Working Paper

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Abstract

The COVID-19 pandemic has forced us to reconsider the relationship between public and private research and development (R&D). The policy issue is whether, over the next 20 years, governments' only negotiating position on biomedical technologies will be to sign one purchase contract after another and transfer value from tax payers to investors in pharmaceutical companies. Knowledge and technologies that are crucial to Covid-19 vaccine development and production were created with the contribution of governments. Patents filed by pharma companies do not protect the public interest arising from such earlier research. The paper offers a case study on the privatization of knowledge created in the first place by R&D in the public sector or supported by public funds and eventually being appropriated by pharmaceutical corporations.

Keywords: COVID 19 pandemic, vaccines, public and private R&D, Big Pharma, public funding, USA

JEL Codes: H51, I11, L32, O32

Introduction

President Biden's surprise statement on May 5, 2021 about the US government potentially supporting the suspension of patents for Covid-19 vaccines, in the context of the World Trade Organization rules on intellectual property, has had considerable resonance[1]. The initial motivation of the US administration was to enlarge to less developed countries the access to vaccines. The inequality of access and the persistence of the pandemic in Africa, Asia, and elsewhere is in fact an issue of social justice, but also a health challenge for everybody in the planet. Many, however, starting with the pharmaceutical firms themselves, hastened to say that by doing so the US government would destroy any incentives for innovation, would create confusion on the stock market, and there would be no increase in available doses. The US Government, many claimed, should instead stop restricting exports of vaccines, and suggested that Biden was just offering political propaganda, not a solution.

In this paper, I argue that the current Covid-19 pandemic has forced us to reconsider the relationship between public and private research. More in general, the case history of Covid-19 vaccines is an example of the controversial standing of intellectual property rights in a landscape where knowledge is increasingly created as a public good by scientists working with governments' support in the first place, and later on such knowledge is appropriated by private investors.

I use the Covid-19 vaccines, and US President Biden's proposal to waive certain intellectual property rights on them, as a case study on the widespread continuity between public investment in science and private downstream R&D: patents (and other uncompetitive mechanisms of privatization of knowledge) break such continuity, and establish artificial "enclosures" in favor of private investors, but against the public interest.

Polanyi (1944, p. 36) discusses his case study on privatization of open fields as follows:

> For an illustration of this we shall turn to what may at first seem a remote subject: to enclosures of open fields and conversions of arable land to pasture during the earlier Tudor period in England, when fields and commons were hedged by the lords, and whole counties were threatened by depopulation. Our purpose in thus evoking the plight of the people brought about by enclosures and conversions will be on the one hand to demonstrate the parallel between the devastations caused by the ultimately beneficial enclosures and those resulting

[1] Ambassador Tai statement, May 5, 2021, https://ustr.gov/about-us/policy-offices/press-office/press-releases/2021/may/statement-ambassador-katherine-tai-covid-19-trips-waiver

> from the Industrial Revolution, and on the other hand - and more broadly - to clarify the alternatives facing a community which is in the throes of unregulated economic improvement.

The question can be updated as follows: are the economic benefits of creating intellectual property rights for companies, downstream of the "open fields" of the scientific commons, greater than their social costs? The question cannot be answered just by looking at the financial returns of the investors arising from market revenues and profits. One should also consider the opportunity costs for the society at large, and "to clarify the alternatives facing a community", an issue that will be discussed here in terms of alternatives for public health of a different arrangement for property rights on Covid-19 vaccines.

It is well known that R&D for drugs and vaccines comes in different stages: basic research, pre-clinical or translational research, and clinical development, which typically comprises three phases of trials with patients. Phase I is about the safety of the new drug or vaccine, Phase II explores efficacy with small-scale trials, while Phase III confirms (or not) Phase I and Phase II results with large-scale trials. In facts R&D continue after the marketing authorization by a regulator, to detect adverse effects. There is no doubt that pharmaceutical R&D implies high risks and expenditures and requires time (UNCTAD, 2015, Schuhmacher et al., 2016). According to OECD (2018), the development of a new drug requires an average 10-15 years from the beginning of the process to marketing authorization, with many failed projects along the path.

The COVID-19 vaccines case-history reverses the conventional wisdom as it suggests that the duration of the process is endogenous: in fact it is a variable depending from the pressure from a public health emergency, government subsidies to R&D, and/or other forms of public intervention. Thus, we have here an exemplar of what can be achieved when government step in R&D and dramatically change the usual functioning of the industry. However, the current intellectual property rights arrangements for COVID-19 vaccines fall short of the proper acknowledgment of such role.

