Open Innovation as A Driver of Industrial and Organizational Mutations during the Pandemic: Case Study of the Pharmaceutical Sector

L'innovation ouverte comme moteur des mutations industrielles et organisationnelles pendant la pandémie : Etude de cas du secteur pharmaceutique

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RÉSUMÉ. La Covid-19 a montré les défaillances des systèmes de santé (à travers le manque de dispositifs médicaux) mais également de nouvelles façons d'innover, en particulier via l'innovation ouverte. Une étude de cas exploratoire illustrant l'intérêt de l'innovation ouverte dans le cadre pandémique seront développées. La question de recherche est : comment l'innovation ouverte a-t-elle stimulé la production de soins pour faire face à la pandémie ? L'étude de cas de l'alliance pharmaceutique Pfizer/BioNTech s'appuie méthodologiquement sur le référencement complet et l'analyse systématique des publications, documents scientifiques relatifs à l'innovation ouverte. Suivant ce travail, nous serons en mesure de montrer que dans le contexte pandémique, l'innovation ouverte est un vecteur efficace pour élargir les partenariats afin d'accélérer les activités de R&D et de production.

ABSTRACT. The Covid-19 pandemic emphasized health system failures, lack of medical devices, and new ways to innovate, in particular based on Open Innovation. An exploratory case study that exemplified the value of implementing Open Innovation in the pandemic context will be shown. The research question is: how has Open Innovation boosted healthcare production to cope with the pandemic? The case study of the Pfizer/BioNTech pharmaceutical alliance is methodologically built on full referencing and systematic analysis of published articles, scientific documents, and reports related to Open Innovation. Based on this case study, we will be able to show that in the context of pandemic emergency, Open Innovation is an efficient vector that allows expanding partnerships to accelerate R&D and production operations.

MOTS-CLÉS. Innovation ouverte, Source ouverte, Pandémie de Covid-19, Industrie pharmaceutique.
KEYWORDS. Open Innovation, Open Source, Covid-19 Pandemic, Pharmaceutical Industry.

1. Introduction

As we witnessed, the Covid-19 pandemic led to severe failures of global healthcare system. In the fight against Covid-19, mitigating the spread of the coronavirus SARS-CoV-2 and treating Covid-19 patients is a priority for public health authorities. Among numerous resolutions, accelerating vaccine development is one of the most effective solutions worldwide. In such extraordinary circumstance, the ongoing development roadmap of Covid-19 vaccine has witnessed unprecedented collaboration at the global scale between industry, government and academia. For instance, the collaborative networks, open research calls and joint call for proposals are common models around the world [PAT 22]. All these efforts spurred the development of innovation and technology in the search for effective Covid-19 treatments and vaccines. The Covid-19 pandemic, thus, has prompted a wide variety of open, collaborative responses that is referred as the root of open innovation. The "openness" in the scientific domain and in medical science would allow to develop Covid-19 vaccine sooner. Being "openness" in this context could help us to save money and time in the fighting against Covid-19 [CHE 20]. However, the open innovation models in this fighting are very nuanced depending on different sectors.

In line with the analyses of researchers and experts on how to contribute to solving major disasters of this new century, including related with the pandemic [UZU 22] [UZU 23], within this research, we will focus on exploring open innovation paradigm to develop vaccines related to Covid-19 in pharmaceutical enterprises. A related research question is how has Open Innovation boosted healthcare manufacturing in response to the pandemic according to case study.

To respond to this global health crisis COVID, the development of vaccines indeed required the global mobilization and cooperation among both private and public stakeholders [LIU 22]. For instance, we witnessed the development of numerous Open innovation models, such as the collaboration between universities and industries (*e.g.* the case of Astra Zeneca), or among pharmaceutical enterprises, especially between large firm and start-up, as the case of Pfizer/BioNTech, etc. Among these open innovation models, the collaboration of large corporations with start-ups as a means to accelerate innovation has been long been studied in several industries [COR 23]. During the pandemic period, the value of this innovation model has been once again confirmed through the success case of vaccine Pfizer/BioNTech. The partnership between Pfizer and BioNTech has quickly addressed each other's unique challenges in the urgent context of pandemic. For that reason, to shed light on how the open innovation model can accelerate innovativeness in the healthcare sector, we choose to explore further the cooperation mechanism of Pfizer/BioNTech, focusing on which and how issues of innovation in vaccine development can be solved, and which and how advantages that each business partner can obtain thanks to their cooperation.

Our results show that open innovation model is actually effective innovation approach in vaccine development during the Covid-19 period. The open innovation paradigms of pharmaceutical industry show the diversity in innovativeness pathway. The open innovation model of Pfizer and BioNTech is typical for the cooperation among businesses, even though competitors in the same industry. This model also presented for collaboration networks among large and mature partners who are responsible of providing essential resources (financial and manufacturing resources from Pfizer and know-how and technology from BioNTech) for co-developing innovation. To further explore the collaboration process, our case study collects information current and archived documents about their vaccine development activities (including from press releases and their websites) to outline their open innovation model. From that model, we analyze and compare it with other existing models to address our research questions.

The paper is as follows: the first part depicts the research design and presents literature on open innovation. The second part describes the case of the collaboration between Pfizer and BioNTech regarding the development of a vaccine against Covid-19. Then, a discussion followed by a conclusion are closing the paper.

