Industrial and Organizational Mutations in the Medical and Pharmaceutical Sectors impulsed by Open Innovation during the Pandemic

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Abstract

The Covid-19 pandemic tragically emphasized severe failures of health systems. In particular, the saturation of hospital infrastructures and the lack of medical devices is crucial for respiratory ventilators. The medical and pharmaceutical sectors had to find urgently new ways to innovate efficiently in R&D, to produce devices, therapeutic trials, and vaccines, and make them available on a large scale. Our work will analyze that these innovations related to Covid-19 have been largely based on Open Innovation. For that purpose, exploratory case studies will be shown that exemplify the value of implementing Open Innovation in the pandemic context. These case studies concern the pharmaceutical firm Pfizer, the biotechnology company BioNTech, and the respiratory ventilator open development coalition OxyGEN (from design company Protofy. xyz to the hospitals' network of Barcelona and manufacturer SEAT). Methodologically, these case studies build on a full referencing and systematic analysis of articles, scientific documents, and published reports related to the Open Innovation involvement of these organizations since the start of the pandemic. Based on the operative contributions from these revelatory case studies, we can show that Open Innovation is a highly efficient vector for extended partnerships for accelerated R&D and operational production contextually to pandemic emergencies.

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Introduction

For the first time in history, the Covid-19 pandemic led to severe failures in the global healthcare system. In the fight against Covid-19, mitigating the spread of the coronavirus SARS-CoV-2 and treating Covid patients is a priority for public health authorities. Among numerous resolutions, accelerating vaccine development and increasing the production of ventilators are the most effective solutions worldwide. In such extraordinary circumstances, the ongoing development roadmap of the Covid-19 vaccine and ventilators has witnessed unprecedented collaboration at the global scale between industry, government, and academia. For instance, collaborative networks, open research calls, and joint calls for proposals are common models worldwide (Patrucco et al., 2021). 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 are referred to as the root of Open Innovation. The "openness" in the scientific domain and medical science would allow the development Covid-19 vaccine sooner.

Similarly, the openness also allowed us to overcome the severe shortage of ventilators during this pandemic through the broad collaborative networks among ventilator manufacturers with other companies, NGOs, universities, and even with carmakers and aerospace firms to speed up ventilator production. Being "openness" in this context could help us to save money and time in the fight against Covid-19 (Chesbrough, 2020). However, the Open Innovation models in this fighting are very nuanced depending on different sectors.

This work will explore the Open Innovation paradigm to develop vaccines and medical devices as ventilators related to Covid-19 in three pharmaceutical and medical device enterprises. Regarding Covid-19 vaccine development, a case study will be developed about the association of the pharmaceutical firm Pfizer and the biotechnology company BioNTech. Concerning the production of medical ventilators, two case studies will be discovered: the first one is linked to the open development coalition OxyGEN (from the design company Protofy.xyz to the hospitals' network of Barcelona and the manufacturer SEAT), and the second one about the opening of Covidien PB 560 from the multinational medical engineering firm Medtronic.

Our results show that the Open Innovation model is an effective innovation approach in vaccine development and medical device manufacturing during the Covid-19 period. The OI paradigms of the pharmaceutical industry show the diversity in the innovativeness pathway. The OI model of Pfizer and BioNTech is typical for cooperation among businesses, even though competitors are in the same industry. This model is also presented for collaboration networks among large and mature partners responsible for providing essential resources (financial and manufacturing resources from Pfizer and know-how and technology from BioNTech) for co-developing Innovation. Further, the OI paradigm of respiratory ventilators has shown either the aspect of collaboration networks in OI or the aspect of technology combination (namely, 3D printing and open-source hardware) in accelerating medical devices.

Research design: Theoretical analyses of Open Innovation and case studies on Open Innovation in Covid-19 vaccine development and respiratory ventilators manufacturing

For that purpose, a theoretical analysis will first present the Open Innovation paradigm and modalities (including outbound, inbound, and coupled Innovation) and Open Innovation realities in the pharmaceutical sector and the development of respiratory ventilators (building on open-source hardware and 3D printing).