The structure of the paper, in five sections, is the following: first, I discuss how the 'miracle' of getting several vaccines against an unknown virus in less than one year is actually not a miracle at all, but the consequence of previous research and development over more than 20 years; second, I remind that legislation in the US about patents based on public sector funding of R&D would support certain direct actions by the government if the owners of such patents were unable to use them in the public interest; third, I discuss the amount of R&D funding by the public sector in the USA (particularly through the

operation "Warp Speed")[2] and show that for example in the case of Moderna, until recently a minor biotech company, the vaccine should potentially be co-owned by the US government; fourth, I discuss the 'de-risking' action by governments through advance payments for not yet approved vaccines; lastly, I suggest that there is a paradox arising from quick emergency authorizations of the COVID 19 vaccines by the US Food and Drug Administration (FDA) and the European Medicines Agency (EMA) (and other regulators) giving exclusive marketing authorization to pharmaceutical companies. In the name of public interest such authorizations created long-term legal monopolies for a small group of pharma companies (for around 19 years) about vital technologies, with huge financial rents for investors.

I conclude with the wider policy implications of the Covid 19 vaccines case study on the social costs of the privatization of knowledge.

1. The science behind the Covid-19 vaccines

President Biden and his advisors may know that some patents related to messenger ribonucleic acid (mRNA) vaccines, filed by pharmaceutical companies last year, are crucially linked to earlier fundamental findings of publicly-backed research. An mRNA vaccine is based in a single-stranded molecule of RNA, a genetic sequence of a gene that is instrumental in the process of synthesizing a protein.

Three notable examples of how previous research is embodied in current vaccines, according to Allen (2020) are: (i) the concept of mRNA modification for therapeutic use (undertaken by David Weissman and Katalin Karikó at the University of Pennsylvania)[3], (ii) the lipid nanoparticle vehicle invented at the MIT (Massachusetts Institute of Technology) in the Langer Lab, (iii) the technology for stabilizing viral spike proteins developed by Barney Graham, Jason McLellan and other inventors[4], at the US National Institutes of Health, in particular at the National Institute for Allergy and Infectious diseases (NIAID), the institute headed by Dr. Anthony Fauci [5], chief medical advisor to the US President.

[2] A reviewer has suggested that Universities Allied for Essential Medicines has been keeping a tracker of public funding for COVID technologies: https://publicmeds4covid.org/

[3] https://www.scientificamerican.com/article/for-billion-dollar-covid-vaccines-basic-government-funded-science-laid-the-groundwork/

[4] https://patents.justia.com/inventor/jason-mclellan

[5] See Prefusion Coronavirus Spike Proteins and Their Use, US Patent Office, patent issued 2021-03-30 https://www.ott.nih.gov/technology/e-234-2016

Vaccines as those produced by Pfizer and Moderna, two US companies, work by introducing into certain human cells small amounts of mRNAs encoding a small, inert portion of the viral machinery – in the case of Covid-19, a modified version of the so-called spike protein. The protein product of the mRNA vaccine is not harmful for the cell, but its structure mimics the actual viral proteins enough to "train" the immune system to recognize, and thus neutralize, Covid-19 in case of a later exposure.

Delivering mRNAs to target cells, however, proved to be no minor undertaking, as mRNA, and RNA in general is an extremely unstable molecule, highly prone to degradation. For a fascinating history of the recent discoveries and biotechnologies related to RNA, see Isaacson (2021) focusing on the work of Jennifer Doudna, a biochemist at the University of California, Berkeley (Nobel Prize for Chemistry 2020, shared with her co-author Emmanuelle Charpentier).

A breakthrough in RNA vaccine technology came much earlier from the application of lipid nanoparticles as drug delivery vectors: all RNA vaccines today work by encapsulating the spike-protein-encoding mRNA into small lipidic droplets, which compartmentalize the RNA, protecting it from degradation while it travels through the bloodstream and facilitating its uptake from target cells. The idea of using lipid nanoparticles as vehicles for drug delivery long predates RNA vaccines: it was initially developed in the 1960s by Robert Langer and others at the Massachusetts Institute of Technology (MIT) and further developed in later years in the Langer Lab at the MIT Department of Chemical Engineering. See for example this statement from the Lab website[6]:

> The main current theme of our lab is utilizing polymers to deliver drugs, particularly various small molecules, genetically engineered proteins, DNA and RNAi, continuously at controlled rates for prolonged periods of time. Work currently in progress includes: a) investigating the mechanism of release from polymeric delivery systems with concomitant microstructural analysis and mathematical modeling; b) studying applications of these systems including the development of effective long-term delivery systems for insulin, anti-cancer drugs, growth factors, gene therapy agents and vaccines; c) nanotechnology; d) delivery through different routes in the body including the skin, lung, vagina, gi tract, eye, and brain; and e) synthesizing new biodegradable polymeric delivery systems which will ultimately be absorbed by the body. To gauge the innovativeness and relevance for the pharma industry of this research, including for vaccines development, one may consider that (again according to the Lab website) Professor Langer's "patents have been licensed or

[6] http://langer-lab.mit.edu/research/drug_delivery, accessed October 5, 2021.

> sublicensed to over 350 pharmaceutical, chemical, biotechnology and medical device companies".

This is a notable example of the cumulativeness of knowledge upstream of the design of a specific pharmaceutical product, and particularly of an mRNA vaccine.

A second challenge that RNA vaccine therapeutics had to face was posed by the cell's anti-viral immune system – which normally targets and degrades "alien" RNA molecules. Pharma companies were previously unable to find a way to avoid premature degradation of such key ingredient in the generation of new vaccines. The solution was found initially by a Hungarian biologist, Katalin Karikó. According to Allen (2020):

> Our innate immune systems evolved to kill RNA strands because that's what many viruses are. Karikó came up with the idea of modifying the elements of RNA to enable it to slip past the immune system undetected. The modifications she and Weissman developed allowed RNA to become a promising delivery system for both vaccines and drugs.

The story of this biotechnological innovation hence goes back to research by Karikó in 1970 in Hungary, where she was born, at that time still a Soviet-bloc country, and to a NIH (National Institutes of Health) grant to her in 1989, and further work in collaboration with Weissman in 2004. Later on:

> Eventually, the University of Pennsylvania sublicensed the patent to Cellscript, a biotech company in Wisconsin, much to the dismay of Weissman and Karikó, who had started their own company to try to commercialize the discovery. Moderna and BioNTech later would each pay $75 million to Cellscript for the RNA modification patent.

This story is highly revealing about the long journey from academic research to development and shows how patents are interlinked. It suggests that both Moderna-NIH and Pfizer-BioNTech[7] Covid-19 vaccines share the same concept developed elsewhere.

The third ingredient in the story is even more powerful, as it is not just relevant to mRNA vaccines, but also several others, including the DNA-based vaccine developed by Johnson & Johnson. This is the design of a bioengineered

[7] A reviewer has suggested that even though Pfizer likes to talk about how they didn't get US public funds to develop their COVID vaccine (directly), BioNTech of course did receive significant funding from the German government for that purpose: https://www.bloomberg.com/news/articles/2020-11-09/pfizer-vaccine-s-funding-came-from-berlin-not-washington

protein developed by Graham and his collaborators at the National Institutes of Health Vaccine Center, a public sector body. The concept here is slightly more technical, but in fact is relatively simple. Graham was studying "fusion proteins"— small molecular machineries on the outer surface of viruses that mediate the virus' ability to anchor to, fuse with, and thus ultimately infect target cells. Upon binding to the cell's receptors, these proteins can change their conformation: from a "pre-fusion" to a "post-fusion" shape. While most people at the time were developing vaccines against "post-fusion" viral proteins, Graham realized that certain prefusion antibodies were several times more effective in generating an immune response than the post-fusion forms, while minimizing the side effects that were frequent in the case of pre-fusion antibodies.

According to Allen (2020), two papers by Graham and his team, published by Science in 2013 paved the way for the NIH's Vaccine Research Center to develop a

> "generalizable, rapid way to design vaccines against emerging pandemic viruses… In 2016, Graham, McLellan and other scientists, including Andrew Ward at the Scripps Research Institute, advanced their concept further by publishing the prefusion structure of a coronavirus that causes the common cold and a patent was filed for its design by NIH, Scripps and Dartmouth—where McLellan had set up his own lab. NIH and the University of Texas—where McLellan now works—filed an additional patent this year for a similar design change in the virus that causes COVID-19… Graham's NIH lab, meanwhile, had started working with Moderna in 2017 to design a rapid manufacturing system for vaccines. In January, they were preparing a demonstration project, a clinical trial to test whether Graham's protein design and Moderna's mRNA platform could be used to create a vaccine against Nipah, a deadly virus spread by bats in Asia."