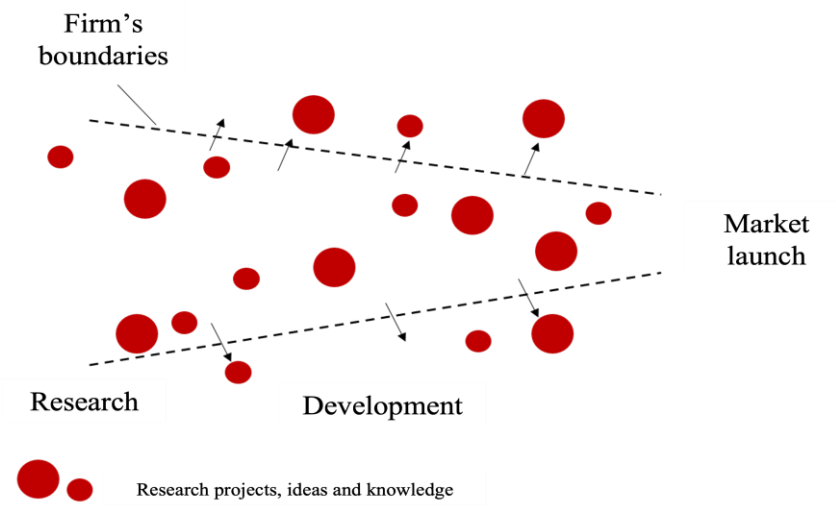
2. Research design: Theoretical analyses of open innovation and case study on open innovation in Covid-19 vaccine development

For that purpose, at first, a theoretical analysis will present in detail the open innovation paradigm and modalities (including outbound, inbound and coupled innovation) and open innovation realities in the pharmaceutical sector. Then, to be able to explore the open innovation pathway of Covid-19 vaccine development we use qualitative methodology of [YIN 06, p. 111] which is stated that "*Compared to other methods, the strength of the case study method is its ability to examine, in-depth, a 'case' within its 'real-life' context*". Particularly, one exploratory case study is presented to exemplify the value of implementing these agile, cooperative and innovative manufacturing processes of open innovation paradigm. To boost the development of Covid-19 vaccine to face with the pandemic, our research focusses on Pfizer/BioNTech vaccine case study due to its expected relevance to open innovation in a crisis context. The data of each case study will be collected based on a systematic analyzing full range of current and archived documents of the considered projects [CRO 11].

2.1. *Open Innovation: Definition and typology*

Since the pioneering work of [CHE 03], open innovation now occupies an important place in the literature on innovation management. For [CHE 03, p. 59], "*open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as firms look to advance their technology*". This definition proposed by Chesbrough highlights the extent to which interesting ideas can emerge and be marketed inside and outside the boundaries of the company.

The concept of open innovation is effectively illustrated through the pierced funnel model (Figure 1), which aligns with Chesbrough's perspective. He views open innovation as a dynamic process that facilitates multiple inputs and outputs within a company. This approach enables firms to externalize projects that, while valuable, may not align closely with their core business activities. Simultaneously, it allows companies to harness external resources through strategic alliances, fostering both financial and innovation performance [CHE 19] [LUQ 21].



Source: [AOU 22]

Figure 1. *Open Innovation*

Furthermore, [CHE 03] defines a resource as "open" when it can be acquired or exploited by an external actor under specific conditions regulated by intellectual property rights. This notion underscores the structured yet flexible nature of open innovation, where firms can strategically manage knowledge flows to maximize value creation.

[DAH 10] further refine this framework by distinguishing between different modes of resource openness. When a company engages in outside-in practices by acquiring external knowledge or technology through financial transactions, this is classified as acquisition, a strategy widely adopted in industrial sectors. Conversely, when external resources are leveraged without financial compensation, the process is considered an appropriation of external knowledge. This distinction highlights the varying degrees of openness companies adopt, depending on their strategic objectives and industry-specific factors.

The results of [DAH 10] thus underline the existence of different forms of open innovation. Indeed, the literature on open innovation, three open innovation modalities are widely studied [ENK 09]: Outbound innovation; Inbound innovation and Coupled Innovation.

- **Outbound innovation**: Outbound Open Innovation aims to promote internal innovations and ideas that are not used by the company. The latter will take them out of these R&D activities (publications, databases, patent licensing) through the transfer of solutions and ideas to other

actors in order to promote the use or adoption by other companies. The interest for the company is to favor a strategic positioning by imposing a technological standard. [HEN 06] recognizes that in this strategy, the information provided to third parties by companies is selectively revealed in such a way as to encourage collaboration while keeping control of the invention.

- **Inbound innovation**: Inbound Open Innovation refers to a company's ability to obtain ideas and solutions from outside in order to feed and strengthen the internal innovation process [BAG 20] [DAH 10]. By exchanging with experts, consumers, companies call on creativity and external intelligence. The main limits of such a strategy are based on the cognitive capacities of the company, namely the capacity to absorb new knowledge from the external environment [COH 90].

