by reporting the risks and returns of the biggest companies. S&P stands for Standard and Poor, the names of the two founding financial companies. It was officially introduced on March 4, 1957.

saw a growth thanks to the increase of acquisitions, partnerships[11], IPOs, and fundraising, which is a completely different situation from the period before the pandemic outbreak.

[11] A partnership is a formal arrangement by two or more parties to manage and operate a business and share its profits. There are several types of partnership arrangements. In particular, in a partnership business, all partners share liabilities and profits equally, while in others, partners may have limited liability.

1.2.1 The great biotech acceleration and resilience

The biotech industry's response to the crisis, its record of innovation, and its reputation as a safe haven for investment, which attract the majority of investors, have made this sector flourishing. Data show that investments increased during the pandemic as thousands of venture capital firms focused on investing in companies that were developing Covid 19 vaccines and treatments. Further investments were utilised, for example, towards areas where biotech has shown to have potential, such as artificial intelligence and cancer-detection technology.

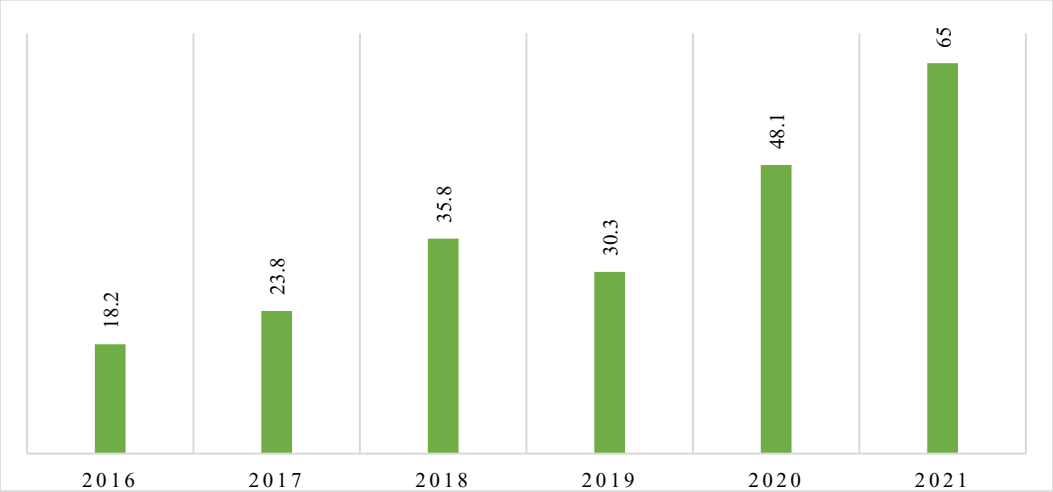

FIGURE 4: Global Biotech industry investments, total $ invested, Crunchbase database.

It's worth to observe that, as shows in Figure 4, a significant portion of total investments comes from the companies that place themselves specifically in the biotech category. Investors have always pay particular attention to investments in this sector. What emerges from the illustration above is that since 2016 investors have always invested many dollars in the biotech sector.

Moving forward with the analysis, between 2019 and 2020, biotechs experienced a double-digit annual growth in fundraising from VCs. In fact, through an analysis of the venture capital activity, biotechs grew by 45 percent in a year, taking the 2020 global total from $25.3 billion to $36.6 billion.

By January 2021, venture capitalists had invested some 60 percent more than they had in January 2020, with more than $3 billion invested worldwide in January 2021 alone.

Although the US biotechs continues to lead the investments, they were followed a short distance by the European ones. In fact, the European mean funding size grew at more than twice the rate than in the United States. The fact that, the European more conservative markets are experiencing larger funding rounds, indicates that the local offer is more advanced in its development cycle. Also, in deals[12] such as

[12] Includes acquisitions, partnerships, co-developments, and joint ventures; covers only disclosed deal values (26% of deals in PharmaDeals).

partnerships, co-developments, and joint ventures[13] biotech saw double-digit annual growth. Especially between 2019 and 2020, they grew by 84 percent in a year, taking the 2020 total global from $92.5 billion to $170.6 billion. It is significant to say that Biotechs partnered with a broad range of other organizations, from big pharma to investment funds and other biotechs. Pharma companies have long used acquisitions to sustain their portfolio strategy while also pursuing the top-line growth. The deal growth was mostly driven by the United States, where the average deal size doubled, and the number of deals increased by 25 percent. While the European market saw strong growth as it started to catch up from a smaller base. The deals in January 2021 were on average 66% larger than in January 2020 at an average of more than $500 million invested per deal. The average deal size reaching more than $500 million that is up by more than 66 percent on the 2020 average. Finally, the IPO funds also experienced a triple-digit growth. This activity which has grown faster than any other category of fundraising, with companies raising from $12 billion to $34.3 billion in 2020, an increase of 186 percent on the previous year. IPO activity grown powerfully,

[13] A joint venture (JV) is a business arrangement in which two or more parties agree to combine their resources with the aim to accomplish and realize a specific task. This task can be a new project or any other business activity. In a JV, each of the participants is responsible for profits, losses, and costs associated with it.

actually, there were 19 more closures than in the same period in 2020, with an average of $150 million per raise, 17 percent more than in 2020[14].

These data show that biotechs have constituted and continues to constitute the driving sectors of an economy in serious difficulties, by being one of the main gainers in terms of revenue and market growth during the pandemic times. Biotechs come out strengthened by the pandemic scenario. In facts, they have experienced one of its best years up to now. The explanation whereby the biotech sector had been so resilient during the worst economic crisis in decades should be seen in many factors. First of all, the resilience depends on the fact that biotechs' revenues have not been so affected by the numerous lockdowns as it has been the case in most of other sectors. Another factor that plays a fundamental role in the biotech sector is that larger pharmaceutical companies are continuing to rely in biotechs as a source of innovation. Biotechs also have the scope to improve the rhythm and quality of their clinical development, which is critical in meeting investors' expectations and securing funding. Getting to market quickly requires biotechs to intensify their focus on clinical operations, plan early, and find ways to reduce the clinical development's risk.

[14] Compare with "*What's ahead for biotech: another wave or low tide?*" April 30, 2021, by Laura Cancherini, Joseph Lydon, Jorge Santos da Silva, and Alexandra Zemp.

Moreover, thanks to the convergence of biological and technological advances, the number of assets transitioning to clinical phases is still rising. Many biotechs, together with the pharmaceutical industry, did not only take steps to address the Covid 19 pandemic, but they are studying to realise vaccine candidates in their pipelines along with a various number of therapeutics.

In conclusion, despite this challenging macroeconomic environment, biotechs continue to increase in quality as well as in quantity.

2. BIONTECH AND MODERNA

The motivation behind investing in biotechs can be found in the sector itself. The biotech sector has become important in recent years. As we already said in the previous chapters, the pandemic has had an enormous financial impact on many sectors, but biotechs, after a brief downturn early in the crisis, have overcome the period very quickly.

Among the worldwide major biotechnology companies by market capitalization, the attention is on two biotech companies, namely BioNTech and Moderna.

At the beginning, when they were founded, these companies were mainly known to those who followed biotech and pharma dealings, but the majority do not know them at all. It is from 2020 that these companies have become known to the entire world population. The Covid 19 has been the deadliest pandemic since the Spanish flu of 1918-1920 and while people in the twentieth century had to wait for the pandemic to run its course before life could return back to a pre-pandemic normal, Covid 19 saw the emergence of several effective vaccines within a year. In record time, BioNtech and Moderna have become well-known names thanks to their pioneering mRNA vaccines against the Covid 19 virus.

They both used a technology based on the synthetic messenger RNA, a short for ribose nucleic acid, which is a short transcript of a longer DNA code. They both refer on the mRNA technology developed by Katalin Kariko from the University

of Pennsylvania and her collaborator Drew Weissman, an immunologist from Boston University. These two scientists have worked together in order to find a way to get the human body to accept strands of mRNA without generating an immune reaction. What these companies have developed was a revolutionary approach that allowed to realize vaccines within a short period of time.

Many biotech companies have developed vaccine solutions to contrast the expansion of Sars-cov2 disease, but BioNtech and Moderna vaccines were the first two vaccines to be approved by the regulators and government officials and then to be introduced in the market.

At the first glance, the companies may seem very similar because they developed the first two Covid vaccines by using mRNA but, in the reality, Moderna and BioNtech may differ in important ways. They began differently, they are managed differently, and the path they are taking post-pandemic is also diverging.

2.1 Firms' history and foundation

Biopharmaceutical New Technologies, also knowns as BioNtech, is a biotechnology next generation immunotherapy company that is pioneering in innovative therapies for patient-specific serious diseases treatment.

It is a German company where it has the founding place and global headquarters in Mainz. Although the main activities were successfully achieved in Mainz, the company has many research locations around the world. Its foundation dates back to 14 years ago. It was founded by a group of scientists and doctors, namely Dr. Ugur Sahin, Dr. Özlem Türeci, and Professor Christoph Huber on the understanding that *"every cancer patient's tumor is unique and therefore each patient's treatment should be individualized"*. In order to translate this idea into reality, they have combined research with innovative technologies to develop innovative therapeutics to fight cancer and other human diseases. This makes necessary to develop customized treatments to meet each patient needs on an individual basis for the greatest degree of effectiveness.

In addition to cancer, BioNTech is dedicated to the development and production of active immunotherapies for the treatment of many serious diseases. In record times it has become one of the leading global biotechnology companies.

In this sense BioNTech, as well as Moderna, has established a broad set of relationships with many global pharmaceutical collaborators, including Genmab,

Sanofi, Bayer Animal Health, Genentech, a member of the Roche Group, Regeneron, Genevant, Fosun Pharma, and Pfizer, and it has published with them many scientific publications. Especially, in 2020, BioNtech, partnering with Pfizer for testing and logistics, has developed the mRNA vaccine for preventing Covid 19 infections, which represents the first mRNA vaccine ever authorized.

Like BioNtech and other biotech companies, the history of Moderna is quite recent. In this view, Moderna is a Massachusetts-based pharmaceutical and biotechnology company established in 2010, that focuses mainly on the development of mRNA technology and therapeutics. This can be understood also through its name which is ModeRNA. The acronym simply means "Mode RNA" since its founder invented a revolutionary RNA modification method which then became the entire basis of the company. Although it was founded in 2010, it officially revealed its activities to the public as of 2013 and until December 2012 Moderna worked invisibly.

The company's studies and researches are mainly based on the basic scientific work of Derrick Rossi at Harvard, whose laboratory developed a method for modifying mRNA. Derrick Rossi is a Canadian stem cell biologist that co-founded Moderna in 2010. As anticipated, Moderna is pioneering mRNA science and it is continually striving to push boundaries and explore new frontiers of mRNA research to treat, to prevent rare human diseases, to help patients and to impact their lives.

Its programs extend to a wide range of therapeutic areas, including infectious disease, oncology, cardiovascular disease and rare genetic diseases.

It has forged strategic alliances with pharmaceutical and biotech companies, government organizations, foundations and research institutes with therapeutic area expertise and resources to help advance in development programs. These include AstraZeneca, Merck, Vertex, Barda, Darpa, Institute Pasteur, Karolinska institute and Bill&Melinda gates foundation.

Even though it was born several years ago, it is only with the spread of Covid 19 that, together with BioNtech, it has experienced the most relevant growth. Another significant aspect that should be defined is that even before the virus was spreading around the world, Moderna was focusing on vaccines while BioNTech was much more focused on individualize cancer medicines and its foray into the Covid 19 vaccine can be seen as an opportunistic strategy.

2.2 Research locations

There are many things to consider when comparing two enterprises and one of these is surely the location analysis. The location analysis is a dynamic process where entrepreneurs select and figure out, by using data, the best sites for a given enterprise. Choosing the right site selection for a given enterprise influences whether the firm succeeds or fails to in being profitable. The location analysis, in this specific case, concerns BioNtech and Moderna. One of the remarkable differences is certainly consists of their research locations, in fact both pioneering companies are based on opposite sides of the Atlantic.