The outcome was a crucial innovation, that supports several current vaccines for Covid 19. In their 2016 paper published by Nature, Kirchdoerfer et al. (2016) state that:

> "The structure and mechanistic insights presented here should enable engineering of pre-fusion stabilized coronavirus S proteins as vaccine immunogens against current and emerging beta coronaviruses, similar to recent efforts for other viral fusion protein… This work also acts as a springboard for future studies to define mechanisms of antibody recognition and neutralization, which will lead to an improved understanding of coronavirus immunity."[8]

[8] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4860016/

The authors mention specifically SARS (Severe Acute Respiratory Syndrome) and MERS (Middle-East Respiratory Syndrome), that as we now do know are to a certain extent (overlap of over 80% of the genome) related to SARS COV2, the virus of Covid 19 pandemic.

In a recent official statement, the NIH announced that "NIAID scientists have created stabilized spike proteins for the development of vaccines against coronaviruses, including SARS COV-2...", and claimed to have filed patents in this regard "to protect the rights of government concerning these inventions" and to have adopted a non-exclusive licensing approach in favor of several private companies, (NIH Statement to Axios)[9]. As it turns out, Moderna[10], BioNTech and other firms[11] have also obtained this license (conditions are not in the public domain).

As is often the case, knowledge, innovation and intellectual property are closely interlinked.

In the case of Pfizer-BioNTech and Moderna-NIH vaccines, but probably for other vaccines as well, the core response mechanism of the vaccines goes back to an innovation, protected by a valid patent, of the US government (and others) through the NIAID/NIH, and to other previous advances in R&D outside the Big Pharma scope. This has potentially legal and policy implications.

2. The protection of the rights of government in the public interest

This paper focuses particularly on the legal and policy issues around patents for vaccines in the US, because this is the core country for the pharmaceutical industry and its R&D. According to the Bayh-Dole Act (the bipartisan law of 1980 that governs the subject of patents obtained with the assistance of the US federal government)[12], if the price of the drug or other

[9] https://www.documentcloud.org/documents/6956323-NIH-Statement-to-Axios

[10] https://www.documentcloud.org/documents/6935295-NIH-Moderna-Confidential-Agreements.html, https://www.citizen.org/article/the-nih-vaccine/

[11] According to correspondence with NIAID in December of 2020, the following companies have licenses to this invention: Medigen Vaccine Biologics Corp.; Noachis Terra, Inc.; OncoSec Medical Incorporated; BioNTech AG; N4 Pharm UK Limited; Dynavax Technologies; RNAceuticals, Inc.; Sanofi Pasteur; GlaxoSmithKline Biologicals SA; Adimmune Corporation; Vaxess Technologies; Meso Scale Diagnostics, LLC; The Binding Site Group Ltd.; ReiThera Srl; GeoVax, Inc.; ExcellGene SA; and Thermo Fisher Scientific Inc."
https://www.keionline.org/35746

[12] https://en.wikipedia.org/wiki/Bayh%E2%80%93Dole_Act#References

conditions are not "reasonable", the government can recover its rights and enter the market directly ("march-in" clause)[13] with its own initiatives.

The policy objectives of the Bayh-Dole Act are stated as follows[14]:

> It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally supported research or development; to encourage maximum participation of small business firms in federally supported research and development efforts; to promote collaboration between commercial concerns and nonprofit organizations, including universities; to ensure that inventions made by non-profit organizations and small business firms are used in a manner to promote free competition and enterprise without unduly encumbering future research and discovery; to promote the commercialization and public availability of inventions made in the United States by United States industry and labor; to ensure that the Government obtains sufficient rights in federally supported inventions to meet the needs of the Government and protect the public against nonuse or unreasonable use of inventions; and to minimize the costs of administering policies in this area.

The wording of these opening statements carefully balances different goals of the law: on one side to disseminate innovations, particularly of small enterprise and non–profit organizations, including universities, but on the other side to protect government rights on inventions and patents supported by tax payers' money.