- **Coupled Innovation**: Coupled Open Innovation combines the two previous processes. It is defined by [ENK 09, p. 313] as "*co-creation with (mainly) complementary partners through alliances, cooperation, and joint ventures during which give and take are crucial for success*". This particularity makes it more complex due to the "paradox of openness" [LAU 14], namely for the company the need to open up to seize new opportunities and feed the internal process and at the same time the need to protect innovations during the commercialization phase.

In the case of Pfizer and BioNTech, this collaboration can be classified as inbound innovation with financial compensation for Pfizer and, conversely, as outbound innovation for BioNTech. Indeed, for Pfizer, this collaboration allowed the company to invest financial resources as well as expertise in BioNTech to jointly develop the vaccine, while relying on BioNTech's expertise. On the other hand, for BioNTech, this collaboration involved sharing an innovation in mRNA technology in exchange for financial compensation and support for scaling up and distributing the vaccine.

2.2. *Open Innovation drivers*

During decades, the openness of innovation has been studied by academics and practitioners under a number of different angles [CHE 19] [LIU 21] [LAP 21]. Openness to innovation is not an end in itself, but rather a means of fostering innovation and business performance [UZU 17]. Given the increasingly importance of open innovation, the road to openness require the efforts not only from organizations but also from policy makers. In current globalization epoch, organizations need diverse capabilities in order to explore, adapt, adopt and combine external knowledge with internal ones to thrive in their quest for openness and innovation. Further, inter-organizational relationships and networks serve as critical channels, providing more access to the essential knowledge, information, and resources in driving innovation and sustainable growth. Empirical and conceptual studies from various disciplines such as innovation, networks, strategy, business, resilience and entrepreneurship have long been addressed the evolution of open innovation strategies and models as well as its benefits and challenges [CHE 20]. Most studies emphasize the importance of interorganizational networks in different contexts.

Besides, the crisis of Covid-19 pandemic appears as critical drivers of open innovation among different industries and countries around the world. The Covid-19 pandemic has led to significant disruptions that are rapidly transforming business and social models, so it was also necessary to rethink open innovation in response to the crisis. The urgent need of new products/services to cope with the Covid-19 pandemic forces all economic actors (not only businesses but also the research community and each government) to cooperate with each other. Many examples of "open innovation" around the world and among several industries has been studied (see [LIU 22] [VER 20] [CHE 20]). The results showed that an open, collaborative approach with joint efforts were crucial in the fight against Covid-19 [VER 21]. The problems arising during this Covid-19 period require openness and knowledge sharing between different sectors to develop innovative solution [CHE 20]. The literature on open innovation and innovation management has been enriched by diverse theoretical and empirical researches and investigations from multi perspectives and at various degrees of openness to innovation.

3. Open innovation in the pharmaceutical industry

The pharmaceutical industry is classified by the National Institute of Statistics and French Economic Studies (INSEE)[1] as an industry that contributes to the manufacture of basic pharmaceutical products and pharmaceutical preparations. It also includes the manufacture of chemicals for medicinal use and herbal products. The pharmaceutical industry has several characteristics that make it unique [BOR 15], for instance, technologies in the vaccine technical system can be recombined, created, and absorbed from outside the enterprise to constitute their own technology trajectory as the case of Sanofi [BOU 23a] [BOU 23b]. For that reason, this industry is well-positioned for implementing an open innovation strategy [HUN 10] [BIG 21].

The pharmaceutical and biotechnology industries are among the highest in research and development (R&D) intensity [SCH 13], allocating a significant portion of their net sales to R&D activities. According to the European Federation of Pharmaceutical Industries and Associations (EFPIA), the pharmaceutical industry leads in R&D investment relative to net sales[2]. The 2023 EU Industrial R&D Investment Scoreboard indicates that health industries, which encompass pharmaceuticals and biotechnology, invested approximately 12.9% of their net sales in R&D in 2022. During the COVID-19 pandemic, other countries made substantial R&D investments to expedite the creation of vaccines and therapeutics. As reported by the Knowledge Portal on Innovation and Access to Medicines, over €6 billion had been invested in COVID-19 vaccine research and development by March 2021. The United States contributed the largest portion, providing approximately €2 billion (31% of total funding), followed by Germany with €1.3 billion (21%) and the United Kingdom with nearly €433 million (7%)[3]. The Biomedical Advanced Research and Development Authority (BARDA) in the US invested more than $2 billion by June 2020 to support companies like AstraZeneca ($1.2 billion) and Moderna ($483 million) in accelerating vaccine development and manufacturing[4]. In 2020, the German government allocated €750 million to support national COVID-19 vaccine research and development, funding BioNTech, CureVac, and IDT Biologika to accelerate vaccine progress and expand production capacities[5]. The first phases of the Covid-19 pandemic has witnessed an investment of nearly 7 billion euros in R&D in France. Sanofi, a major French pharmaceutical company, invested €2.5 billion in R&D since the pandemic's onset, reaffirming its commitment to innovation [LEE 21].

However, the pharmaceutical industry is characterized by the largely dependence on regulatory policies in terms of drug authorization [BOR 15]. This industry also copes with rising costs related to the financing of clinical studies and the growing demand for R&D personnel [SCH 13]. All of these constraints are factors that can hinder the R&D performance of this industry. Innovative organizational strategies in R&D management must be implemented in order to foster the dynamics of innovation in this industry.