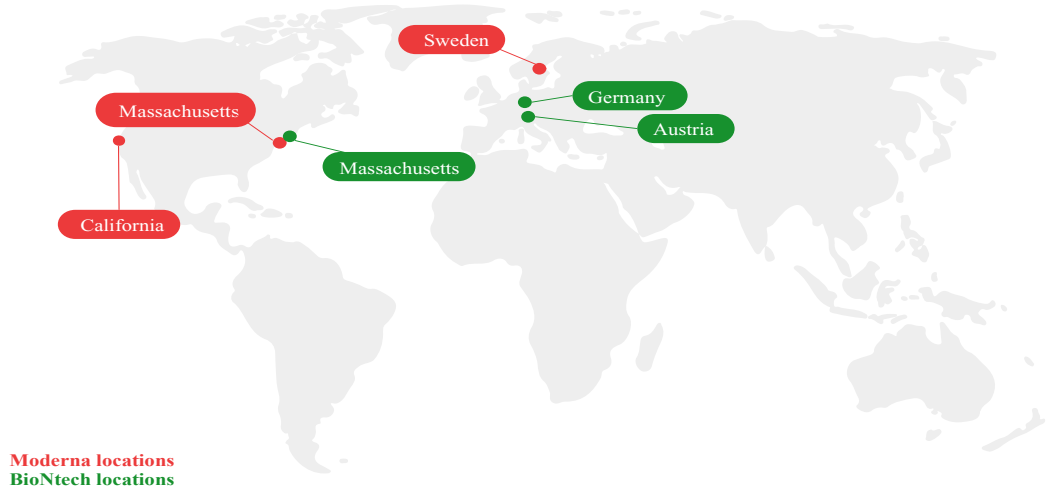

FIGURE 5: Moderna and BioNtech locations illustration, own processing on BioNtech and Moderna data, 2022.

Moderna was founded in Massachusetts in 2010 under the name Moderna Therapeutics by a team of investors and two years after BioNTech began operating from a small lab in Mainz, Germany.

From its roots in Mainz, where BioNtech has created the Covid 19 vaccine, the company brought a global immunotherapy powerhouse by opening sites not only in the home country but also in other locations. In fact, the company runs additional research locations in Austria and in USA, especially in California and Massachusetts, which represent also the North American headquarters. Instead, Moderna is headquartered in Massachusetts, and it has three office locations there and one in Sweden.

The fact that both BioNtech and Moderna have their sites in Massachusetts is not a coincidence. Although Massachusetts is one of the smallest states in the USA by size, the state benefits from the biotech industry as clustering. There is a high concentration of hospitals, leading universities, and private companies in a relatively small area, and this stimulates collaboration and innovation. From investing in innovation to collaborative partnerships between government, universities, hospitals, and the private sector, Massachusetts has built the world's leading biotech hub. Although clustering and collaboration with government have helped the state's biotech industry grow, what really drives the industry is one of Massachusetts' greatest natural resources, namely talent.

Actually, the state's high density of colleges and universities have created an enviable talent pipeline, one that remains strong even as low unemployment creates more competition for talent.

2.3 Ownership highlights

BioNtech is owned by 61.91% insiders and by 16.28% institutional shareholders. The rest, mainly by 21,81%, is owned by the public. BioNtech owners are mainly institutional stakeholders and mutual funds. From Figure 6 is possible to understand that most of the capital is held by the insiders[15]. Insiders have frontline knowledges of what is taking place at a company and consequently, they are more informed on what impact to the company's stock. The fact that most of the capital is held by insiders is a positive thing because since the insiders have specific goals to achieve, they will probably maintain a large share of control to orient their decisions.

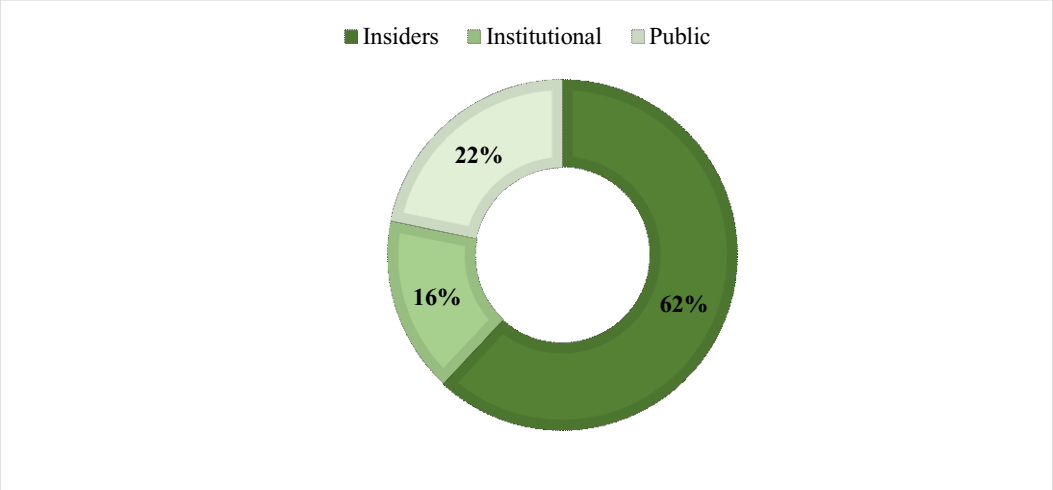

FIGURE 6: BioNtech ownership, 2022, Datastream database.

[15] In legal terms, an insider is an officer or director of a public company, or an individual or an entity that own 10% or more of any class of a company's shares.

If we look at the institutional owners of BioNtech, the top 10 institutional shareholders represent 9.85% of BioNTech's total shares outstanding. From the top ten, the largest institutional shareholders of BioNtech are "*Baillie Gifford & Co Limited*.", "*PRIMECAP Management Company*" and "*Jennison Associates LLC*".

FIGURE 7: Top BioNTech's institutional shareholders, April 1, 2022, Datastream database.

An in-depth analysis of these three largest institutional shareholders will be carried out. Baillie Gifford was founded in 1908 in Scotland and is an independent investment manager, managing pension funds, investment trusts and unit trusts. The company is entirely owned by partners that work within the firm. The company, which is the largest BioNtech's shareholder owns 6.53M shares of

BioNtech, representing 2.65% of BioNTech's total share outstanding. Using the stock price dating back to April 1, 2022, of $170.56, Baillie Gifford & Co Limited's current total stake in BioNtech is worth $1,11B. Then, there is PRIMECAP Management Company, that was founded in 1983 in Pasadena, CA, as an independent investment management company. It manages US-focused equity portfolios for a limited number of institutions and mutual funds. The company, which is the second-largest shareholder, owns 4.19M shares of BioNtech, representing 1.70% of BioNTech's total share outstanding. Using the stock price on April 1, 2022, of $170.56, PRIMECAP Management Company's current total stake in BioNtech is worth $714.66M. Finally, there is Jennison Associates LLC that operates as an investment management firm. The company offers financial strategies, fundamental research, wealth management and advisory services. The company, which is the third-largest shareholders, owns 3.13M shares of BioNtech, representing 1.27% of BioNTech's total share outstanding. Using the stock price on April 1, 2022, of $170.56, Jennison Associates LLC's current total stake in Biontech is worth $533.85M. According to this analysis, on April 1, 2022, using Datastream database, those three shareholders currently own together 5.62% of BioNTech's total shares outstanding. In the following exhibit, there is the representation of the largest mutual fund shareholders of BioNtech.

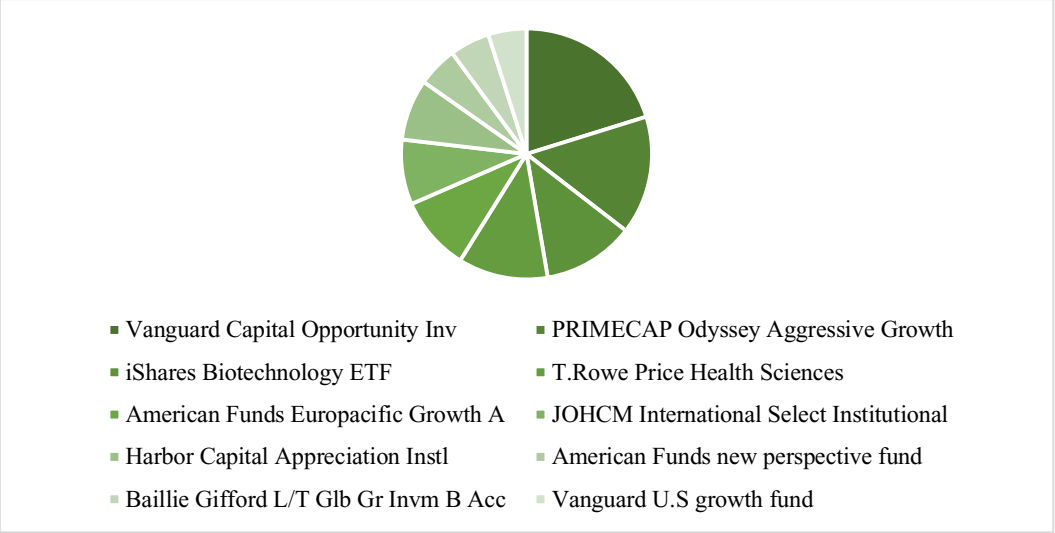

FIGURE 8: Top BioNTech's mutual funds holding, April 1, 2022, Datastream database.

Among the most important mutual funds holding[16] there are "*Vanguard Capital Opportunity*", "*PRIMECAP Odyssey Aggressive Growth*" and "*iShares Biotechnology ETF*". Vanguard Capital Opportunity holds 2.03M shares, representing 0.82% of BioNtech's total shares outstanding. Then, PRIMECAP Odyssey Aggressive Growth" holds 1.53M shares, representing 0.62% of BioNtech's total shares outstanding. Then there is iShares Biotechnology ETF

[16] A mutual fund is an investment vehicle that pools money from investors to purchase securities. A mutual fund's holdings represent the securities held in the fund.

which holds 1.18M shares, representing 0.48% of BioNtech's total shares outstanding.

Moderna's ownership is completely different from the BioNtech's one. In fact, Moderna is owned by 62,78% institutional shareholders, by 9.32% insiders and the rest 27,9% is owned by the public. From Figure 8 is possible to understand that most of the capital is not held by the insiders as in BioNtech, but it is held by institutional shareholders. Institutional shareholders enjoy some preferential treatment in the markets and among the main ones is that of the lower commissions to which they are subject compared to other market participants.

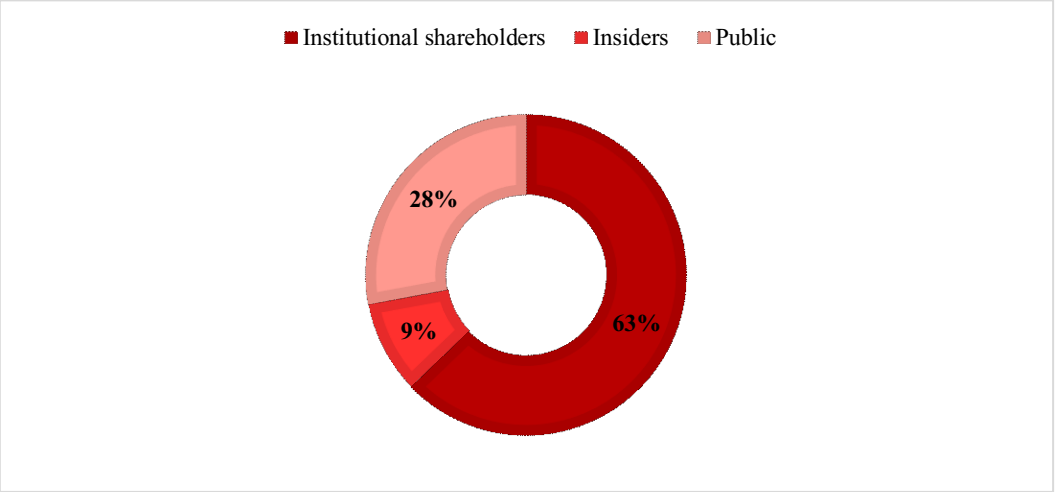

FIGURE 9: Moderna Ownership, 2022, Datastream database.

From the top ten, the largest institutional shareholders of Moderna are "*Baillie Gifford & Co Limited.", "Blackrock Inc"* and *"Vanguard Group Inc"*. An in-depth analysis of these three largest institutional shareholders will be carried out.