Then, to be able to explore the Open Innovation pathway of Covid-19 vaccine development and respiratory ventilators manufacturing, we use the qualitative methodology of Yin (2014), 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". Three exploratory case studies will be presented to exemplify the value of implementing these agile, cooperative, and innovative manufacturing processes of the Open Innovation paradigm. To boost the development of the Covid-19 vaccine and the production of respiratory ventilator devices to face the pandemic, our research focuses on three case studies chosen due to their expected relevance to Open Innovation in a crisis context. The data from each case study will be collected based on a systematic analysis of the considered projects' current and archived documents.

Open Innovation: Definition and typology

Since the pioneering work of Chesbrough (2003), Open Innovation now occupies an important place in the literature on innovation management. For Chesbrough (2003), "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 company's boundaries. This strategy is a source of companies' financial and Innovation performance (Chesbrough, 2019; Lu & Chesbrough, 2021).

In the literature on Open Innovation, three OI modalities are widely studied (Enkel et al., 2009): Outbound innovation (1), Inbound Innovation (2), and Coupled Innovation (3).

Outbound Innovation (1): Outbound Open Innovation aims to promote internal innovations and ideas that the company does not use. 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 to promote the use or adoption by other companies. The company intends to favor a strategic positioning by imposing a technological standard. Henkel (2006) 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 (2): Inbound Innovation refers to a company's ability to obtain ideas and solutions from outside to feed and strengthen the internal innovation process (Bagherzadeh et al., 2020; Dahlander et al., 2010). Companies call on creativity and external intelligence by exchanging with experts and consumers. 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 (Cohen et al., 1990).

Coupled Innovation (3): Coupled Open Innovation combines the two previous processes. It is defined by Enkel et al. (2009) 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*" (Laursen et al., 2014), namely for the company, the need to open up to seize new opportunities and feed the internal process while simultaneously the need to protect innovations during the commercialization phase.

Open Innovation in the pharmaceutical industry

The pharmaceutical industry is defined by INSEE (The National Institute of Statistics and French Economic Studies) as an industry that contributes to manufacturing basic pharmaceutical products and preparations. It also includes the manufacture of chemicals for medicinal use and herbal products. The pharmaceutical industry has several characteristics that make it unique (Borja et al., 2015) and conducive to implementing an Open Innovation strategy (Hunter et al., 2010).

Indeed, the pharmaceutical industry is a complex, globalized sector that requires significant investment in R&D. This industry is one of the leading investors in R&D in the world (Schuhmacher et al., 2013). The first phases of the Covid-19 pandemic have witnessed an investment of nearly 7 billion euros in R&D in France.

However, the pharmaceutical industry largely depends on regulatory policies regarding drug authorization (Borja et al., 2015). This industry also copes with rising costs related to the financing of clinical studies and the growing demand for R&D personnel (Schuhmacher et al., 2013). 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 to foster the dynamics of Innovation in this industry.

Fetterhoff & Voelkel (2006) stated that the biopharma industry is fertile ground for expanding Open Innovation practices. This is due to the increasing technological intensity of activities, the complexity of the innovation process, the diversity of skills mobilized, the strong networks of the innovation ecosystem, and in particular, the intense relations between the sectors of this industry and research centers (Madhok et al., 2000). The pursuit of Open Innovation strategies, thus, allows companies in this industry to benefit from external know-how via outsourcing processes to respond to this industry's current cost or deadline issues (Schuhmacher et al., 2013).

Although the characteristics of the pharmaceutical industry have made a relevant case study for the analysis of Open Innovation processes, relatively few works focus on this area (Bianchi et al., 2011; Mazzola et al., 2016). Indeed, most works on Open Innovation have concentrated on the case of high technology industries (such as Xerox, IBM, and Intel) (Chesbrough et al., 2002; Chesbrough, 2003; Chou et al., 2016). In addition, Bianchi et al. (2011), 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 to acquire the best existing technologies and thus support their commercial development.

More recently, the case study conducted by Borja et al. (2015) 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 the multilateral and multi-stakeholder requirements of Open Innovation. Finally, the authors showed how the industry value chain works, characterized by an integrated but 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 transforming the innovation process into a collective affair. All of these elements justify the research work undertaken in this study.