[FET 06] stated that the biopharma industry is fertile ground for the expansion of open innovation practices. This is due to the increasing technological intensity of activities, the complexity of innovation process, the diversity of skills mobilized, strong networks of innovation ecosystem and in particular the intense relations between the sectors of this industry and research centers [MAD 00]. The pursuit of open innovation strategies, thus, allows companies in this industry to benefit from external know-how via outsourcing processes in order to respond to current cost or deadline issues of this industry [SCH 13].

[1] https://www.insee.fr/en/metadonnees/cpfr21/division/21

[2] https://efpia.eu/media/2rxdkn43/the-pharmaceutical-industry-in-figures-2024.pdf

[3] https://ec.europa.eu/newsroom/rtd/items/713446/en

[4] https://www.genengnews.com/news/vaxart-oral-covid-19-vaccine-joins-trumps-warp-speed-ramps-up-manufacturing-capacity/

[5] https://donortracker.org/donor_profiles/germany/globalhealthrd

Although the characteristics of pharmaceutical industry that have made a relevant case study for the analysis of open innovation processes, relatively few works focus on this area [BIA 11] [MAZ 16]. Indeed, the majority of works on open innovation have concentrated on the case of high technology industries (*e.g.* Xerox, IBM, Intel) [CHE 02] [CHE 03] [CHO 16]. In addition, [BIA 11], in a study analyzing the adoption of open innovation in the bio-pharma industry, found that inbound innovation is one of the most typical methods of open innovation in these companies. The authors admit that pharmaceutical companies "open" their innovation process in order to acquire the best existing technologies and thus be able to support their commercial development.

More recently, the case study conducted by [BOR 15] in the pharmaceutical industry, Eli Lilly shows to what extent open innovation is practiced in large pharmaceutical companies and this very often happens bilaterally due to the complexity of technologies and intellectual property issues. Eli Lilly's case study allowed the authors to point out the critical role of crowd-sourcing in the open innovation process, the existence of open source medicines and multilateral and multi-stakeholder requirements of open innovation. Finally, the authors also showed how the industry value chain works, which is characterized by an integrated but also highly decentralized network. The creation of consortiums to explore other areas is at the heart of open innovation development prospects in this industry. According to the authors, this contributes to the transformation of innovation process into a collective affair. All of these elements justify the research work undertaken in this study.

3.1. *Description of the collaboration between Pfizer and BioNTech*

Open innovation is a smart strategy that firms can use to develop efficiently and with a faster time plan than innovation development alone. Two companies can work together to achieve common goals more efficiently. A case study of this research project focuses on the alliance between the American firm Pfizer and the German firm BioNTech.

Pfizer, established in 1849, is a leading global pharmaceutical company, specializing in the development, manufacturing, and distribution of healthcare products, medicines and vaccines, with a strong foothold in the U.S. market, complemented by substantial operations in Europe and Asia. In 2019, before the Covid-19 pandemic, Pfizer reported revenues of approximately $51.75 billion[6]. BioNTech, established in 2008 by Uğur Şahin, Özlem Türeci, and Christoph Huber, is a German biotechnology company headquartered in Mainz. Prior to the Covid-19 pandemic, BioNTech focused on developing immunotherapies for cancer and other serious diseases. This firm carries out biotechnology activities, specifically messenger RNA (mRNA) technology.

During the Covid-19 pandemic that started early 2020, the race for a vaccine development lasted several months. Pfizer-BioNTech alliance enables to develop one of the first vaccine late 2020. This vaccine's technology allows the coding of an S protein of Covid-19 envelope. The main function was for the human body to recognize the virus presence and even to stock it into the memory, so that the body will be able to fight against a potential future infection.

In the paper, the case study of this corporate alliance between two big pharmaceutical firms, BioNTech and Pfizer, aims to illustrate how open innovation can lead to urgent products available on a large scale. Different press releases are analyzed to search for elements in relation with collaboration between Pfizer and BioNTech.

3.2. *The collaboration objectives*

"*Pfizer is proud of its long history of successfully partnering with external organizations that share in our purpose to deliver breakthroughs that change patients' lives*". This quotation is available on Pfizer's website. The firm is promoting the collaboration and partnering for the creation, development and dissemination of efficient solutions that can impact a lot of people.

[6] https://www.statista.com/statistics/266171/revenue-of-pfizer-since-2006/

"*Pfizer engages in a variety of partnership models that includes research collaborations, venture capital investments, academic alliances, early-stage seed funding, establishing incubators, licensing, and spinning out of companies*"[7].

Hence, Pfizer and BioNTech signed a partnership in March 2020, to conduct research for accelerating the development of Covid-19 vaccine candidates into clinical trials. One month later, the two companies announced "*that the German regulatory authority, the Paul Ehrlich Institute, has given approval for the Phase 1/2 clinical trial of the BNT162 vaccine development program for the prevention of COVID-19 infections*"[8]. Following this announcement, Pfizer and BioNTech conducted clinical trials in the United States.