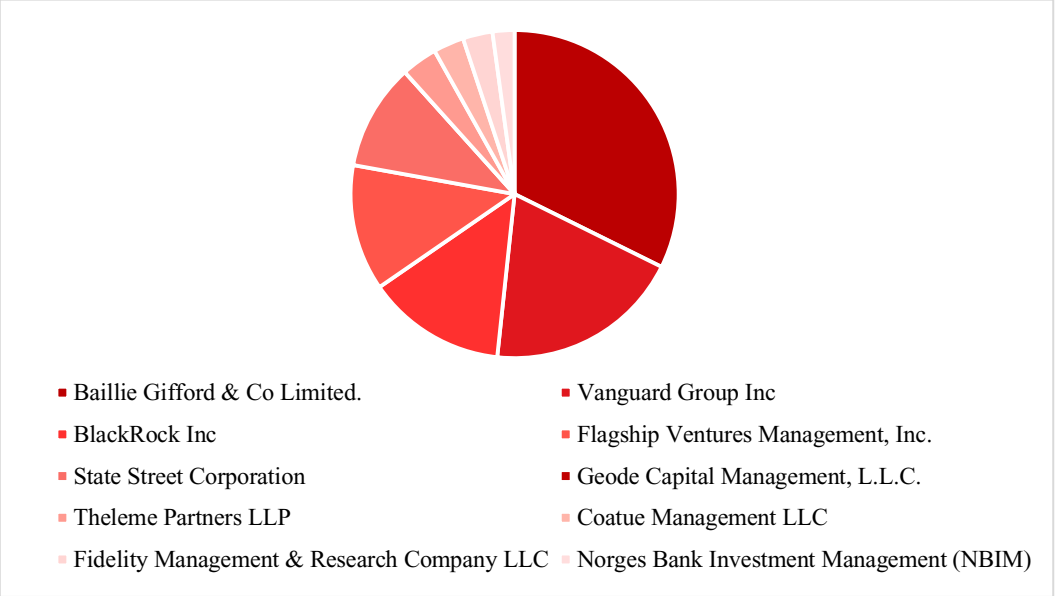

FIGURE 10: Top Moderna's institutional shareholders, 2022, Datastream database.

Baillie Gifford, the first-largest shareholder, owns 45.77M shares of Moderna, representing 11.36% of Moderna's total share outstanding. Using the last stock closing price of $176.59 on April 1, 2022, Baillie Gifford & Co Limited's current total stake in Moderna is worth $8.08B. Then, there is Vanguard group, which is one of the world's largest investment companies, offering a large selection of low-

cost mutual funds, ETFs, advice and related services. The company, which is the second largest shareholder owns 27.43M shares of Moderna, representing 6.81% of Moderna's total share outstanding. Using the last stock closing price on April 1, 2022, of $176.59, Vanguard Group Inc's current total stake in Moderna is worth $4.84B. Then, there is BlackRock which is one of the world’s leading asset management firms and a premier provider of investment management, risk management and advisory services to institutional, intermediary, and retail clients worldwide. The company, which is the third-largest shareholder, owns 19.43M shares of Moderna, representing 4.82% of Moderna's total share outstanding. Using the last stock closing price on April 1, 2022, of $176,59, BlackRock Inc's current total stake in Moderna is worth $3.43B. In conclusion, those three own together 22,99% of MRNA's total shares outstanding. In the following figure, there is the representation of the largest mutual fund shareholders of Moderna.

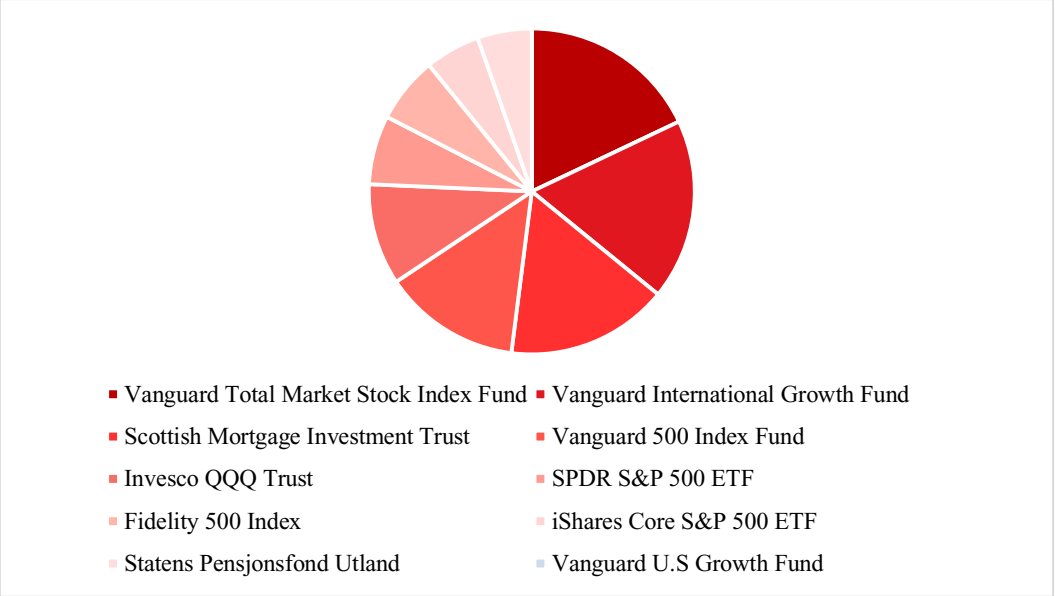

FIGURE 11: Top Moderna's mutual funds holding, 2022, Datastream database.

The largest mutual fund holders of Moderna are "*Vanguard Total Stock Mkt Idx Inv*", "*Vanguard International Growth Inv*" and "*Scottish Mortgage*". Vanguard Total Stock holds 9.88M shares that represents 2.45% of Moderna's total shares outstanding. Then, Vanguard International Growth Inv holds 9.90M shares, representing 2.46% of Moderna's total shares outstanding. Finally, Scottish Mortgage Ord holds 8.91M shares, representing 2.21% of Moderna's total shares outstanding. Together these mutual funds hold 7.13% of Moderna's total share outstanding. What clearly emerges through the comparison of these two companies, is that Baillie Gifford & Co Limited as well as Blackrock, have invested both in BioNtech and Moderna. Another important financial aspect that should be analysed

when dealing with the ownership could be the companies' free float. The free float represents the part of the share capital actually in circulation on the stock market. Moderna free float, as a percentage of traded shares, is at 90.68% meaning that the share of shares traded on the market is at 90.68% level. This free float corresponds to 365.45M. While BioNtech's free float, as a percentage of traded shares is below 50%, in fact it is about to 38.09% which corresponds to 94.02M. This value depends on the fact that, the share capital is mostly held by those who founded the company. It is relevant to underline that Moderna's CEO, namely Stéphane Bancel, holds share as well. He became CEO of Moderna in 2011 and owns a roughly 8% stake in the publicly traded company. Even though he has sold millions of dollars in shares, nowadays, he still owns more than 21.8 million shares of Moderna stock by remaining the largest insider shareholder.

2.4 Expansion

Since 2014, BioNtech has published many research results on mRNA mechanisms. Especially, thanks to a broad set of relationships that it has established with multiple global pharmaceutical collaborators, it was able to publish many publications on its scientific methodology.

It is relevant to underline that starting from 2015 many collaborations and commercialization programs have been concluded with several companies and scientific institutions in order to more quickly and effectively identify and develop individualized treatments. In the meantime, BioNTech has filed many patent applications and has advanced a multi-layered strategy to protect the intellectual property in the cancer's treatment and other serious human diseases. In August 2018, the company entered into a research and development collaboration with the US company, namely Pfizer[17], to develop mRNA-based vaccines for influenza prevention. After BioNTech's accomplishment of a first-in-human clinical study, it is Pfizer that assume the exclusive responsibility for further

[17] Pfizer Inc. is an American multinational pharmaceutical and biotechnology corporation that was founded and headquartered in New York City in 1849 by two German immigrants, Charles Pfizer and his cousin Charles F. Erhart. Pfizer develops and produces medicines and vaccines for immunology, oncology, cardiology, endocrinology, and neurology.

clinical development and commercialization of mRNA-based flu vaccines. This collaboration was profitable and since 2020, BioNtech, partnering with Pfizer for testing and logistics, has developed the mRNA vaccine for preventing Covid 19 infections. This represents the first mRNA vaccine ever authorized.

In addition, a relevant collaboration that should be analysed, is that between BioNtech and Fosun Pharma. Actually, BioNtech wants to open headquarters in Singapore and also a vaccine manufacturing plant with the support of the Singapore Economic Development Board. The Singapore factory is expected to be active by 2023 and produce doses of mRNA vaccines each year. Similarly, Moderna has forged strategic alliances with pharmaceutical and biotech companies, government organizations, foundations and research institutes with therapeutic area expertise and resources in order to help advance development programs. Probably Moderna's aim is certainly the maximization and the subsequent expansion of the vaccine industry. In fact, Moderna has announced a plan to expand its sales network to six more European countries such as in Belgium, Denmark, Norway, the Netherlands, Poland, and Sweden in the near future. This will be done in order to support the delivery of mRNA vaccines and therapies locally.

Moreover, just like BioNtech, Moderna made a recent announcement that consists in planning four new branches in Asia, more specifically in Malaysia, Taiwan, Singapore, and Hong Kong. The main goal according to Stéphane Bancel, CEO of

Moderna, is "*to deepen collaborations with European researchers and partners to exploit our mRNA technology and expand treatment options to improve patients' lives*".

2.5 Nasdaq IPO

BioNTech is the latest in a series of large biotech companies that go public in the US. On September 24, 2019, the German immunotherapy developer, has announced that it has filed a registration statement on Form F-1 with the United States Securities and Exchange Commission[18] to offer 10,000,000 ADSs[19] representing 10,000,000 ordinary shares at a public offering price of $15.00 per ADS for total gross proceeds of $150,000,000. The company had originally aimed to sell 13.2 million ADS with the initial public offering price between $18.00 and $20.00 per ADS but then the deal size was cut to 10 million ADS between $15 and $16 per share. BioNTech also aims to grant the underwriters a 30-day option to purchase up to an additional 1,500,000 ADSs at the public offering price. The ADSs begin to trade on the Nasdaq Global Select Market on October 10, 2019, under the ticker symbol "BNTX." The company raised $150 million in a US IPO that values the company at $3.4 billion. Nevertheless, the lower price in its last round, BioNTech is the third-largest biotech to list in the past decade. The IPO deal was underwritten

[18] The Securities and Exchange Commission, also known with the acronym "SEC", is the U.S. federal agency responsible for overseeing the stock exchange.

[19] ADS stands for American Depositary Share. It is an equity share of a non-U.S. company that is held by a U.S. depositary bank and is available for purchase by U.S. investors.

by J.P. Morgan, BofA Merrill Lynch, UBS, and SVB Leerink which are acting as lead joint book-running managers for the offering, Canaccord Genuity, Bryan, Garnier & Co. and Berenberg which are acting as joint book-running managers for the offering and finally Wolfe Capital Markets and Advisory, Kempen and Mirae Asset Securities which are acting as co-managers for the offering. Although the IPO didn't yield the expected results, BioNTech has been savvy in their fundraising efforts. The company raised $325 million in venture capital in a large private financing round, that was completed in July 2019, and this was among the largest of its kind in the history of European biotechnology. This funding round was concluded in July of 2019. There has been no lack of private funders willing to invest in the firm. BioNtech has been savvy in their fundraising efforts, actually the company raised a total of $1.6B in funding over 8 rounds. Their latest funding was raised on September 15, 2020, from a grant round. BioNTech is funded by 16 investors and the German Federal Ministry of Education and Research (BMBF) and Temasek Holdings are the most recent investors. Moreover, there are private funders willing to invest in the firm. The situation changed when dealing with Moderna. Tim Springer, the Harvard University faculty member, along with Kenneth Chien, Bob Langer, and Flagship Pioneering, co-invested at the company's founding. Moderna is a commercial-stage biotech that and had its initial public offering only in December 2018. When Moderna went public in 2018 it was reported at the time to be the largest biotech initial public offering in the history of

the biotech sector. The underwriters are characterized by Morgan Stanley, Goldman Sachs, Barclays Capital, JP Morgan and other major financial firms. Moderna is funded by 20 investors and Biomedical Advanced Research and Development Authority (BARDA) is the most recent investor. Moderna initial public offering of 26,275,993 American Depositary Shares ("ADSs") represents 26,275,993 ordinary shares with a selling price of $23.00 per share. The gross proceeds of the offering generate of $604,347,839 million, from investors exceeding the company's revised goal. Furthermore, Moderna exceeds the IPO objectives without doing anything precise and without a long-term goal, while BioNtech with well-defined plans and advanced work does not get the hypothesized funds. Moderna's common stock begin to trade on the Nasdaq Global Select Market on December 7, 2018, under the ticker symbol "MRNA." In addition, Moderna has granted the underwriters a 30-day option to purchase up to an additional 3,941,398 shares of Moderna's common stock at the initial public offering price. Moderna's outsized IPO values the company at around $7.5b. This is a huge valuation, particularly for a company that has no products on the market or even in late-stage clinical trials. The offering represents Moderna's distinctive business development strategy and impressive facility for raising money. The IPO deal was underwritten by Morgan Stanley, Goldman Sachs & Co. LLC and J.P. Morgan which are acting as joint lead book-running managers for the offering, BofA Merrill Lynch, Barclays Capital Inc., and Piper Jaffray & Co. that are acting as book-running managers for the offering and

finally Oddo BHF SCA, Oppenheimer & Co. Inc., Needham & Company, LLC and Chardan which are acting as co-managers for the offering. Moderna has been savvy in their fundraising efforts, actually the company raised a total of $2.7 billion in funding over 12 rounds. Their latest funding was raised on July 26, 2020, from a grant round. What seems to be very uncertain is that while most biotech companies might have two or three financing rounds as private firms before considering an IPO, Moderna, which was founded in 2010, remained private and secret, far longer, while raising a cumulative total of $2.6 billions in equity financing, sometimes from investors that had only been given a narrow peek at the firm's scientific data.