In this context, the so-called "march-in rights" are a legal mechanism intended to give the government a final say when the patent holder does not act in the public interest. The law in fact states that:

> "With respect to any subject invention in which a small business firm or non-profit organization has acquired title under this chapter, the Federal agency under whose funding agreement the subject invention was made shall have the right, in accordance with such procedures as are provided in regulations promulgated hereunder to require the contractor, an assignee or exclusive licensee of a subject invention to grant a nonexclusive, partially exclusive, or exclusive license in any field of use to a responsible applicant or applicants, upon terms that

[13] https://fas.org/sgp/crs/misc/R44640.pdf

[14] A reviewer has suggested that there is significant debate in the US access to medicines world about the intent of the law, in part because the march-in component has never been used for pricing issues, and in part because of the clear consequences for access to essential medicines since Bayh-Dole's passage. See Alex Zaitchick article: https://theintercept.com/2021/08/29/bayh-dole-act-public-science-patents/

> are reasonable under the circumstances, and if the contractor, assignee, or exclusive licensee refuses such request, to grant such a license itself, if the Federal agency determines that such
> - action is necessary because the contractor or assignee has not taken, or is not expected to take within a reasonable time, effective steps to achieve practical application of the subject invention in such field of use;
> - action is necessary to alleviate health or safety needs which are not reasonably satisfied by the contractor, assignee, or their licensees;
> - action is necessary to meet requirements for public use specified by Federal regulations and such requirements are not reasonably satisfied by the contractor, assignee, or licensees; or
> - action is necessary because the agreement required by section 204 has not been obtained or waived or because a licensee of the exclusive right to use or sell any subject invention in the United States is in breach of its agreement obtained pursuant to section 204."

It is easily predictable that a litigation between the federal government about the appropriateness of the price, production and distribution strategies of pharma companies such as Moderna and Pfizer ("to alleviate health or safety needs which are not reasonably satisfied by the contractor, assignee, or their licensees") would take considerable time and resources. Thus the NIH and the federal government may not actually be willing to use their 'march-in' rights, which may or may have not been mentioned in the agreements with the companies (but that – as they are written in the law – cannot be easily overwhelmed if so the US government would decide to claim them). However, it is interesting to look more in depth into the potential legal issues arising in this context.

The 'march-in' option, while not mentioned by Biden, is common knowledge amongst insiders[15]. It would be far more radical than the temporary suspension of patents. Discussions among health policy and law experts about this option have also been disclosed by the New York Times (March 21, 2021 and May 7, 2021)[16] and confirmed by other authoritative sources.

According to Hickey (2020), as stated in a Congressional Research Service report: firstly, it is beyond dispute that the law would apply to any company, not just to small business; and, secondly, that:

> "The federal government has never exercised march-in rights under Bayh-Dole. Advocacy groups have petitioned the National Institute of Health (NIH) several times to exercise march-in rights based on the high prices of certain drugs developed with federal funding, such as

[15] https://crsreports.congress.gov/product/pdf/LSB/LSB10422
[16] https://www.nytimes.com/2021/03/21/world/vaccine-patents-us-eu.html

> treatments for HIV/AIDS. NIH has rejected these petitions, contending that pricing concerns alone are insufficient to exercise march-in rights—so long as the invention is on the market and available to patients. In the context of a pandemic like COVID-19, the "health or safety needs" language would appear to provide a possible basis for the exercise of march-in rights, should the federal agency determine that compulsory licensing is necessary to address public health needs unmet by a federal contractor."

Moreover in the US legislation in principle[17] there would be a more powerful option. According to the same Report:

> A broader statutory authority than march-in rights, 28 U.S.C. § 1498 (section 1498), applies to any patented invention—not just inventions made with federal funding. Under section 1498, sometimes described as an "eminent domain" provision for patents, the U.S. government has the authority to use or manufacture any patented invention "without license." In practice, this means that if the U.S. government determines that it needs to practice an invention, it need not ask permission from the patent holder to do so, and—despite the existence of the patent—courts will not order the government to cease infringing activity. The patent holder, however, has the right to sue in the U.S. Court of Federal Claims for "reasonable and entire compensation" for the government's use of the patented invention. In effect, then, section 1498 allows the United States to issue itself a compulsory license to make and use any patented invention without obtaining the permission of the patent holder, in exchange for consenting to liability in a suit seeking reasonable compensation for the government's use. In the context of COVID-19 medical countermeasures, the U.S. government could rely on section 1498 to make and use any patented invention without the consent of the patent holder. Because section 1498 extends to infringement "by a contractor, a subcontractor, or any person, firm, or corporation for the [U.S.] Government and with the authorization or consent of the [U.S.] Government," the federal government could also extend its section 1498 authority to the actions of private entities by authorizing them to practice a patented invention on behalf of the government.