The collaboration between Pfizer and BioNTech is based on the expertise and know-how of both firms. One first important element of the openness of the innovation process is the increasing capacity for innovation. The know-how, knowledge and expertise of each partner involved in a project in open innovation can lead to mutual benefits. In the case of the Covid-19 vaccine, Pfizer brought the commercial and regulatory capabilities. BioNTech contributed with the technological experience that this firm accumulated over the years. Both firms have human resources and infrastructures resources that are supportive in the development of the project (Pfizer website, 2020)[9].

Moreover, Pfizer developed a 5-point plan to supporting scientists and research in the fight against Covid-19. One point concerns the sharing of Pfizer's technology and knowledge. An open access tool is developed through an open source platform with the aim to share it to the scientific community. Another point of the scale is related to the sharing of expertise on clinical development and regulatory issues for firms engaged in vaccine development but with limited capabilities on the regulatory and licensing topics. One more point of this plan concerns the future collaboration of experts through different American health institutions (*e.g.* Pan American Health Organization (PAHO), Centers for Disease Control and Prevention (CDC), National Institutes of Health (NIH), etc.) in projects to develop health solutions for potential future epidemics. Through these formulations, the pharmaceutical company is concretely using the principles of open innovation.

In November 2020, the two firms announced "*that they have reached an agreement with the European Commission to supply 200 million doses of their investigational BNT162b2 mRNA vaccine candidate against SARS-CoV-2 to European Union (EU) member states, with the option for the European Commission to request an additional 100 million doses. Shipments are expected to begin by the end of 2020, subject to clinical success and regulatory approval*". The vaccines that will be delivered in Europe will be produced in the German manufacturing facilities and the Belgium manufacturing facilities.

3.3. *Different collaborations for multiple initiatives*

Many stakeholders of the pharmaceutical industry signed an agreement "to preserve the integrity of the scientific process for filing the first COVID-19 vaccines". Several pharmaceutical industry leaders unite to advance science: "*Several pharmaceutical companies have agreed to sign a landmark agreement to preserve the integrity of the scientific process for filing the first COVID-19 vaccines. These companies are AstraZeneca, BioNTech, GlaxoSmithKline plc, Johnson & Johnson, Merck, Moderna, Inc, Novavax, Inc, Pfizer Inc, and Sanofi*" (AstraZenzca website, 2020)[10].

[7] https://www.pfizer.com/about/partners/research-and-business-development-partnerships

[8] https://investors.biontech.de/news-releases/news-release-details/biontech-and-pfizer-announce-regulatory-approval-german/

[9] https://www.pfizer.com/news/press-release/press-release-detail/pfizer-and-biontech-announce-further-details-collaboration

[10] https://www.astrazeneca.com/media-centre/press-releases/2020/biopharma-leaders-unite-to-stand-with-science.html#!

Furthermore, an initiative with 37 partners from Europe and the United States was launched in 2020, in order to accelerate the discovery and development of therapeutic options for the treatment of Covid-19 and avoid potential threats of futures coronaviruses (Vaccine research institute, 2020a)[11]. This initiative is entitled CARE (Corona Accelerated R&D in Europe) and is supported by Europe's Innovative Medicines Initiative (IMI). The aim of this initiative is to bring together the expertise of 37 academic teams, non-profit research institutes and pharmaceutical firms "*into a comprehensive drug discovery gas pedal*". The maximization of complementarities and synergies with other initiatives (the Gates Foundation-supported Covid-19 Therapeutics Accelerator, MANCO, SCORE, and the ECRAID) is also possible with CARE.

The senior scientific director and head of emerging pathogens R&D, Global Public Health, Janssen Pharmaceutica NV, and CARE project leader, Marnix Van Loock added: "*As part of this initiative, we look forward to applying lessons learned from an ongoing collaboration on COVID-19 with the Rega Institute for Medical Research, part of KU Leuven, to examine a library of thousands of existing drug compounds*" (Vaccine research institute, 2020b)[12].

These elements highlight the need to build on external resources and expertise with the goal to develop a vaccine.

3.4. *Theoretical and managerial implications*

The collaboration between the German and the American firms successfully outcome on an innovative product, a vaccine against Covid-19. The mobilization of a big number of resources, private and public organizations and the adaptation of procedures were involved in this success. In less than one year a successful vaccine was produced and diffused in many countries to protect the populations. First, a global cause and the personal impact that the health crises resulted in were two determining elements in the acceleration of the innovation production. Everyone could be infected by the virus; therefore, the mobilization was bigger than for other projects in these unprecedented times. Then, innovation management following the principle of collaborative engineering ("*ingenierie concourante*") was strategically used in the case of the alliance between BioNTech and Pfizer. At almost every step of the vaccine development, the firms had the opportunity to coordinate different phases in parallel, that was not possible until that time. Trials, logistics, production lines were all engaged in parallel, so that the firms were not expecting the following phase and the validation to continue the innovation process [GAR 22].

It is now acknowledged that open innovation relies on the combination of relevant and internal expertise, know-how and knowledge of the partners. In the case of the Covid-19 vaccine development by Pfizer and BioNTech, the openness degree of the open innovation process was wide. Consequently, the partners seized the multiple opportunities related to shared resources (production facilities, knowledge, regulatory provisions) and a huge number of disciplines were involved in the vaccine development (biologists, epidemiologists, clinicians, virologists, etc.).