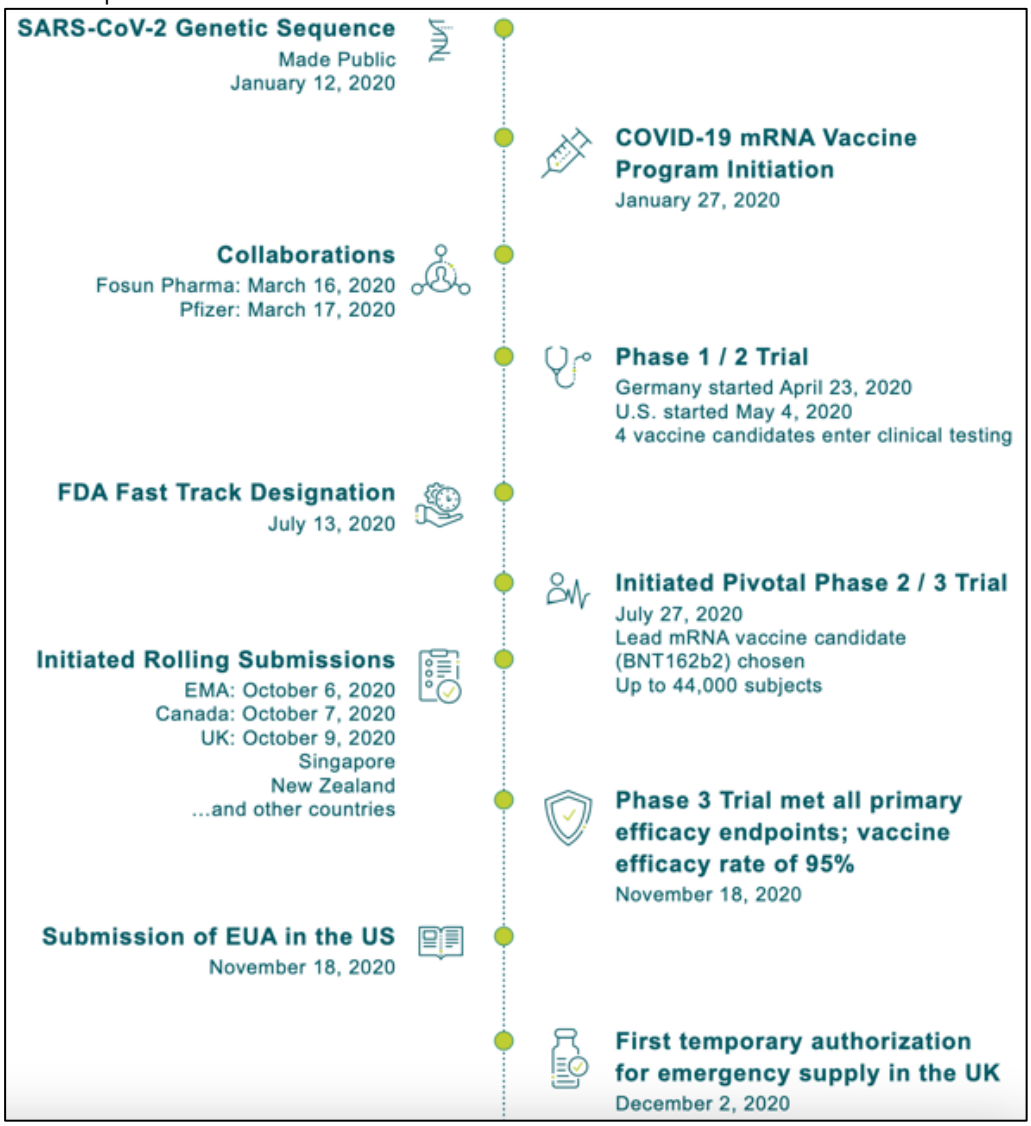
Case study Pfizer-BioNTech

As mentioned, the first case study of the paper will concern the development of the Pfizer-BioNTech vaccine. 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 specializes in producing healthcare products, medicines, and vaccines. BioNTech is a firm that owns expertise in developing individualized cancer therapies. This firm carries out biotechnology activities, specifically messenger RNA (mRNA) technology.