2.6 Business activity

Both Moderna and BioNTech with its partner Pfizer commenced deliveries of their Covid 19 vaccines and it's safe to assume that the shots will represent the biggest driver of their revenues over the next years.

Covid 19 vaccine is the first commercial product for both companies, with 2021 being the first full year of sales. At the beginning of mid-January 2020, the project to develop a novel mRNA technology for a Covid 19 vaccine has begun, right after the SARS-Cov-2 genetic sequence was first made public.

BioNtech initiated its project "Lightspeed" and in March they engaged in cooperation with the US company Pfizer and the Chinese company Fosun. By then, the scenery of vaccine development had virtually exploded, actually together they have developed the mRNA vaccine for preventing Covid 19 infections. Covid 19 vaccines were rapidly developed with the aim to mitigate the virus effects on public health and on global economy.

With respect to usual clinical development rules, several vaccines have been put on the market in less than one year. Moreover, all these vaccines were made in order to reduce severe forms of diseases and strongly impacted the mortality by changing the course of the pandemic.

Of course, the vaccine production was followed by clinical trials and its success and safety is the fundamental prerequisite for commercialization and marketing.

Most of these vaccines have shown their safety and efficacy in the first clinical trials and have demonstrated an overall efficacy from 70 to 95% in both phase III trials and real life.

BioNTech together with Pfizer announced that 43,500 people in 6 countries had received a test vaccine against Covid 19 with more than 90 percent effectiveness on November 9, 2020. Based on successful testing, they asked for the right to distribute vaccines in the United States, as well as in the European Union, the United Kingdom and Japan. On December 21, 2020, the US and Europe-based BioNTech vaccine was officially approved. Evidence shows that the increase in the German economy would have been one size smaller in 2021 without the business success of BioNtech with its Covid-19 vaccine. According to the Scientific Director of the IMK, Sebastian Dullien, there was a clear BioNtech effect meaning that the now world-famous company may have contributed about 0.5 percent to the German gross domestic product (GDP) in 2019. This single German company has contributed also to the European growth, actually, Europe's largest economy grew by 2.7 percent in 2021.

Furthermore, while some biotech companies focus on one or few product candidates at the same time, BioNTech has more than 20 products in their pipeline. This deep and broad portfolio of product candidates derived from four drug classes that focused on cancer treatments, infectious and rare diseases. Nowadays BioNTech has already reached the clinical trial stage for eight of its product

candidates. This means that there is a greater potential for the commercialization of a variety of products. Of course, this will ensure a continual stream for the company. This represents good news for investors, but it is even better for ill patients that have unmet medical needs. The term unmet medical needs means that there are not treatment options currently available through medicals and all of this gives patients hope of treatment and possibly even a cure. The fact that eight of BioNTech product candidates have made it to the clinical trial stage and that there are other ongoing clinical trials underway, brings the company one step closer to submission for FDA approval. Once approved, these products will be authorized to be on the market. In 2021, the total commercial revenues of biotech companies stood at some 18.9 billion euros, of which over 18.8 billion were due to the Covid 19 vaccine. Moderna is the first all-American company to receive the US authorization for its vaccine, on December 18, 2020, that is just one week after than the US and Europe-based BioNTech, which was approved on 21 December 2020. While BioNtech and its partner Pfizer gave informations related to the Covid 19 vaccine, Moderna did not. Moderna Covid 19 vaccine is the first medicine of the company to enter in the market ever. Moderna's pipeline shows the progress the company has on clinical programs currently in development, to create mRNA medicines for a wide range of diseases and conditions. The company has 40 programs in development, including 23 in ongoing clinical studies about mRNA infectious disease vaccines and mRNA therapeutics spanning seven different modalities. This pipeline includes nine

vaccines and 13 therapeutic candidates in areas including immuno-oncology and rare diseases.

BioNTech research pipeline is principally focused on cancer drugs while Moderna's is more varied, focusing also on infectious diseases, vaccines, rare diseases and cancer. The firm's mRNA technology was rapidly authorized with its Covid 19 vaccine. Moderna Covid 19 vaccine, also known as Spikevax, it is the vaccine developed by Moderna, the United States National Institute of Allergy and Infectious Diseases, and the Biomedical Advanced Research and Development Authority. Shortly after, Moderna's vaccine has received full approval for the use in individuals aged 18 years or older from the U.S. Food and Drug Administration (FDA). Vaccines distribution complications arise with vaccines' typical refrigeration requirement, this was an early concern, for example, with the ultracold storage need of the Pfizer-BioNTech vaccine, while Moderna's shot is easier to distribute and doesn't need to be stored at those super-cold temperatures. It was authorized for people aged twelve years and older in some jurisdictions and for people eighteen years and older in other jurisdictions to provide protection. Nowadays Moderna's vaccine is accepted in over 70 countries around the world. Obviously Moderna's primary source of revenue is currently through sales of its Covid 19 vaccine, which accounted for about 96% of total revenue while the other 4% involved funding revenues and collaboration revenues.

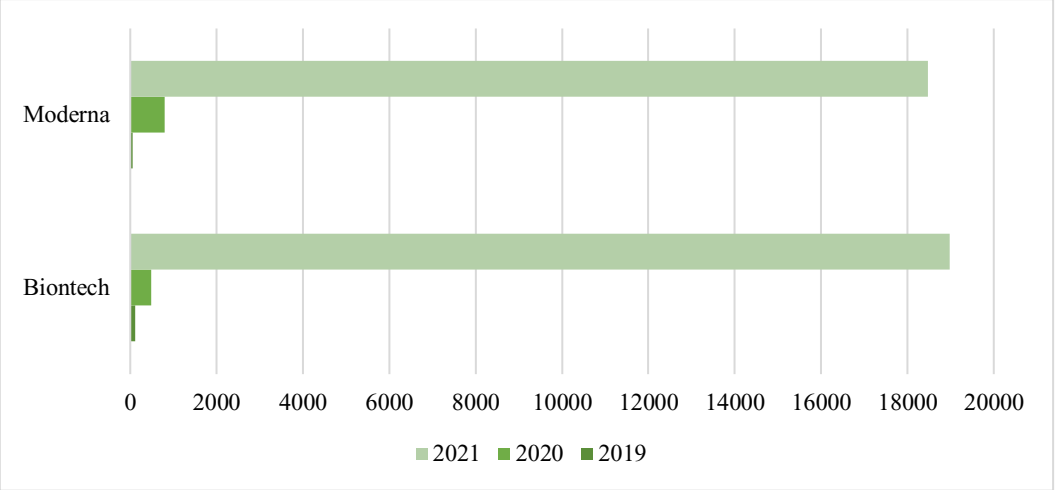

FIGURE 12: Moderna's and BioNtech's revenue growth from 2019 to 2021 in million U.S dollars, Statista database.

Figure 12 illustrates the annual worldwide revenue of BioNTech and Moderna from 2019 to 2021. For the full year of 2021 Moderna total revenue was about $18.4 billions U.S dollars generated from the sales of vaccine million doses. There was a massive rise compared to the previous year when revenues amount was only 803 million. This rise is essentially attributed to commercial sales of its Covid 19 vaccine. While for the full year of 2021 the annual revenues of BioNTech were nearly 19 billion euros, which is increased compared to around 482 million euros in the previous year. As well as Moderna, these revenues are essentially due to the Covid 19 vaccine diffusion and marketing. Another aspect that needs to be analysed is the price to sales ratio. Since the beginning of the pandemic, the price to sales

trend, for BioNtech as well as Moderna, has experienced an increase in 2020 followed by a huge decrease in 2021.

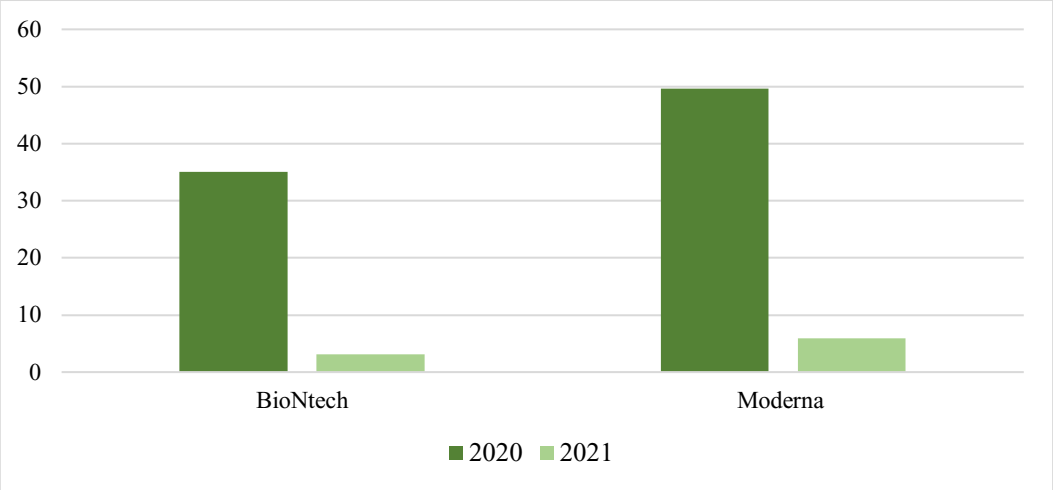

FIGURE 13: Moderna's and BioNtech's price/sales from 2020 to 2021, Crunchbase database.

Figure 13 shows both Pfizer-BioNTech and Moderna price to sales ratio[20]. Price to sale ratio, also known as the P/S ratio, is an indicator used to assess the

[20] Price to sales per share is calculated by dividing the company's market capitalization by its total sales. Market cap is calculated by multiplying current total shares outstanding by latest close price. Sales is last twelve months total revenue. Price to sales per share is not calculated when last twelve months sales is less than or equal to zero. This indicator varies by industry and does not take into account either the financial structure or the indebtedness of a company. Consequently, its use to

value of shares. It is necessary for measuring the total value that investors place on the company in comparison to the total revenue generated by the business. It is calculated by dividing the share price by the sales per share. As suggested by Figure 13, both Moderna and BioNtech have a higher price to sales ratio in 2020 rather than 2021. From 2020 to 2021 BioNtech's price to sales ratio fell from a high of about 35,05 to 3,1. For Moderna its price to sales ratio fell from a high of about 49,59 to 5,93. For both companies, higher price to sales ratio displays a strong market price and equally indicates strong companies. Moreover, the higher price to sales ratio gets, the more money investors are spending to gain a return on investment. There is a completely different situation in 2021, where both companies have lower price to sales ratio. This is a sign that companies are performing strongly and have a good chance of outperforming the general stock market. This represents a value for investors that look to buy in low in order to generate a profit.

compare two undertakings, is based on the implicit assumption that their financial structure is essentially identical.

3. VENTURE CAPITAL

The central topic of this chapter is to shed light on the relevance of venture capital as a source of financing to promote firms' innovation performances. The present chapter work aims to analyze the venture capital operation in two biotech start-ups, namely BioNTech and Moderna, which are realities born respectively in 2008 and 2010, with the idea of making and developing innovative therapeutics to fight human diseases. The decision to analyse venture capital financing depends on the fact that both BioNtech and Moderna have been financed through risk capital in their early-stage financing. Since they have achieved success with their pioneering products, they have become two of the largest biotechs IPOs listing of all time. During this chapter there will be an in-depth review of venture capital literature, and, in addition, it will be highlighted the phases and processes to put a be a venture capital operation and also its role in financing start-ups, especially biotech start-ups. Throughout the years, financial innovation has led to the birth and to a subsequent spreading of a series of alternative channels for financing the productive realities, aimed at promoting investments in risk capital. Firms can be financed by equity capital (i.e. risk capital[21]), debt capital, or a combination of both

[21] The term risk capital is commonly given two different meanings. One is in a broad sense including all kinds of capital that are invested in risky projects. The other is a narrower definition meaning

options. The major difference between these sources of financing is that risk capital providers have a higher expected return than other types of capital providers by taking however a higher risk. For all the firms that do not have the possibility or the will to directly access the official market, they can place the financing through private equity and venture capital's use. While venture capital concerns the financing of new businesses start-up, private equity includes the operations of investments made in companies' life cycle phases subsequent to the initial one[22]. To further confirm this, the European Venture Capital Association refers to venture capital as a form of financing operated by professional investors where the target company is situated in the embryonic phase or start-up of its life cycle of the investment that receives funds in exchange for risk capital, while it refers instead to private equity whenever there is financing to companies already existing on markets, which use this tool to achieve growth objectives, rehabilitation and restructuring. Sahu et al., 2009, define the term private equity as a large sector, within which various activities are carried out, ranging from the financing of nascent companies, a characteristic of venture capital, to more complex operations,

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equity capital. The narrower definition is the one primarily used by researchers, practitioners, and legislating bodies. In some cases, risk capital is defined even more narrowly as: "equity financing to companies in their start-up and development phases" (European Commission, 1998).