[17] A reviewer has suggested that 28USC 1498 has also been used in practice for procuring lower-priced medicines for the public sector. In fact, it was used routinely in the past, as documented in this excellent paper by Yale legal scholars: https://digitalcommons.law.yale.edu/cgi/viewcontent.cgi?article=1124&context=yjolt. The contention of many US access to medicines advocates and experts is that the current lack of use of either Bayh-Dole or 1498 provisions to lower drug prices or increase supply/access is entirely political and has to do with industry capture and larger ideological capture of the nation, and thus, of our public servants both in elected and appointed positions.

To conclude this section, in principle the US government has several policy options to directly enter in the Covid 19 vaccines arena if the US-based pharma companies are unable to manage a global vaccination campaign at the speed needed to avoid that new dangerous variants emerge in other countries, see for example Quigley (2020) on such options (even before the current pandemic).

The concept of an economic externality here fully applies: to protect its own citizens any government has a public interest in the fast track vaccination of all other countries. In fact, the basics of viral epidemiology would suggest that no country can fully protect its own residents during a pandemic as long as there remains a large human reservoir around the world in which the virus can continue to be transmitted and continue to mutate. This is a particularly serious concern with coronaviruses, RNA-based viruses with frequent mutations. Hence, there is a global public good, the protection of human health against a highly contagious disease, and any policy aiming at protecting the citizens of one country, cannot overlook that such a policy has both a national and an international dimension. After all, borders cannot remain closed forever, and vaccines cannot protect forever the citizens of one country if in another country the virus has the opportunity to circumvent the vaccine through a mutation.

3. Government funding of R&D of vaccines

The narrative about the "miracle" of fast track discovery of the Covid-19 by pharma companies is deeply flawed, firstly because, as mentioned in the previous section, the science behind the vaccines is largely based on advancements in university laboratories or government-sponsored research institutes, but also because of the impressive amount of money and regulatory support offered by governments and public sector agencies.

I shall discuss later the latter point, while I focus here on the unprecedented amount of money that flowed from the tax payer to corporate R&D. I cannot discuss here a third point (suggested by a reviewer) related to the time dimension of the inefficiency of the patent system: if modern intellectual property rights (IPR) did not provide barriers to sharing scientific data and learnings in real time, then effective vaccines or therapeutics could have been discovered even faster, or vaccines that don't rely on ultra cold-chain mechanisms could have been delivered earlier, or vaccines that are better able to provoke immune responses against more variants of SARS-Cov2. Such counterfactual analysis is empirically difficult: we shall never know if there were such alternatives under an open science scenario.

Going back to tax-payers money behind the vaccines 'miracle', the most important mechanism was Operation Warp Speed (OWS), launched during the

President Trump administration, and mostly managed through another federal agency (BARDA, Biomedical Advanced Research and Development Authority)[18] by the end of October 2020, barely ten months after the beginning of the pandemic; the budget of Warp Speed was 18 billion USD[19].

OWS was designed as a public–private partnership. The objectives of the United States government were clear from the beginning (May 2020): to facilitate and accelerate the development, manufacturing, and distribution of COVID-19 vaccines, therapeutics, and diagnostics. OWS was headed from May 2020 by Moncef Slaoui (a former researcher and manager in the pharma industry) and by January 2021, under Biden Administration, it was transferred to the White House COVID-19 Response Team.

An interesting aspect of the OWS is that it took a 'portfolio' approach, as it funded different vaccines and technologies, well before evidence of safety and clinical effectiveness, in fact discounting possible failures. Several projects were later abandoned, meaning that the US tax payers through OWS had to feel the burden of failures as the benefit of successes.

Initial funds for OWS were $10 billion from the CARES Act (Coronavirus Aid, Relief, and Economic Security) passed by the United States Congress on March 27 2020, that coordinated the efforts of the Department of Health and Human Services, particularly the Centers for Disease Control and Prevention, the Food and Drug Administration (FDA), the National Institutes of Health (NIH), and BARDA. Also involved under CARES were the Department of Defence, the Department of Agriculture, the Department of Energy, and the Department of Veterans Affairs and several private companies.

According to different sources [20] the targets of OWS included the following:

- Seven companies were supported for R&D on vaccines: more directly Johnson & Johnson, Astra Zeneca, Moderna, Novavax, Merck and IAVI, Sanofi and GSK, plus some others for specific compounds. Only the first three are currently authorized by the Food and Drug Administration and European Medicines Agency, respectively in the USA and the European Union (EU).