Figure 1

Development of the SARS-CoV-2 vaccine



Source: BioNTech

During the Covid-19 pandemic that started in early 2020, the race for vaccine development lasted several months. The Pfizer-BioNTech alliance enabled the development of one of the first vaccines in late 2020. This vaccine's technology allows coding an S protein of the Covid-19 envelope. The main function was for the human body to recognize the virus's presence and stock it in the memory so that the body could fight against 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.

One first 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 commercial and regulatory capabilities. BioNTech contributed to the technological experience that this firm accumulated over the years. Both firms have human resources and infrastructure resources that are supportive of the development of the project.

Different press releases are analyzed to search for elements concerning collaboration between Pfizer and BioNTech. Furthermore, interviews with the firm's experts are planned to be developed within the next few weeks. These interviews will add important information besides the secondary data collected.

Previously to collect data from the press releases, the chronology of the vaccine development was taken from the BioNTech website. Figure 1 shows the development of the SARS-CoV-2 vaccine.

The collaboration objective

"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." (Pfizer) This quotation is available on Pfizer's website. The firm promotes collaboration and partnering to create, develop, and disseminate efficient solutions that can impact many people.

The firm is involved in three types: academic and public partnerships, biotechnology partnerships, and ventures.

Pfizer seeks to involve partnerships like research collaborations, venture capital investments, academic alliances for drug development, licensing, establishing incubators, spinning out of companies, and early-stage seed funding.

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 approved the Phase 1/2 clinical trial of the BNT162 vaccine development program to prevent COVID-19 infections." 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: "BioNTech's messenger RNA-based vaccine development platforms and Pfizer's extensive vaccinology expertise, regulatory capabilities, and global production and distribution network." (Pfizer,23.4.2020)

Moreover, Pfizer developed a 5-point plan to support scientists and researchers 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 to share it with the scientific community. Another point of the scale is related to sharing 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 in projects to develop health solutions for potential future epidemics. Through these formulations, the pharmaceutical company is concretely using the principles of Open Innovation.

Press releases related to the Pfizer-BioNTech collaboration

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." (Pfizer,11.11.2020) The vaccines delivered in Europe will be produced in the German manufacturing facilities and the Belgium manufacturing facilities.

Different collaborations for multiple initiatives

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." (Pfizer,08.10.2020)

Furthermore, an initiative with 37 partners from Europe and the United States was launched in 2020 to accelerate the discovery and development of therapeutic options for treating COVID-19 and avoid potential threats of future coronaviruses. This initiative is entitled CARE (Corona Accelerated R&D in Europe) and is supported by Europe's Innovative Medicines Initiative (IMI). This initiative aims to combine the expertise of 37 academic teams, non-profit research institutes, and pharmaceutical firms "into a comprehensive drug discovery gas pedal". (Pfizer,23.4.2020) 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.

Rienk Pijpstra, vice president and head of clinical development, hospital portfolio, Pfizer, said, "In the week that the WHO declared a pandemic, Pfizer affirmed its commitment to collaborate across the innovation ecosystem to fight COVID-19. We can be even more confident that science will win through initiatives like IMI CARE, which combine an impressive combination of scientific expertise, technical skills, and development capabilities." Pfizer was then a pioneer in the collaboration to create Innovation for a global impact within the health sector.

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."

These elements highlight the need to build on external resources and expertise to develop vaccines.

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 did not. Firms must accumulate experience to complete 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, regulation, and manufacturing were confirmed through previous collaborations for mRNA influenza vaccines backed in 2018.

The CEO of Pfizer, Albert Bourla, stated, "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."

Applications of Open-source hardware and 3D printing on medical devices production (such as ventilators) in the context of the Covid-19 pandemic

The open-source movements as parts of Open Innovation

The open-source movements, software, and hardware can be considered as determining parts of the field of Open Innovation. While open-source software highlights free access to the source code, open-source hardware is based on opening all the information required to construct materials. This information may include specifications, plans, design procedures, calibration, and computer-aided elements. All of this information is mainly edited as digital files. Because of that, updates of these information files of open-source hardware can be instantly accessible from storage on remote computer servers: an analogy of the source code's permanent availability in open-source software projects.