[22] L'attività di venture capital e private equity, il Sole 24 Ore Libri.

such as buy-outs[23]. In this view, venture capital is located in the private equity sector.

Often venture capital and private equity terms are used indiscriminately, sometimes as synonyms, while in reality they refer to different methods. According to some scholars, namely Durango Gutiérrez & Arango Vásquez, (2014) and Aizenman & Kendall (2008), there must be a distinction between private equity funds and venture capital funds. Private equity funds, invest and acquire property rights in already established companies, with recurring revenues and with well-defined customers and market while investors, in venture capital, turn to the start-up of new businesses, which are very risky companies and with great long-term growth prospects, especially in their start-up phase. The main element that unites the two types of financing is represented by the presence of an intermediary who, with a view to realize a future capital gain[24], invests in the equity of a company in order to

[23] A buyout is the acquisition of a controlling interest in a company and is used synonymously with the term *acquisition.* If the stake is bought by the firm's management, it is known as a management buyout and if high levels of debt are used to fund the buyout, it is called a leveraged buyout. Buyouts often occur when a company is going private.

[24] The capital gain can be identified as the difference between the issue price and the redemption price, i.e., a capital gain consisting of the difference between the price received at the time of the sale of the investment and the purchase cost gross of ancillary charges.

guide it along a path of growth that often leads to listing on official markets. In the early eighties, venture capital's term was defined as the provision of equity capital or subscription of securities convertible into shares, by specialized operators, over a limited period of time, to unlisted companies with high development potential in terms of new products or services, new technologies and new business ideas. According to this definition, the participation was generally understood as a minority, temporary and aimed at obtaining high capital gain at the time of disposal, since the combination of the new capital contribution and know-how would have led to a significant increase in value. The identified characteristics of venture capital in the early 80s have not changed over the time.

Moreover, it is also worth highlighting the terminological difference between the American and European definitions. The more developed concept of venture capital investing, as we know it today, with subscribers, professional managers, and its own terminology, was however first developed after the Second World in the U.S. War (Gompers, 1994). Since then, venture capital investment has become an institutionalized segment in the general economy. Venture capital is often, especially in Europe, seen as synonymous with "private equity". In the USA, the most widespread practice generally considers private equity activity as an institutional investment activity in risk capital that is divided into venture capital operations or buy-out operations, depending on the type of operator that puts it in place. In addition, within the activity carried out by venture capital it is possible to

identify two subclasses that in turn identify numerous types of investments by virtue of the phase of the life cycle in which the financed company is located. The first one is the early-stage financing that indicates the companies financing in the first years of life, while the second one is the so-called expansion financing that indicates the interventions carried out in already developed and mature companies which need new capitals to consolidate their growth. In Europe, the reference variable is the business phase that is intended to be financed through this operation. In general, through the contribution of new capital by the venture capitalists[25], new products and new technologies can be developed to expand the working capital, to finance acquisitions or to strengthen the financial structure of the society. Private equity can also be used to solve problems related to the company's proprietary aspect, in fact, this is the favourite tool for buy out and buy in operations by experienced managers. Entrepreneurs, that decide to invest in a new innovative company, often have constraints linked to their economic availability in financing their projects. Financial support and capital are necessary in order to support activities such as research, product prototyping, production, patent, legal expenses,

[25] A venture capitalist (VC) is a private equity investor that provides capital to companies with high growth potential in exchange for an equity stake. This could be funding start-up ventures or supporting small companies that wish to expand but do not have access to equities markets. They are operators active in the market that are generically defined in this way regardless of the type of operation.

salaries and marketing expenses. At each stage of an enterprise development, different levels of investment are required, which are always increasing over time[26]. Not all the demand for capital qualifies to obtain financial support and there is always a "funding gap". Not surprisingly, one of the main obstacles to the development of an entrepreneurship lies in access to finance[27]. The gap in the supply of capital for small businesses could be interpreted as a consequence of entrepreneurs' financial decisions. Entrepreneurs tend to prefer internal sources of financing, starting from personal savings, continuing with any retained profits. Not always, however, all this is feasible. It becomes necessary to use debt capital, or new infusions of venture capital. As suggested by Coopers & Lybrand, 1993, many entrepreneurs, especially those who lack from experience and professionalism, fail to identify the right form of financing needed between debt and equity, by tending almost always towards the first one. On the other hand, it happens that traditional investors base their investment choices more on the presence of new company collateral rather than focusing on the business actual quality. This strategy, however, does not go well with a young company characteristics. Start-ups are able to look for capital in the early stages of their life and, as a result, they have limited access to standard capital markets, bank loans or

[26] Cfr. Yetisen et al., 2015).

[27] (Hamilton & Fox, 1998)

particular debt instruments. This phenomenon is very frequent for those companies that operate on technologies frontier and on emerging markets, that are particularly characterized by a high presence of intangible assets and negative earnings projections for several years. In this context, venture capital emerges as a more accessible source of financing in order to support the innovative enterprise growth, for all those entrepreneurs who agree to sell a part of their property rights. The concept of venture capital as a source of investment has been around if there have been individuals prepared to put at risk part of their wealth for a potential gain. Venture capitalists distinguish themselves from other categories of lenders for their innovative investment philosophy. They never aim to take control of the investee enterprises or to increase their shareholding, by definition they are a temporary partner of the enterprise, and their objective is the completion of the financed project in order to allow the return on the invested capital and the consequent mobilization of the investment. In all businesses, venture capitalists must have an investment strategy. This is usually formulated by targeting a special set of investment opportunities, from investing in a certain geographical area or in certain industries for example investing in the biotechnology sector (Gupta and Sapienza, 1992; Norton and Tenebaum, 1993; Carter and Van Auken, 1994). Even though, the biotech industry is one of the riskiest and volatile sectors, because the majority of biotech early-stage companies do not generate revenues for years and have large financial needs to cover expensive clinical trials, this does not discourage investors

to attract and invest increasingly more venture capital and public funding. Over the last ten years the biotech investment sector has been increased bringing significant financial returns for both public and private investors. As it happened for BioNtech and Moderna, most venture capital have been raising and deploying a lot of capital especially in their early-investment phase. Moreover, in the late 1990's, demand side factors also played a fundamental role for the growth in the venture capital industry, as the increase in the supply of venture capital were met by an increase in high technology ideas like biotech industries.

3.1 Biotech start-ups

Start-ups[28], which are young companies in the development phase that have innovation at the center of their business model, have a higher risk in the initial phase than companies already consolidated on the market, a risk that enhances both the possibility of gain and losses. Not all start-ups achieve success and if they manage to achieve success, they benefit from the fact that, having just been started, they generally use a limited amount of both human and financial resources. Start-ups, in fact, are looking for capital already in their early stages of life and, as a result, they have limited access to standard capital markets, bank loans or particular debt instruments. During the start-up process, alongside the formulation of a solid business idea, it is important to ensure the necessary financial resources availability to support the entire project. There is a real financial gap for start-ups that is connected to companies' characteristics and, consequently, it is important that the entrepreneur acquires full awareness of the financial obstacles and tools to

[28] In the economic field, the term "start-up" refers to the period during which a business is started, in English it indicates precisely the verb "to launch", "to start". "A startup is an organization formed to search for a repeatable and scalable business model". Scalability is the possibility of growing a business (in terms of revenues, users, customers) through the use of additional resources (investments, cash, human resources, infrastructure) at a decreasing incremental cost.

overcome this gap. The start of an entrepreneurial experience has very strong financial implications, which are not necessarily concentrated predominantly in the initial phase, but certainly emerge and evolve during the phases of its life cycle. For entrepreneurs, therefore, the ability to know or at least quantify in advance, the initial and prospective business financial needs are required; to estimate their ability to attract and mobilize financial resources independently and to evaluate the largest number of financing sources available on the market. In addition to the criticality of the capital search function for a start-up, it is necessary to ensure a sustainable financial balance over time. The financing of a start-up can take place with different interlocutors, methods and times, variable depending on the stage of development in which the company is located. In the initial phase of the project, mainly the activities of research and development, market analysis, choice of collaborators and planning of activities will be financed. The next step will be the financing of the so-called structural investments aimed at production capacity (equipment, plants, machinery, buildings) and those necessary to ensure business operations, such as the commercial and administrative function activation. The different stages of the company's life correspond to different activities to be financed, needs to be addressed and available sources of financing.

Venture capital financing is preferred by the majority of business start-ups including the biotech ones. Venture capital plays a major role in financing biotech start-ups. It is important to note that most biotech venture firms receive investment

from several sources. Biotech start-ups investments increased during the pandemic as thousands of venture capital firms turned their attention to breakthrough artificial intelligence, cancer-detection technology, mental health treatments, digital doctor visits, diagnostics and more. Biotech start-ups, such as BioNtech and Moderna, which are funded through capital venture, outperform their counterparts in job creation and revenue growth. Most of biotech start-ups financing comes from venture capital and it is not just in terms of money but also in the managerial guidance. This means that venture capitalists provide insights, managerial skills and entrepreneurial spirit to biotech companies. As suggested by Chen, Marchioni, 2008, this is attributable to the fact that biotech, being a knowledge intensive industry, need large amount of capital that is necessary for research and development. Venture capitalists are involved in the development of biotech firm by becoming board of members. Moreover, venture capitalists also advice biotech firms on their potential strategic partnership and give advantages to the venture capital backed firms over the non-venture capital backed firms. The biotech venture activities are clustered in urban centers, where there is a strong life science research base, a large pool of life scientists, large pharmaceutical firms, many venture capital providers and a strong entrepreneurial spirit. The geographic clustering of venture capital financed biotech firms is similar to the geographic pattern of the biotech industry. The biotech business is clustered together in a single region for several benefits. Through clustering, companies achieved scale

economies, have knowledge and technology spill over in addition to labor pooling and decrease in transaction costs. With a large concentration of talent, technology, and tolerance, a favourable environment exists for new ideas and technological breakthroughs (Florida 2003). An urban environment also provides more geographic proximity between various economic agents (Storper and Venables 2004), helps in building trust and facilitating the knowledge communication in biotech industry (Dalpe 2003). In addition, this enhances socialization within the professional network an stimulates co-operation, competition, and innovation. The clustering of biotech industry relies on venture capital availability, life science knowledge, large pharmaceutical companies and urban diversity. The area that are near the science research institutions have better access to train graduated and post-graduate students. As mentioned in the previous chapter, in the biotech industry, most of the investments in venture capital is concentrated in Massachusetts (Gompers, Lerner 2006). Both BioNtech and Moderna have their sites in Massachusetts and many studies suggests the geography role in venture capital investment in the biotech industry. Geography plays a fundamental role in the development of venture capital industry and venture capital clusters become innovative centers for the economy. Massachusetts is the first life science cluster in the world and with a pipeline of engineering and data science talent graduating from world-class institutions, major public investments in innovation infrastructure and research, and a world-leading life sciences workforce, all the biotech companies

locating there are at the center of the next generation of development in advanced biomanufacturing. This proximity encourages people with ideas to communicate and collaborate with people with fiscal resources and business expertise. The Massachusetts Biotechnology Council[29] released its 2021 Massachusetts Biopharma Funding Report which demonstrates continued growth and confidence in Massachusetts' world-leading early-stage R&D cluster. Following record-breaking numbers in 2020, 2021 saw an increase of 70 percent, $13.66 billion in total, in venture capital funding to Massachusetts-based biopharma companies. This increase in venture capital funding mirrors international trends, and provides additional capital which will drive a continued and significant growth of labs, biomanufacturing, and jobs across the world. The increase in venture capital funding going to Massachusetts biopharma companies, is the result of this little state success as the leader of early-stage R&D. The increase in venture capital funding

[29] MassBio is a not-for-profit organization founded in 1985 that represents and provides services and support for the #1 life sciences cluster in the world. It is an association of more than 650 biotechnology companies and its mission is to advance Massachusetts' leadership in the life sciences to grow the industry, add value to the healthcare system, and improve patient lives. MassBio represents the premier global life sciences and healthcare hub, with 1,500+ members dedicated to preventing, treating, and curing diseases through transformative science and technology that brings value and hope to patients.

was paired then with a strong IPO market for emerging biotech companies and this is what happened to BioNtech and Moderna object of this analysis, which became IPO respectively in 2019 and 2018. As new biotech companies are launching every day across Massachusetts, investors want to be involved from the start, not only for potentially good returns, but also for the chance of playing a role in the creation of a breakthrough medicine.