On a managerial level, relying on previous internal know-how, resources and knowledge is crucial for the effective development of an innovation [GAR 22] [SCH 22]. Within this example, prior knowledge on mRNA was fundamental to build trials and experiences to develop the vaccine against Covid-19. The German laboratory BioNTech knowledge and expertise in mRNA related to tests on other vaccines for a decade, combined with the distribution and regulatory systems of the American company Pfizer was then fruitful.

[11] https://vaccine-research-institute.fr/18-08-2020-care-press-release-europes-largest-initiative-launches-to-accelerate-therapy-development-for-covid-19-and-future-coronavirus-threats/

[12] https://vaccine-research-institute.fr/wp-content/uploads/2020/08/20200819_CARE-press-release.pdf

The type of Open Innovation chosen by the partners involves inherent risks, that can be minimized. [SCH 22] found that pharmaceutical firms rely more on traditional Open Innovation processes combined with external networks. Furthermore, intellectual property was protected through the use of Open Innovation platforms facilitating knowledge exchange between partners and tracking ideas [SAL 23].

Finally, the gap in cultures inherent to the type of firms and the national context has to be filled in by the partners engaged in collaborations. Hence, in the case of the vaccine development at the global scale, the large pharmaceutical firms found a way to bridge this important gap [SCH 22].

3.4. *Combination of resources for Open Innovation success*

Different reasons can be highlighted to explain why Pfizer and BioNTech succeeded in the vaccine market delivery and others do not. Firms have to accumulate experience for completing the regulatory process, specifically for drug approval. While BioNTech had no products on the market, Pfizer used an open innovation strategy for clinical trials, and regulation. Moreover, its capabilities related to the global supply chain infrastructure, regulatory, manufacturing were confirmed through previous collaborations for mRNA influenza vaccines backed in 2018 [KAY 21].

The CEO of Pfizer, Albert Bourla stated that: "*We were able to move faster than biotech companies, faster than companies that are founder-based or backed by venture capital - all of which are known to be able to move very quickly*"[13].

4. Finding discussion

Many firms engage in open innovation strategies with the goal to introduce new management concepts, new uses, or new technologies, for instance. The open innovation approach could effectively contribute to the introduction of POC (Proof of Concept), POV (Proof of Value) or POT (Proof of Technology). Large and mature firms can therefore incentivize the involvement of actors and their collaboration to maximize the opportunity for innovation success and upscaling.

In the literature on innovation management, open innovation pathways across organizations, industries and nations can be diverse due to various reasons, including the differences in institutional contexts, culture and industrial characteristics [CHE 19]. As a result, more analysis on open innovation models (in both theoretical and empirical) is needed to gain a more comprehensive understanding about open innovation from multi perspectives. Our research, thus, contribute more nuances about open innovation models existing in a specific industry: the pharmaceutical sector. It is worthy to note that the emergence of open innovation models analyzed in our research is due to a special "open innovation driver" - the Covid-19 pandemic. Open innovation strategies in the pharmaceutical industry during period of crisis demonstrates importance of collaboration knowledge among inter-organizational network.

The collaboration type might have evolved differently in this pandemic, as many digital platforms emerged. Digital transformation appeared to accelerate the collaboration between different partners. [LIU 22] highlighted four themes as open innovation solutions to the Covid-19 crises: crowdsourcing and social innovation, digitalization and platform innovation, modularity, design, and technology exaptation; and relationship, network and ecosystem. These open innovation strategies fostered diverse responses and new ways of working while firm cooperation benefited from Information and Communication Technologies advancements and recent technological development.

Furthermore, this research is in line with [CHE 20] focusing on innovation as a means of surmounting the pandemic phase. The economist has shown that managerial dynamics in various fields

[13] https://digitaledition.strategy-business.com/publication/?i=696981&article_id=3931025&view=articleBrowser

linked to overcoming Covid-19 would benefit from open innovation. Sectors reviewed included the pharmaceutical industry, in its search for care and prevention solutions, in particular in relation to vaccines.

As he published during the first pandemic phase: "*Covid-19's assault has prompted a number of encouraging developments. One development has been the rapid mobilization of scientists, pharmaceutical companies and government officials to launch a variety of scientific initiatives to find an effective response to the virus. As of the time of this writing, there are tests underway of more than 50 different compounds as possible vaccines against the virus. Most of these will ultimately fail, but the severity of the crisis demands that we investigate every plausible candidate. We need rapid, parallel experimentation, and it must be the test data that select our vaccine, not internal political or bureaucratic processes*" [CHE 20, p. 410].