3D Printers as a key vector for the development of open-source hardware

Another innovative technology with increasing diffusion can be combined to promote open-source hardware production: 3D printing. Also known as additive manufacturing, it constitutes an innovative mechanical construction technology that combines parts of chemical reaction, fusion process, and computer system management. Furthermore, 3D printing is a manufacturing process that allows autonomous production. Related to this technology, user innovation, online platforming, and community dynamics are a lever for openness strategies that can mix complementary open and proprietary components (West & Kuk, 2016). As a disruptive innovation (Rayna et al., 2016) with an almost unlimited field of applications and markets, 3D printing is considered a new industrial revolution, synergistic with the perspective of high-tech sectors' future developments (Gausemeier et al., 2011). Simultaneously building on low-volume production economical and mass-customization, 3D printing platforms are a preferential vector of user innovation and co-creation in the Open Innovation paradigm (Rayna et al., 2015).

OxyGEN and Medtronic case studies

Following the preliminary theoretical analysis of open-source hardware and 3D printing technologies and processes, this part will reveal their interest, especially symbiotic, in producing Covid-19 related medical devices. Two major and complementary cases, thus, will be analyzed: the open development coalition OxyGEN and the Medtronic Covidien PB 560 opening.

- Respiratory ventilators as complex medical devices

Technically, ventilators are the most complex medical devices that must be produced during Covid-19. They include components related to the power supply, engine, electronics, filtration, ventilation, connectors, pipes, and belts. Their specifications must include all the details related to each component, their design, and the various processes involved in the devices' assembly, calibration, and use. As

well as the crucial safety specifications. Safety features also include elements of probe and monitoring. Despite this complexity, projects could be carried out using open-source hardware and 3D printing processes, as they will be developed in the following cases.

- Categories of ventilators with open architecture and 3D printing components under Covid-19

Two categories of ventilators, illustrated in succession, emerged from initiatives related to Covid-19: ventilators initially developed as open-source hardware and existing ventilators produced by the medical industry whose specifications are revealed specifically due to the pandemic context. Both categories integrate components that can be produced according to additive manufacturing.

- Open-source hardware / 3D printing ventilators created specifically within the Covid-19 context: the OxyGEN case study

Considering the first category, a double project of open-source hardware ventilators was launched by the Catalan mechanical and industrial engineering design company Protofy.xyz, the medical and scientific expertise of the Barcelona hospitals Clínic and Germans Trias I Pujol, and the University of Barcelona.

Two models of open-source hardware ventilators have been produced for two types of shaping.

The OxyGEN-IP ventilator, for machine production, supports metal work and is labeled by ESMA, the Spanish medical agency related to medical devices. The automobile manufacturer Seat joined the project to promote the model's industrialization.

The OxyGEN-M ventilator, whose design is specially adapted for local production by requiring only common tools and components.

As universal development results, the specifications and elements necessary for the implementation of the two models of ventilators are freely available on the projects' download page.

- Pre-existing ventilators from the medical industry, whose specifications are open-sourced in the Covid-19 context: Medtronic Covidien PB 560

As we mentioned, another category is making available the architecture and elements of ventilators for local production by third-party actors. It is this time linked to pre-existing ventilators developed by the health industry.

A leading project concerns the Covidien Puritan Bennett 560 ventilator. The model is linked to the multinational medical engineering firm Medtronic.

Medtronic is an innovative firm that developed the first pacemaker in 1957 and has since developed millions of units. The firm's turnover reached 23 billion dollars in 2018, with more than 80,000 employees.

Medtronic produces models of medical ventilation equipment requiring a very high number of parts, over 1,500 components, and a large team of engineers specialized in niche areas. However, such ventilators are not in sync with the contextual need to make available the specifications of a model to be produced by external technicians who are not mainly specialized in the production of niche architectures and do not have the infrastructure, tools, and factories of the parent firm.