3.2 The structure of venture capital process

Venture capital process is about how both venture capitalists and entrepreneurs develop their businesses. Investors (fund providers), venture capitalists, and entrepreneurs are the main actors involved in the venture capital process. Venture capitalists and investors represent the supply side of venture capital whereas the entrepreneur represents the demand side. As suggested by Amit et al. 1998 venture capitalists serve as intermediaries between investors and entrepreneurial firms in need of growth capital, i.e., they act both as a supplier of capital (financial and non-financial) to entrepreneurs and a seeker of capital from investors. In addition, there is mutual trust relationships between actors involved. If one of these actors loses this trust, the relationships will be damaged (Shepherd and Zacharakis, 2001). In these relationships exist different kinds of interaction and the most important is the relationship between investors and venture capitalists. The reason why investors want to enter in a relationship with venture capitalists is because they believe that venture capitalists are more effective in evaluating and developing entrepreneurial ideas (Amit et al.,1998). In the early stage of the fund formation process, investors have the strongest influence. As suggested by Bygrave and Timmons, 1992; Fried and Hisrich, 1995, the venture capital company is relatively free to operate as it sees fit once the agreement has been settled. The other relationship that should be analysed is between the venture capitalist and the

entrepreneur. Venture capitalists pursue a relationship with entrepreneurs who have business ideas and who also are prepared to share the ownership and control with them. Instead, entrepreneurs have relationships with venture capitalists in order to gain access to financial capitals, different networks, customers, by trying to retain maximum control over their firms. As suggested by Smith, 2001, the issue of ownership and control between venture capitalists and entrepreneurs might cause some difficulties in their relationships. The process of venture capital companies takes the form of a venture capital cycle since venture capital management companies don't raise funds continuously but periodically. Briefly, a complete venture capital cycle involves the following steps: raising funds, screening & due diligence, investment, monitoring & value added, and exit which include generally an IPO. Moreover, a new cycle begins after one is concluded. It is important to underline that the phases in the process are not always developed in a logical and sequential order and each of the phases is connected to the others and involves a wide range of stakeholder. Venture capital management companies are simultaneously involved in more than one fund.

3.2.1 Fundraising

According to Gompers and Lerner, 1998, venture capital process starts when the venture capital firm start its operations by raising funds. Once funds have been raised, the venture capital investment activity begins. Funds are frequently collected from a variety of sources such as banks and pension funds. The most important reasons for placing money in a venture capital fund is high return. As suggested by Gompers and Lerner (1998) *"regulatory changes affecting pension funds, capital gains tax rates, overall economic growth, and research and development expenditures, as well as firm-specific performance and reputation, affect fundraising"*. Another important aspect developed by Gompers and Lerner (1998) and Jeng and Wells (2000) is that governments can play a strong role in influencing the growth of venture capital investing. In order to affect venture capital investments there must be a creation of new conditions or a modification of the existing ones. What Gompers (1996) highlights is also the so-called grandstanding, which can be summarized as the need for young venture capital firms to signal their ability to potential investors. Venture capitalists have an investment strategy which is usually formulated by targeting a special set of investment opportunities like geographical area or a certain industry[30]. Other parameter concerns when to place

[30] Gupka and Sapienza, 1992; Norton and Tenebaum, 1993; Carter and Van Auken, 1994.

funds strategy in the stage in the development of a venture. Investments can be placed into the pre-seed, seed, start-up and expansion phases of the development of a venture. The selection of stages contributes to the risk and return profile of the venture capital fund, for example early stages usually imply high risk and a high expected return[31]. Venture capitalists, in order to minimize risk, take an active role in the development of their portfolio firms, for example by being part as the firm board. Funds that place their investments in later stage investments focus more on the long-term goals and less on daily routines in the firm. Gompers, 1995; Sahlman, 1990, suggest that investors must place investments according to specific milestones in order to control the risk of early stage. Kiholm and Smith, 2000, remark that investors provide funding when specified milestones have been reached.

[31] Kiholm and Smith, 2000.

3.2.2 Deal flow

The following step is the "deal flow" phase, which aims to seize investment opportunities. According to Sweeting, 1991 there are two different approaches, the proactive and the reactive approach, through which venture capital companies discover new venture opportunities. In the proactive approach venture capitalists are actively seeking up potential entrepreneurial firms to invest in, while, the reactive approach implies that venture capitalists wait for the business plan proposals to arrive. Most of the time the behaviour of venture capitalists in seeking out deals was to wait passively for deal proposals to be put to them. Also, Sweeting (1991) found that most deals were referred by third parties and that venture capitalists rarely try to discover new investment opportunities proactively. The main conclusion was that venture capitalists almost without exception were applying a reactive, passive approach to deal generation. Deal flow is in turn divided into "screening" and "selection". With screening, the venture capitalist identifies the most interesting projects based on some documents presented by the entrepreneurs, where profitability, competitive advantages and development strategies of each project are highlighted. Then, venture capitalist selects the most advantageous projects among those previously identified and obtains from the entrepreneurs the related business plans which determines the objectives that the entrepreneur wants to achieve with his new company, the strategy the venture

capitalist intends to use to achieve them and, moreover, it serves to highlight all the problems and dangers that may arise during this journey.

3.2.3 Investment decision

The investment decision may be divided into investment evaluation, valuation, contracting and financial structuring. In the investment evaluation research has shown that for each project that is accepted, venture capitalists reject most of the proposals in the screening process (Mason and Harrison, 1999). The investment evaluation phase includes a complete examination of the venture (due diligence), which then receives funding based on very specific conditions. A study conducted by Tybjee and Bruno (1981) found that venture capitalists spend almost fifty per cent of their time screening and evaluating. Selecting new entrepreneurial enterprises is not easy considering the difficulty that investors have in estimating their potential and the high risk of failure. Determine the firm's value is an important step of the negotiation process. The valuation process is necessary to reach an acceptable and suitable price for the deal. The investor must be able to recognize projects with the greatest potential, evaluate future revenue and profitability and calculate a fair price for trading. As soon as the evaluation process is completed the deal structuring is reached. Venture capitalists as external investors, they must judge between risky projects, control for the risks they undertake and add value to those firms that they select. In this phase, the clauses of the contract between the investor and the entrepreneur are regulated, concerning, for example, management practices, profit-sharing rules, management costs, the

constraints of conduct for the company, the criteria for the contribution of capital and mainly the disinvestment methods by the venture capital. Interactions between venture capitalists and entrepreneurs, that negotiate on a potential investment, are subject to scrutiny. In fact, conflicts may easily arise due to divergent expectations about their roles in the future. As indicated by Barney et al., 1994, the established roles are subject to contracts and that's why the initial contract between the parties may be viewed as the beginning of a successful co-operation. This justifies all the time spent on negotiation and contract writing. Landström et al. (1998) suggests that the negotiation process that led to a final contract is intended to create a mutual understanding between the actors. The transfer of capital and competences from venture capital to the enterprise is at the heart of venture capital investment. The transformation of competence is done in the value adding phase while the transformation of capital can be seen as the final ending of the investment decision phase. Nonetheless, as suggested by Kiholm and Smith, 2000 all capital is provided through many stages often according to predefined milestones. Through this multi-stage organization, venture capitalists are able to better control the management and the operation of the portfolio business (Sahlman, 1990).

3.2.4 Value adding and monitoring

The penultimate stage is the value added and monitoring, with the aim of protecting the capital contributed to the start-up. As part of a venture capital transaction, monitoring is the set of activities aimed primarily at examining the performance of the investee company and defining actions to promote its growth in value and to allow the investor to choose the most appropriate time for the way-out, to maximize the return on investment; a further purpose is the verification of the obligations provided for by the contract. Monitoring allows the intermediary to reduce the degree of ex-post information asymmetry and the problem of moral hazard and free riding by the entrepreneur and management. The problem of information asymmetries arises when the investor has to evaluate the uncertainties about the capabilities of the proposers of an initiative, its validity and its potential; it also arises for the entire duration of monitoring, since the intervention of the investor never implies full involvement in the daily management of the company, which remains entrusted to the entrepreneur and the management of the company whose skills and competences are one of the main motivations behind the investment. Alongside the problems of information asymmetries, there must consider the presence of significant agency costs borne by the investor, also related to the impossibility, on the part of the investor, to fully control the work of the entrepreneur and management, to verify that their activity complies with the

established plans. In fact, they may be induced not to engage fully in the development of the enterprise or to adopt opportunistic behaviours aimed at increasing their private benefits deriving from the management of the enterprise to the detriment of the interests of the fund; can implement strategies significantly different from those agreed with the investor or adopt strategies that involve a non-optimal level of risk, in the knowledge that the same is also borne by third parties. For example, in the case of biotech companies, the proposer/researcher could also have an interest in research projects other than those being invested, possibly to increase his reputation in the scientific community with the effect of reducing his commitment to the funded initiative by jeopardizing the potential return for the investor. The adoption of actions aimed at improving the performance of the company is subject to evaluation by the investor and is a necessary condition to carry out the entire financial intervention provided for by the contract; in fact, stage financing provides the investor with an effective monitoring tool, since it conditions each stage of financing to the ex post verification of the adoption of behaviours, of the entrepreneur and of the management, such as to allow the final results to comply with those envisaged in the plan. The role of the venture capitalist continues after the investment is made in the venture. Venture capitalists take an active role in the development of their portfolio firms, for example, by participating on the board of directors, by acting as a sounding board to the management of the firm or by helping with contacts and networks. By their active governance, venture capitalists have the

opportunity to transfer their resources and competencies for example skills, networks and reputation to the firm in which they have invested. The ability to create value in the firms in which venture capitalists have invested is essential for the existence of the venture capital market. The role of venture capital is therefore not only that of the fund lender but is also active within the company management.

3.2.5 Exit

The final stage is obviously that of the "exit", or divestment. The exit is the process that allows venture capitalists to realize their returns. Venture capitalists can exit at different stages of the process and the right decision on how and when to exit significantly impacts on the return of the investment. Bygrave *et al.* (1994) discuss the exit issue. Relander *et al.* (1994) introduce the concept of exit strategy while Black and Gilson (1998) highlighted the importance of exit mechanisms for a venture capital industry. This phase can be partially regulated by contractual clauses that have already been previously recognized in the "deal structuring". A reason why exits are of such importance in the venture capital industry is that ventures in the early stages of their development are not in a position to pay dividends to owners. Those at following stages use capital for growth and expansion. Since firms have difficulties to pay out dividends in times of financial need, most venture capitalists prohibit their payment through contractual agreement. Therefore, the main return that venture capitalists get from their investments is the profit they obtain from the sale of their holdings in the ventures. In this section, we discuss the five main types of exit strategy used by venture capitalists to divest their portfolio companies. The five exit methods typically considered for venture capital are as follows:

- Initial public offer (IPO) is public offer of shares of a company that is listed for the first time in a market. Venture capitalists will typically not sell their shares into the public market at the date of the public offering. Reasonably, securities will be sold into the market over a period of months or even years following the public offering. Otherwise, after the offering the venture capitalist may dispose of its investment by making a dividend of investee firm shares to the venture capitalists' owner. IPOs is the most important determinant of venture capital investing. Cummings and Macintosh (2002) said that IPOs are the preferred exit mechanism for highly valued firms. Lerner (1994), in a study of 350 biotech companies, found that venture capital backed companies usually made their IPO at higher market values than companies without VC backing.
- Trade sale (or acquisition) refers to the sale of the whole venture to another company. When the venture capitalist exit to a third party who purchases the entire venture there is the trade sale exit. In order to accomplished this, it is necessary to structure the transactions as a sale of all the shares of the firm, in return for cash, shares of buyer or other assets.
- Management (or secondary sale) refers to venture capitals firm's sell their part of the venture's shares only. Another method trough which ventures capitalists may exit is by means of a sale of its shares to a third party. This type of exit differs from an acquisition in that only share belonging to the venture capitalist

are sold to the third party, which will be often a financial institution or another venture capitalist.

- Buyback refers to the repurchase of shares by the entrepreneur. In a buyback, the entrepreneur repurchases the shares held by the venture capitalist. Buyback can be an effect of the exit clauses that are written in the initial contract between the venture capitalist and venture. As suggested by Cumming, 2002, for the venture capitalist there can be a clause in the shareholder agreement that forces the founder to buy out the venture capitalist if an trade sale or an IPO has not occurred within a certain timeframe.
- Write-off, reconstruction, liquidation when the company files for bankruptcy and represents the worst-case scenario. It occurs when the venture fails, and the venture capitalist tries to minimize its losses. Failure, on the other hand, would result in a so-called "write-off" situation, in which the venture capitalist decides to abandon the investment. The investment may be written off or forced into liquidation or bankruptcy. Reconstruction could be another alternative. This involves a complete acquisition by the venture capitalist, the dismissing of the entrepreneur and the engaging a new management team in the hope of recovering all or part of the investment in the future. In the event that the venture failed there may be something worth recovering, such as assets, technology or patents.