Our work has therefore attempted to highlight the development of this perspective through the analysis of a detailed case study. More precise, in the fight against Covid-19, open innovation approach has demonstrated its importance in accelerating the development of Covid-19 vaccines. The exploratory case study in our work reveal different nuances of open innovation paradigm in pharmaceutical industry during Covid-19 pandemic. Firstly, the Pfizer-BioNTech case study highlights the collaboration between two large pharmaceutical companies which brings many benefits to the end-users of the innovation, *i.e.* patients and the global population in facing with the Covid-19 crisis. The know-how and expertise of BioNTech to create a messenger RNA vaccine, together with the industrial and logistic expertise of Pfizer has enabled a fast and efficient distribution. The success of Covid-19 vaccine co-developed by the partnership established in 2020 between BioNTech and Pfizer is a typical example of efficient open innovation strategy between start-up and mature enterprise - a prevailing partnership in many industries. Particularly, BioNtech is only a start-up so they have met various difficulties in finishing clinical trials, obtaining the approval of health authorities quickly as well as setting up a global supply chain to deliver millions of vaccine doses. By engaging in the collaboration with Pfizer, BioNtech only need to contribute mRNA vaccine candidates whereas Pfizer provides its global vaccine clinical research and development, manufacturing, and distribution infrastructure for their collaboration project. This open innovation model which is driven by start-up engagement is a regime of collaboration between corporations have resources advantages with start-ups who hold the technology or other competitive advantages. This open innovation type is known as an outside-in model where knowledge or know-how externally developed is used internally in corporations. This "openness" type mainly emerged in case that the cost and risk of internal development are higher. In fact, at the beginning period of this collaboration, Pfizer is said to have a risky investment of 2 billion dollars on an unproven technology.

Thanks to this trusted relationship for win-win, on the one hand, within less than one year, BioNtech was "*able to develop our Covid-19 mRNA vaccine following highly scientific and ethical standards, which became the first mRNA drug approved for human use and the fastest vaccine developed against a new pathogen in the history of medicine*"[14]. On the other hand, Pfizer has won Corporate Startup Stars Awards granted by Mind the Bridge in 2021. In fact, the Pfizer's partnership with startup BioNTech is only a part of comprehensive open innovation strategy developed by Pfizer such as collaboration with investments, intrapreneurship and venture builder, etc. This collaboration of Pfizer as well as the development of second mRNA vaccines (by Moderna) show that the pharmaceutical industry a proponent of open innovation. The challenges of pharma industry are the long, risky and expensive process of developing new drug and vaccine. To overcome such challenge, many multinational pharmaceutical firms choose to rely on both their internal R&D effort and strong open innovation engagement. The stories of these two mRNA vaccines can become a reality thanks to open innovation model crossing national, generational and gender borders.

[14] BioNTech|Our comprehensive COVID-19 information portal 2023: https://www.biontech.com/int/en/home/covid-19/covid-19-portal.html

The development of open innovation model has become attractive over time, but, open innovation strategy depicts different downsides. [CHE 19] identified six challenges of open innovation: internal organizational change, relationships with external sources, intellectual property protection, identifying innovation sources, protecting internal critical know-how, avoidance of external or already existing knowledge. On one side, in the specific case of the collaboration between Pfizer and BioNTech and the race against a Covid-19 vaccine, a social and ethical issue has raised up. The public opinion was quickly divided into two sides: on the one hand, people for whom the fact of finding a vaccine was essential to the progress of the development of this vaccine. On the other side, the "anti-vax people" or those who fear that the fact of freeing themselves from certain fundamental steps in the development and administration of a vaccine could harm our health. In this complex situation, the strategy of open innovation is not necessarily a benefit that can serve the cause of the uncertain or distrustful people. It can be the total opposite, as in the pharmaceutical industry, the market is shared by big companies, for whom faster development and market entry can directly benefit.

On the other side, another downside of this management strategy lies in the intellectual property protection, recently identified by [CHE 19] as one of the six challenges against open innovation success. The Intellectual Property Rights (IPRs) are aiming at preventing external actors from using a firm's ideas and inventions. Therefore, it seems the exact opposite goal of OI, which consists of sharing and collectively developing knowledge and access resulting assets. However, outside the health and pharmaceutical sectors, diverse firms that are holding important patents are efficiently using open innovation (*e.g.* Philips NV, IBM, Microsoft). In the IT sector, an external market demand was one of the drivers for firms' adaptation through open innovation. The increase of open-source software' development and the needs of users for interoperability between the Linux and the Windows systems pushed IBM to move towards more collaboration. The patenting rate is now constant, and one cannot see a decrease that could be initially expected [HAL 10].

In accordance to this work related to the Covid-19 context, [CHE 20, p. 412] noted that: "*The pandemic is also stimulating innovation in the management of intellectual property (IP). Some initiatives are now in place to encourage companies and universities to release portions their intellectual property (IP) in the fight against COVID-19. One group of scientists and lawyers in the US and Europe have started the "Open COVID Pledge" that pledges not to assert their IP rights against anyone else who signs the pledge in the quest for solutions to the pandemic*". Thus, these challenges have led to additional angles of the topic, theory and research question related with the promotion of healthcare production linked to Open Innovation during the pandemic.

Agile methods related to the open paradigm and specifications [ADA 18], in addition to the autonomy of reactive teams, the pooling of efforts and the possibility for anyone and any organization (including medical centers, firms, labs) to join the projects and contribute through their work and expertise have been recognized through the completion of these case study projects implemented for the crisis.

In summary, the successful open innovation collaboration of Pfizer/BioNTech, along with other examples in the pharmaceutical industry during Covid-19 period, such as AstraZeneca and the University of Oxford, Moderna and the Coalition for Epidemic Preparedness Innovations (CEPI), Johnson & Johnson and Beth Israel Deaconess Medical Center, Novavax and the Serum Institute of India, Sanofi and GlaxoSmithKline (GSK), highlight the crucial role of open innovation strategies in crisis, facilitating resilience and rapid responses. Open innovation will also have an important role to play in the post-pandemic recovery [LIU 22]. In today's digital era, it is important to explore whether and how the experiences gained from these open innovation models can be leveraged to accelerate open innovation across other industries. Future studies should take this question into account and further develop more nuances of "openness" in the innovation process.