[18] https://public3.pagefreezer.com/browse/HHS%20%E2%80%93%C2%A0About%20News/20-01-2021T12:29/https://www.hhs.gov/about/news/2020/05/15/trump-administration-announces-framework-and-leadership-for-operation-warp-speed.html

[19] https://www.bloomberg.com/news/features/2020-10-29/inside-operation-warp-speed-s-18-billion-sprint-for-a-vaccine

[20] https://en.wikipedia.org/wiki/Operation_Warp_Speed

- Subsidies to manufacturers to increase their capacity.
- Support of clinical trials and FDA review process.
- Creating with the Department of Defence a tracking and distribution system of approved vaccines.

An example of this approach is Moderna,[21] often referred to as a vaccine co-developed with the NIH[22], that is, with the public sector. In fact, it was also developed with BARDA money in the OWS, and as it happens the initial top manager of Warp Speed, Moncef Slaoui, the former head of vaccines research at GSK, was also sitting in the Moderna Board of Directors until his appointment.

Importantly, it seems that the US government retained unlimited rights to the data associated with the "Moderna" COVID-19 vaccine. Thus, the US government potentially has the ability to replicate and to share the know-how for the manufacture of this vaccine. They just have not exercised that right thus far. Rivzi (2021) suggests that

> Moderna likely did not use contract funding simply to make minor modifications to its existing manufacturing process. Instead, Moderna learned how to commercially produce hundreds of millions of doses on the taxpayer's dime. The company went from producing fewer than 100,000 doses across all products *per year* to producing 1.3 million coronavirus vaccine doses *per batch*.

The example of Moderna is not unique in terms of flows of money by governments to support corporate R&D on Covid 19 vaccines (and therapies), see below. Moreover, another major flow of funds accrued to the companies in a different form.

4. De-risking though advance payments

The de-risking in favor of the private sector was also decisive, with public purchases for billions of dollars even before receiving authorizations (with large profit margins for Moderna and Pfizer, which were abundantly reflected in their share values)[23].

The case of Pfizer is interesting, as apparently Pfizer did not want to receive money from Warp Speed for R&D; however they were happy to accept government funds in a different form.

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[21] https://www.modernatx.com/modernas-mrna-technology

[22] https://www.eurekalert.org/pub_releases/2021-04/bu-cvd042121.php

[23] https://theconversation.com/us-backed-vaccine-patent-waiver-pros-and-cons-explained-160480

According to Axios[24]: “Pfizer CEO says he would've released vaccine data before election if possible”[25].

Pfizer CEO Albert Bourla rejected the OWS funds “to liberate our scientists [from] any bureaucracy that comes with having to give reports and agree how we are going to spend the money in parallel or together”.

However, this statement did not prevent Pfizer from accepting a OWS advance-purchase order of $2 billion for 100 million doses of a COVID-19 vaccine for use in the United States conditional to FDA authorization. An even larger advance order was placed by the European Union. The emergency authorization of the Pfizer–BioNTech vaccine was released by FDA on December 11 2020, and Pfizer was ready to distribute the vials manufactured earlier in the very year of the pandemic, thanks to government money support. In fact, Pfizer was in this way an OWS participant: it insisted that they had “not taken federal money for R&D”, even if BioNTech, had received substantial funding (around 445 million USD) for accelerated vaccine development and manufacturing from the German government.

Hence, the Pfizer-BioNtech vaccine was funded by tax payers money in different ways, both in the USA and in Germany. Pfizer accepted government funds for producing doses well in advance of the emergency marketing authorization by the US regulators. It is impossible to discern exactly which corporate expenditures these funds have supported, as one dollar is one dollar. The only reason for the company to claim otherwise was to avoid the above mentioned legal mechanisms to protect the public interest, but de facto they also receive considerable tax payers money.

It is probably impossible to estimate the global amount of governments’ support to R&D of covid 19 vaccines beyond OWS, but research on this topic is going on particularly at the Global health Centre of the Graduate Institute Geneva[26]. Such research shows a substantial flows of funds from governments to specific companies, beyond national boundaries.