As suggested by Bygrave and Timmons, 1992, venture capital companies have a time limit for the investments and usually the time horizon can be in the range from 3-4 years up to 10 years, usually depending on the venture capitalists' investment strategy. Even though exit strategies are the last part of the process, they are considered throughout all the investment periods. Venture capitalists do not consider making an investment unless they have a good idea about a possible exit scenario. Usually, venture capitalists seek to take public (IPO) the most successful firms in their portfolio, and this generates the amount of their returns. The goal of the venture capitalist is to increase the value of the target company in order to achieve a reasonable capital gain. A small number of these are the source of most of their returns while the second most important method is selling the company to a corporation, namely M&A[32].

[32] Mergers and acquisitions (M&A) is a general term that describes the consolidation of companies or assets through various types of financial transactions, including mergers, acquisitions, consolidations, tender offers, purchase of assets, and management acquisitions.

4 DATA SOURCE AND METHODOLOGY

This last chapter is dedicated to data sources and methodology. The main aim of this analysis is to investigate the correlation between BioNtech and Moderna with some market indicators. The market indicators used in this analysis are: Vix, Nasdaq, Nasdaq Biotechnology index and Brent future. A brief explanation of these indicators is necessary to better understand the analysis purpose. The volatility index, also called VIX, is one of the most common tools for measuring market sentiment. For traders, the VIX is not only a useful tool for assessing risk, but it is also an opportunity to take advantage of volatility[33] itself. Actually, on a global basis, it is one of the most recognized measures of volatility. Then, there is the NASDAQ which is a stock index of the U.S. stock exchange Nasdaq and represents all companies listed on that market and as a broad index heavily weighted toward the important technology sector, it has become a staple of financial markets reports. After that, there is the NASDAQ Biotechnology Index that contains securities of

[33] Volatility is a rate at which the price of a security increases or decreases for a given set of returns. Volatility is measured by calculating the standard deviation of the annualized returns over a given period of time. Volatility measures the risk of a security. Volatility indicates the pricing behavior of the security and helps estimate the fluctuations that may happen in a short period of time. If the prices of a security fluctuate rapidly in a short time span, it is termed to have high volatility. If the prices of a security fluctuate slowly in a longer time span, it is termed to have low volatility.

NASDAQ-listed companies classified according to the Industry Classification Benchmark as either biotechnology or pharmaceuticals. This index is calculated under a modified capitalization-weighted methodology. Finally, we see the brent futures that refers to the Brent Crude oil which is a major benchmark price for purchases of oil worldwide. After all of this, we have also analysed the volatility in the M-Garch model. In the following chapters, we will use the correlation matrix to understand how biotech companies did not follow market development trends. Specifically, there will be an analysis of the stock market behaviour of two biopharmaceutical companies, namely BioNtech and Moderna, during the Covid pandemic in comparison with the pre-crisis period. So, the relationship between the returns of BioNtech and Moderna and the technology market index, the biotechnology index, market volatility and brent during the pre and Covid period will be analysed.

4.1 Materials and methodology

The database used in the analysis consist of daily returns of Moderna, BioNtech, Nasdaq, Nasdaq Biotechnology Index, Vix and Brent futures.

The database comprises 812 observations from Dec 7, 2018 – date on which Moderna listed on the Nasdaq – to Feb 28, 2022. For the analysis, two samples were used, the pre-Covid period (from Dec 7, 2018, to Mar 10, 2020) and Covid period (from Mar 11, 2020 – date on which WHS[34] declared Covid a pandemic – to Feb 28, 2022).

Furthermore, you can see a conducted analysis for Moderna and one for Biontech.

The daily returns were calculated following the Campbell et al. method:

$$Ri_t = \ln(Pi_t) - \ln(Pi_t)$$

where Pi_t is the close price of stock/index *i* (Biontech, Moderna, Nasdaq, Nasdaq Biotechnology Index, Vix and Brent) at time *t*.

[34] Founded in 1948, World Health Organization is the United Nations agency that connects nations, partners and people to promote health, keep the world safe and serve the vulnerable – so everyone, everywhere can attain the highest level of health. WHO leads global efforts to expand universal health coverage.

4.1.1 Methods

A GARCH (1,1) Model (Bollerslev, 1986) was used to test the returns and volatility behaviour of Biontech and Moderna:

$$y_t = x_t\beta + \in_t$$

$$\sigma_t^2 = \gamma_0 + \gamma_1 \in_{t-1}^2 + \gamma_2 \in_{t-2}^2 + \cdots + \gamma_m \in_{t-m}^2 + \delta_1\sigma_{t-1}^2 + \delta_2\sigma_{t-2}^2 + \cdots + \delta_k\sigma_{t-k}^2$$

where y_t is the conditional mean; σ_t^2 is the conditional variance; $\in_t^2$ is the squared residuals; γ_i are the ARCH parameters; and δ_i are the GARCH parameters. Specifically, the method proposed was:

a. Mean model

$$Ri_t = \beta_0 + \beta_1 ndq_t + \beta_2 ndb_t + \beta_3 vix_t + \beta_4 bnt_t + \in_t$$

b. Variance model

$$\sigma_t^i = C_i + \gamma_i \in_{t-1}^2 + \delta_i \sigma_{t-1}^2$$

where Ri_t is the daily returns of i in (4) being i Biontech or Moderna σ_t^i is the variance of the residuals derived from Eq. (4); C_i is the constant, $\gamma_i \in_{t-1}^2$ is the ARCH parameter, $\delta_i \sigma_{t-1}^2$ is the GARCH parameter, and β_i is the coefficient of the variables (NASDAQ return, NASDAQ BIOTECHNOLOGY INDEX return, variation of VIX and BRENT return). Dynamic conditional correlations (DCC-GARCH (1,1)) were used to analyze the dynamic co-movements (Engle, 2002). To secure the covariance stationarity of the conditional variance, parameters γ_0, γ_1 and δ_1 should be less than one. In the same way, the sum of γ_1 and δ_1 should be less or equal to one to maintain stability (Corbet et. Al, 2020).

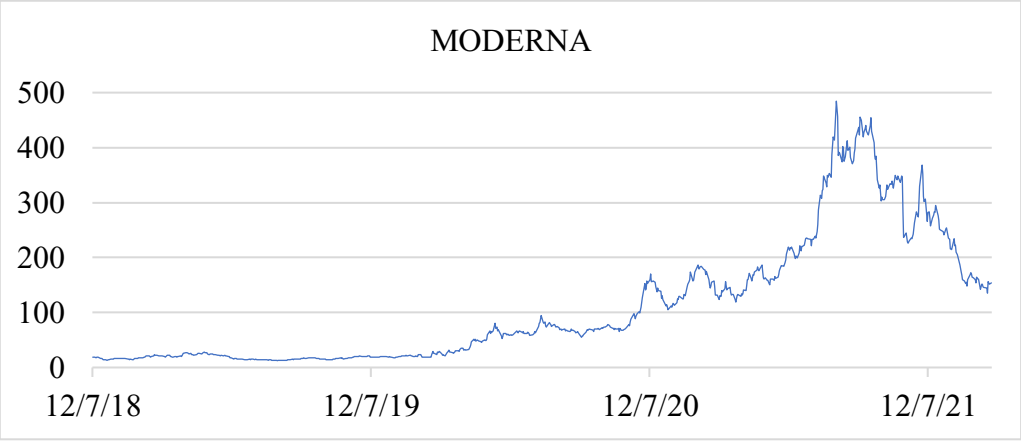
4.2 Results

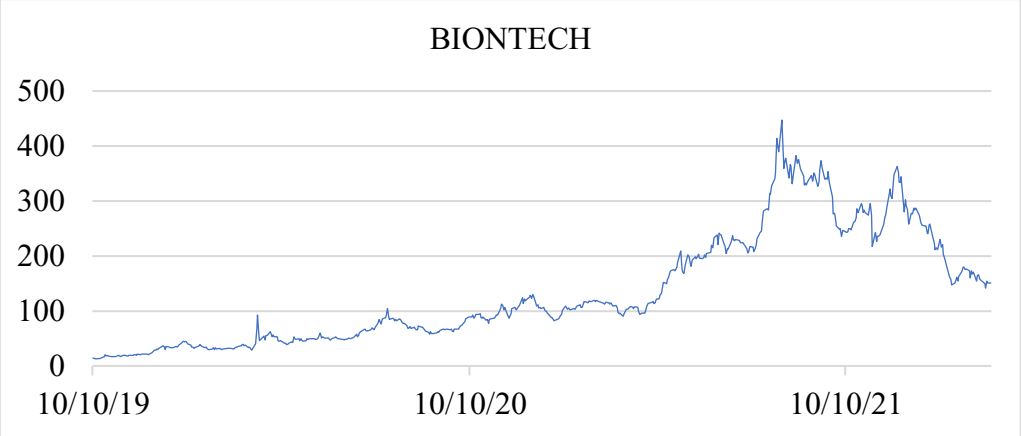
At the beginning of the study period, at the time of the IPO, the price of Moderna was $18.6 and of Biontech was $13.82.

The share prices of the two companies after the listing go up. On March 11, 2020, WHO declares the pandemic and since then the rise in the prices of the two securities began to occur.

FIGURE 14 shows the quote of the two companies from the IPO to the end of period analysed.

Figure 14: *Price of Moderna and Biontech at Nasdaq.*





From Figure 14 we can see how up to Mar 11, 2020, the share price of the two companies show a stable pattern without showing excessive volatility. The maximum price recorded by Moderna is less of $30 on Mar 6, 2020, a few days before that WHO declared pandemic. Biontech, listed for a few months, recorded its maximum values of $45 on Jan 8, 2020. Between this period and the announce of the effectiveness of vaccine the respectively share prices being to increase. On Nov 9, 2020, Pfizer, that developed the vaccine together with Biontech, announces the effectiveness of its product. The same does Moderna a week later, on Nov 16. After this period the two companies show a very marked rise in prices. In fact, on Nov 9, 2020, the stock price of Biontech was $104.8 while on 6 Nov, last market day before the announcement, was $92, with an increase of 13,91% on just one day. In the same way, on Nov 16, 2020, the stock price of Moderna was $97.95, with an increase of 9.57% compared to the previous trading session when it was $89,93. On 11 and 18 Dec 2020, the two vaccines have received approval in USA from Food

and Drug Administration and successively they have received approval and began to be administered in many states. The rise in the share prices of the two companies continued throughout the period analysed. On Aug 9, 2021, Biontech and Moderna reached their maximum value on Nasdaq. Biontech's stock price achieve $447,23 with a market capitalization over $100 B while Moderna's achieve $484,47 with a market capitalization over $200 B. At the end of analysed period Biontech's stock. We have chosen to use these variables because they approximate the market condition well. In particularly, the two companies are quoted on Nasdaq, and they are part of the Nasdaq Biotechnology Index – they are biotech companies – so we use the Nasdaq to benchmark index for the stock market. We use the Vix index to indicate the variability to the US stock market and the expectations of operators. The Brent value is used to approximate the market sentiment. Table 1, in the pre-Covid period, and 2, in the Covid period shows the descriptive statistics of the variables.

TABLE 1. Descriptive statistics for the pre-Covid period.

	MRNA	BNTX	NDQ	NBI	VIX	BNT
Mean	.0005835	.0084381	.0005735	.0002589	.0022645	-.0016081
Variance	.0022338	.0049101	.0001677	.0002126	.00706	.0007436
Min	-.1980474	-.1763963	-.0756658	-.0708563	-.1981435	-.2757515
Max	.2453797	.2372936	.0567238	.0598368	.3821669	.1363918
Skewness	.6531617	.2850929	-.6538439	-.1981961	1.070528	-3.113452
Kurtosis	7.571301	3.749706	9.139862	5.754153	5.805668	37.02359

MRNA: Moderna returns; BNTX: Biontech returns; NDQ: NASDAQ returns; NBI: Nasdaq Biotechnology Index returns; VIX: variation of VIX; BNT: Brent return. Period range: Dec 10, 2018 – Mar 10, 2020. Observations: 314 and 103 for BNTX.

TABLE 2. Descriptive statistics for the Covid period.