However, while open innovation is a strategic business model highly used by many actors for commercial purposes, it has to be smartly managed to avoid failures. Different examples in the

literature highlighted factors and errors that led to failures and limitations of the open innovation model. These limiting factors may, among other things, be related to the issue of resource management allocated to open innovation, which can vary depending on the maturity level and size of the companies.

[ALM 24] raised that managerial issues and specialized resources should be allocated to open innovation by small firms. If not, the implementation of open innovation activities, the communication with external partners and the intellectual property management may suffer. [ZAH 23] found that environmental challenges can directly impact open innovation failure, through a weak relational trust, sector industry and firm size. An organizational learning culture that structures and supports external knowledge transfer is then crucial.

The size of companies plays a crucial role in the success of open innovation projects, particularly due to the influence it can exert on the nature and effectiveness of collaborations. [SCH 22] acknowledge that large pharmaceutical companies are particularly dependent on traditional open innovation processes, in which R&D partnerships are well-established. In this context, open innovation complements internal R&D with external innovations. In contrast, start-ups operate in a more agile environment and are more flexible in their approach to open innovation. Although large companies have more resources, they still face greater challenges in managing the organizational processes associated with open innovation, which can hinder its deployment in a collaborative framework. On the other hand, start-ups are more agile in promoting the success of open innovation, but they lack resources and are often dependent on those provided by large companies. The challenge, therefore, lies in creating partnerships that allow for the effective exploitation of the strengths of both types of organizations.

The firm size is also analyzed by [BER 19]. The author focused her work on the collaboration between start-ups and big firms. The asymmetry lies in various patterns: financial resources, managerial resources, internal culture and commercial experience. This asymmetry induces a potential reliance on investments in communication and understanding. Proximity at inter-organizational and intra-organizational levels appears essential. Management at these two levels are interdependent.

Opening the innovation process implies vulnerability for the partners involved. It means that the firms have to anticipate and clearly identify the competitive advantages that will emerge from the collaboration [CIE 18]. Core capabilities of firms that are superior to other firms' core capabilities is one example of a competitive advantage that is crucial, also in a collaboration framework [ALM 04].

The collaboration capacity generated from such a model is even more complex than the firms are different. One element that differs from startups to big firms is the relationship to time. By their nature, startups are engaged in rapid growth and are facing urgent matters that have to be quickly solved. In that sense, startups are more agile than bigger firms. They are able to explore and exploit new knowledge. This characteristic of startups might have been efficiently used in the case of the Covid-19 vaccine development.

Cognitive distance represents a barrier for a successful collaboration in open innovation model between startups and big firms. The social capital and the experience of startups in adaptation and understanding of the objectives and the means dedicated to reach them are forces that benefit the collaboration [BER 19]. Therefore, cognitive distance should be found at a sufficient cognitive distance to gain from partners' complementarity leading to innovation stimulation, and to avoid hindering mutual understanding and, as a result, losing the benefits of collaboration between different partners [NOO 05].

5. Conclusion

Starting from the fact that benefits of open innovation have been widely studied and many proofs do support that this innovation strategy results in positive consequences at different levels, our work explore open innovation modalities in pharmaceutical industry. During the pandemic that started in 2020, the emergency of Covid-19 vaccine development was such that the answer which will benefit to a large part of the population could only come from a collective intelligence, raised through the partnerships of different economic actors. These actors, ranging from pharmaceutical companies to the academia to government, provided human resources, infrastructures, regulatory expertise, technology expertise and financial resources in the effort of jointly innovation development. The complementarities between Pfizer and BioNTech ended up with an innovative product (*e.g.* a vaccine against the Sars-CoV2) onto the market, with thousands of doses that will be spread around the globe.

The strengths mobilized by the entire ecosystem are serving innovation and enabling the acceleration of innovation development. However, firms must be able to engage in such management, implying an open corporate culture. Collective intelligence aims to foster one's resources thanks to external resources. At the corporate level, the emergence of "open" and "collective" innovation will foster the development of business ecosystems [CHE 03] [UZU 18]. It, in turn, aims at reinforcing the constitution of firms' knowledge capital which is defined as the set of scientific and technical knowledge and information produced, acquired, combined and used in the value creation process [LAP 17]. The collective formation of knowledge capital tends to be emerged in the context of the crisis and especially in large companies [LAP 11]. The open and collaborative research enables firms to reduce innovation development costs and risks. Furthermore, multiple challenges can prevent from engaging in an open innovation strategy like the ethical issued that can emerge from the process. Also, the Intellectual Property Rights should be balanced with a broader objective. The possibility to diffuse the results of the collaboration may raise concerns: the patents that are protecting the Covid-19 vaccine should be placed in the public domain to support more fragile populations that do not have the resources to develop and/or access the vaccine? All these studied improvements building on open innovation can be considered as key developments in the healthcare sector leveraged by the pandemic context.

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