While the opened ventilator model is based on a compact and operational design launched in 2010, the opening of this particular architecture was chosen because it suits open development cooperation. This Open Innovation cooperation could include, in particular medical organizations and start-ups. In addition, different ventilator components can be made by 3D printing to facilitate the implementation of the model.

This disclosure of the elements necessary for the free implementation of an existing model of the medical industry under Covid-19 is in conjunction with an FDA (Food and Drug Administration) pandemic directive.

Its availability to enable its implementation by anyone in the context of Covid-19 is a valuable contribution to the fight against the epidemic. The initiative was supported by Elon Musk, the famous President of Tesla and SpaceX.

Hence the choice to make available the specifications of the Covidien PB 560 ventilator with an architecture easier to implement and with fewer components facilitates its production in the paradigm of open-source hardware.

Discussion

Many firms use Open Innovation strategies to introduce new management concepts, uses, or technologies. 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 fight against Covid-19, the Open Innovation approach has demonstrated its importance in accelerating the development of Covid-19 vaccines and the production of ventilators. The exploratory case studies in our work reveal different nuances of the Open Innovation paradigm in the pharmaceutical industry during the 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 facing the Covid-19 crisis. The know-how and expertise of BioNTech to create a messenger RNA vaccine, together with Pfizer's industrial and logistic expertise, has enabled fast and efficient distribution. The success of the Covid-19 vaccine co-developed by the partnership established in 2020 between BioNTech and Pfizer is a typical example of an efficient Open Innovation strategy.

Secondly, respiratory ventilators case studies emphasize an entirely different nuance of Open Innovation than the Pfizer-BioNTech case. The observations from these ventilator case studies have suggested that the combination of open-source hardware and additive manufacturing can be a dual and symbiotic key vector in creating specialized medical devices, including the most critical elements. In a crisis, the combination of 3D printing and open source hardware, which fully belongs to the field of Open Innovation, allows to speed up the production of such medical devices by overcoming market tensions and trade slowdowns concerning the ranges of these crucial devices.

Indeed, because of the autonomous manufacturing process, endogenous to open source hardware and 3D printing, the tools and means of production can be established in their area of use. As a result, the usual and potentially flawed supply chain can be effectively bypassed. Instead of producing and distributing medical devices worldwide, only the elements necessary for their production are transmitted. And when it comes to digitized information files, open-source hardware and 3D-printed canvas files are instantly accessible via the Internet in any part of the world connected to the global digital network. In addition, digital support allows having the most recent versions following the real-time files' availability that contain the latest project developments. This reactivity is parallel to open-source hardware and 3D printing communities.

Conclusion

Starting from the fact that the 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 explores Open Innovation modalities in the pharmaceutical industry. During the pandemic that started in 2020, the emergency of Covid-19 vaccine development was such that the answer which would benefit a large part of the population could only come from 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 joint innovation development. The complementarities between Pfizer and BioNTech ended up with an innovative product (e.g., a vaccine against 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.

Medical ventilators case studies show that in the Covid-19 context, this open cooperation extends to all categories of actors that can contribute to the rapid improvement of concerning medical devices. It includes, in particular, health institutions, medical firms, start-ups, research laboratories, hospitals, and universities. And beyond that, there is an unlimited range of potential contributors, including health specialists, computer developers, mechanics engineers, and electronics engineers.

These additions of complementary efforts can also be promoted through government actions. Especially in a pandemic crisis, organizations such as the FDA have given guidelines for opening medical architectures. Networks of partners and firms, as shown in the cases of OxyGEN and Medtronic, can play a crucial role by opening their specifications and medical designs.

Also, open-source hardware associated with 3D printing optimizes the free access and circulation of digital files containing all specifications and elements, enabling production, open cooperation, flexibility of deployment, best practices, technological developments, feedback, and knowledge accumulation. All these elements lead to a continuous improvement of the related devices. These processes generate a universal common good that is entirely consistent with the perspective envisioned by Elinor Ostrom (Ostrom & Hess, 2007).

All these studied improvements building on Open Innovation can be considered key developments in the healthcare sector leveraged by the pandemic context.

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