	MRNA	BNTX	NDQ	NBI	VIX	BNT
Mean	.0038792	.0029997	.0010751	.0002491	-.0009061	.0020084
Variance	.0029763	.0044219	.0003173	.0003215	.0029763	.0010688
Min	-.1971629	-.4391793	-.1314915	-.1015873	-.1771629	-.2797615
Max	.2180602	.5098251	.089347	.0682002	.2180602	.190774
Skewness	.0906095	.40611129	-.8765345	-.2686425	.0906095	-.8699473
Kurtosis	4.65349	15.03457	13.0562	6.989203	4.65349	19.05509

MRNA: Moderna returns; BNTX: Biontech returns; NDQ: NASDAQ returns; NBI: Nasdaq Biotechnology Index returns; VIX: variation of VIX; BNT: Brent return. Period range: Mar 11, 2020 – Feb 28, 2022. Observations: 497.

The main indicators are skewness that show the asymmetry of distribution. Both in the Pre and the Covid period are close to zero except, in the pre-Covid period for Vix, equal to 1, and for BNT which shows a negative asymmetry equal to 3. About the kurtosis, in both period the variables show a leptokurtic distribution with the maximum value reached by BNT and BNTX and VIX in the Covid-period.

The Kurtosis, the relative width of the distribution, is always positive and indicates higher returns distributions than normal ones. The correct value, in such a way that the distribution can approach a normal one, should be about 3. The skewness, asymmetry of the distribution around the sample averages whose value should be 0, is negative for NBI, NDQ and BNT.

Following in the analysis, TABLE 3 and TABLE 4 show the correlation between the variables.

TABLE 3. Correlation matrix for the pre-Covid period.

	MRNA	**BNTX**	**NDQ**	**NBI**	**VIX**	**BNT**
MRNA	1					
BNTX	0.1102*	1				
NDQ	0.1225*	0.1558	1			
NBI	0.2212***	0.1531	0.7655***	1		
VIX	-0.1227*	-0.0810	-0.8101***	-0.6456***	1	
BNT	0.0981*	0.1418	0.4797***	0.3916***	-0.3611***	1

MRNA: Moderna returns; BNTX: Biontech returns; NDQ: NASDAQ returns; NBI: Nasdaq Biotechnology Index returns; VIX: variation of VIX; BNT: Brent returns. Period range: Dec 10, 2018 – Mar 10, 2020. Significance level: *0.1 (0.08), **0.01 (0.13), ***0.001(0.17).

TABLE 4. Correlation matrix for the Covid period.

	MRNA	BNTX	NDQ	NBI	VIX	BNT
MRNA	1					
BNTX	0.5441***	1				
NDQ	0.1116*	0.1973***	1			
NBI	0.3912***	0.3712***	0.7913***	1		
VIX	-0.0604	-0.1273**	-0.6872***	-0.5442***	1	
BNT	-0.0640	-0.1124*	0.2705***	0.1930**	-0.2837***	1

MRNA: Moderna returns; BNTX: Biontech returns; NDQ: NASDAQ returns; NBI: Nasdaq Biotechnology Index returns; VIX: variation of VIX; BNT: Brent returns. Period range: Mar 11, 2020 –Feb 28, 2022. Significance level: *0.1 (0.08), **0.01 (0.13), ***0.001(0.17).

The correlation matrix both in the Pre Covid period show a positive and significant correlation between the daily returns of Moderna and all variables except the Vix index that showing a negative correlation. In the Covid period the correlation is positive and significant for NDQ and NBI but is negative and not significant with VIX and BNT. This is due to the nature of the VIX index that measures the volatility of the stock market and therefore the risk associate with it. Comparing Moderna returns with Biontech returns the same behaviour appear, both in the pre and Covid period but for the former the values are not significant. In a period like March 2020

when the world economy had to stop suddenly due to the pandemic it explains how the traditional economic indicators such as traditional sectors of stock market and oil price have decreased while market volatility showed high fluctuations. The biotechnology sector and its constituent companies have shown an uptrend given the importance assumed.

TABLE 5**.** GARCH estimations pre-Covid period.

Variables	**MRNA**	**BNTX**
Mean equation		
NDQ	-.2523498 (.3195246)	.7582596 (.9156187)
NBI	.9733648 (.2169451)***	-.1686779 (.6465262)
VIX	-.0679926 (.0325486)*	.0463199 (.1111356)
BNT	-.0011065 .0990681)	.2014045 (.2815738)
Cons	-.0005922 (.0021455)	.0088268 (.0057491)
Variance equation		
ARCH	.4160375 (.1178873)***	.5172338 (.2390093)*
GARCH	.3391642 (.0809415)***	.0822612 (.2519597)
Cons	.0005983 (.0001153)***	.0020732 (.0010493)*
Log likelihood	555.4634***	136.3391

MRNA: Moderna returns; BNTX: Biontech returns; NDQ: NASDAQ returns; NBI: Nasdaq Biotechnology Index returns; VIX: variation of VIX; BNT: Brent returns. ARCH: ARCH parameter; GARCH: GARCH parameter; Cons: constant.

Significance level: ***0.001, ** 0.05, *0.1. Period range: Dec 12, 2018 – Mar 10, 2020.

TABLE 6. GARCH estimations Covid period.

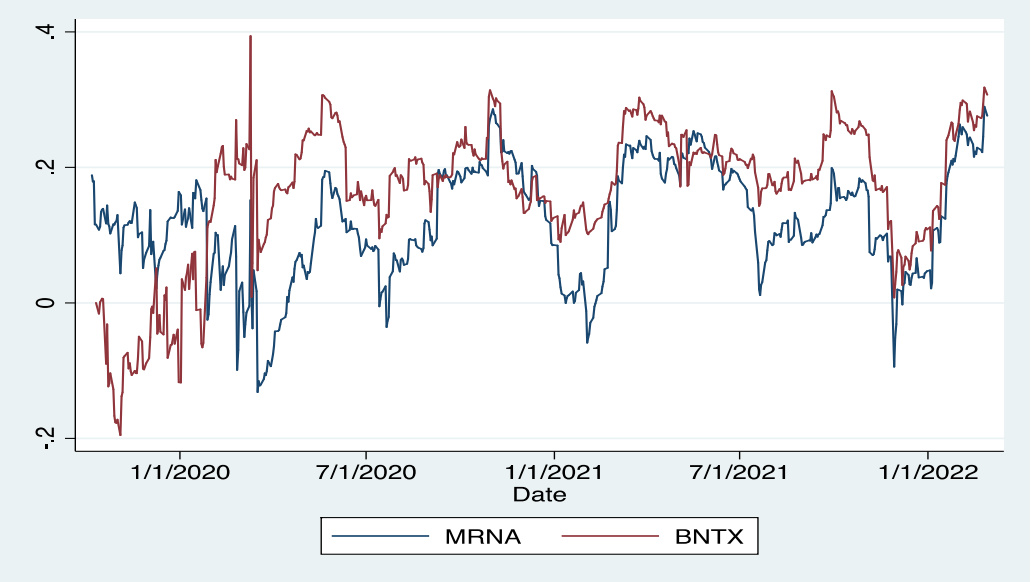
Variables	MRNA	BNTX
Mean equation		
NDQ	-.5227791 (.1881532)**	-1.091522 (.1997819)***
NBI	2.264236 (.1483142)***	1.933076 (.1795379)***
VIX	.0687909 (.0262216)**	-.0267175 (.0364153)
BNT	-.1350655 (.060464)*	-.2271646 (0.396101)***
Cons	.0029639 (.0020396)	.004671 (.0023003)*
Variance equation		
ARCH	.2000849 (.0362015)***	.2953585 (.070235)***
GARCH	.6827308 (.0572928)***	.2591442 (.136669)*
Cons	.0002761 (.0000842)**	.0013503 (.0003035)***
Log likelihood	842.0375***	768.4804***

MRNA: Moderna returns; BNTX: Biontech returns; NDQ: NASDAQ returns; NBI: Nasdaq Biotechnology Index returns; VIX: variation of VIX; BNT: Brent returns. ARCH: ARCH parameter; GARCH: GARCH parameter; Cons: constant. Significance level: ***0.001, ** 0.05, *0.1. Period range: Mar 11, 2020 – Feb 28, 2022.

The ARCH coefficients are significant in all models, meaning that the volatility of Moderna and Biontech in the previous day influenced the volatility of Moderna or Biontech, which is higher, for Biontech, in the two period. The Moderna GARCH coefficient is also significant indicating that market volatility of the previous day influenced the volatility of Moderna, which is higher in the Covid period. Regarding Biontech the GARCH coefficient is not significant for pre-Covid period but the Wald test show that the ARCH 1 and GARCH 1 coefficient are significantly different form zero. Then the model is correctly specified. It can be concluded that the GARCH (1/1) model is suitable for modelling Moderna and Biontech volatility. Comparing both companies, the market volatility, GARCH coefficients, are a greater and significant influence on Moderna's volatility than on Biontech's volatility, suggesting a different reaction of them to market volatility during these periods.

Furthermore, both companies show an ARCH coefficient that in the Covid period is almost double compared to the pre-Covid period. For the GARCH coefficient the opposite occurs. In fact, from pre to Covid period this coefficient more than doubles.

FIGURE 15. Dynamic correlation of Moderna and Biontech with Nasdaq index.



Reference period: Oct 2019 – Feb 2022.

FIGURE 15 shows the dynamic correlation of Moderna and Biontech. During the Covid period the dynamic correlation increased considerably compared to the pre-Covid period, showing a clear effect between these variables.

These results suggest that the biopharmaceutical companies that developed the vaccine could have a positive effect on the market, avoiding the downturn derived from the lockdown and the activity stoppage in most economic sectors.

4.3 Discussion

The analysis investigates the correlation between Biontech and Moderna with some market indicators: Vix, Nasdaq and Nasdaq Biotechnology index and brent futures to the M-Garch model. The correlation matrix is fundamental because in the post period analysed characterized by a high level of risk and market recession, it is necessary to investigate how some companies such as those in the biotechnology sector that should help bring the economy back to a stage of development, do not have followed market trends.

The study conducted on correlation and conditional variances led to a better understanding of the dynamics of the returns of these two assets related to the market variables, showing integration aspects. Another interesting aspect revealed by the analysis was the fact that the two assets increased their volatility after March 2020 and correlation have also been affected by this event.

The aim was to analyze the stock market behaviour of biopharmaceutical companies during the Covid pandemic in comparison with the pre-crisis period. To this end, two companies that were the first to develop the vaccine using the innovative messenger RNA method, Moderna and BioNTech, were considered. Specifically, the paper has analysed the relationship between the returns of both companies and the technology market index, the biotechnology index, market volatility and brent during the pre and Covid period.

The results obtained indicate that the returns of both companies behaved differently depending on the period considered.

The volatility has also analysed through a GARCH model. The results obtained indicate that the volatility of both companies changed from one period to the next. During the pre-Covid period the companies' volatilities of the previous day, arch, was higher than the market volatility of the previous day, GARCH.

However, during the Covid period the opposite was true. In line with the study of Baker et al. (2020), this change can be due to the situation of trading and individual mobility restrictions established during the Covid period.

Furthermore, it was shown that the market volatility, GARCH, on Moderna volatility during the Covid period is greater than on Biontech's volatility. This result highlights that both companies performed differently during the studied period. Specifically, Biontech was less interested by market volatility. This results and the evolution of stock prices of Moderna and Biontech and the Nasdaq indicate the possibility of the existence of contagion effect between Moderna and Nasdaq and Biontech and Nasdaq.

Therefore, an analysis of the dynamic conditional correlations was carried out. The results obtained showed that during the pre-Covid period there was no co-movement between them. However, during the Covid period, the dynamic correlations increased demonstrating the existence of contagion effect between the

companies and the technological market index. This result means that both companies acted as a kind of locomotive for the market.

CONCLUSION

The unexpected spread of the Coronavirus around the world has necessarily prompted the international ruling class and the scientific community to identify the most avant-garde forms in order to contain the pandemic's disastrous health and economic effects. The far-sighted vision of those who, in unsuspected times focused on the development of innovative methodologies, has been rewarded by the necessity of the case. In an attempt to want to identify positive feedback in what has happened in the last two years, it is necessary to count, among the happiest realizations, the rediscovery of research, especially the scientific research, as salvation in the darkest moments of the entire community.

Investing in the future means trying to refine in a more functional way the techniques already available.

Those individuals who succeed with more originality and ability to metabolize this new social and global need will be able to withstand even in near-apocalyptic scenarios such as those faced because of Sars-Cov2. BioNtech and Moderna express in facts the new need for innovation, the opportunity for investment in research and the ability to translate events and read into them the countermoves to be made. The scenarios they have opened up with the development of next-generation vaccines are yet to be discovered, both in socio-health and economic

terms; however, the certainty of a new sensitivity to technology applied to human lives remains.

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Databases

- *Datastream database.*
- *Crunchbase database.*
- *World Economic Outlook database.*
- *S&P Dow Jones Indices, a division of S&P Global.*

Table of figures

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