5. The paradox of emergency authorizations by FDA

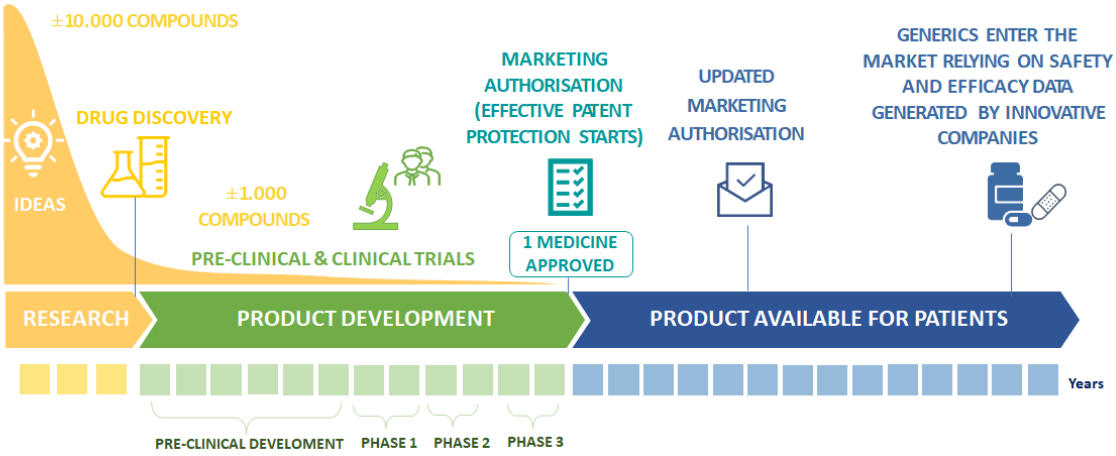
Lastly, authorization times on the part of the Food and Drug Administration (and other pharmaceutical agencies) were shorter than a year because of the emergency.

[24] Axios (November 9, 2020).
[25] Axios. Archived from the original on December 10, 2020. Retrieved November 11, 2020.
[26] https://www.knowledgeportalia.org/covid19-r-d-funding

The usual argument for the long duration of patents (20 years at least) is that pharmaceutical companies after filing a patent need to consume a substantial part of the possible time horizon in pre-commercial activities.

The pharmaceutical industry, like many other contemporary industries, is organized along a global value chain (cf. EP, 2021; Kedron and Bagchi-Sen, 2012; Zeller and Van-Hametner, 2018), including the following stages:

1. the discovery of new drugs through research;
2. the pre-clinical development;
3. the design and execution of clinical trials (3 phases);
4. the approval of new drugs by public health authorities;
5. the manufacturing of approved drugs, including;
6. the supply/sourcing of key starting materials[27];
7. the production of intermediates[28] and active pharmaceutical ingredients (APIs);
8. the production of the finished dosage forms (e.g., pills or capsules) through the combination of APIs with excipients;
9. the marketing and distribution of drugs;
10. post-marketing surveillance.



Source: Authors adapted from https://www.efpia.eu/about-medicines/development-of-medicines/intellectual-property/

The figure above, adapted by information provided by EFPIA, the European Federation of Pharmaceutical Industries and Associations, a lobby-umbrella organization of the pharma industry, suggests that for an 'average' individual drug 10-15 years are spent for R&D and this would leave slightly more

[27] These are raw material refering to chemical compounds that are used as a base to make an API.

[28] The chemical compound which is in the process of becoming an API from a raw material is called an intermediate. Some API passes through over ten kinds of intermediates in a process when it changes from being a raw material into an API.

than ten years before patents' protection expires and 'generics' are available in the market.

I am not aware of systematic independent evidence that could confirm what the industry representatives claim in terms of actual duration of commercial exploitation of a drug under the legal protection offered by a patent; but Covid 19 vaccines show a completely different picture. The authorizations, albeit in an 'emergency' form, were given by the regulators in so short time that a paradoxical consequence is that for such vaccines, urgently needed on a global scale, the patent mechanism would leave the planet dependent on some private companies' monopoly on vaccines for perhaps 19 years, almost a whole generation. The technology legally protected by these patents (and by others based on more conventional approaches, but also supported almost entirely by public funds (as in the case of the Oxford AstraZeneca chimpanzee virus)[29]) will, in all probability, also serve for future campaigns in the presence of variants, the emergence of which is in turn fostered by the extremely slow uptake of vaccines in developing countries, as reported by the World Health Organization (WHO).

Concluding remarks and policy implications

The policy issues raised by this case study on Covid 19 patents have wider implications, beyond the current pandemic. President Biden had every reason to raise the issue of intellectual property at the World Trade Organization (WTO). As varied as the practical and legal solutions may be in the short term, Biden's administration, in principle may have some negotiation leverage with the pharmaceutical industry, with Anthony Fauci being the key advisor in the vaccine strategy, Eric Lander of the Broad Institute of MIT and Harvard (one of the most renowned geneticists in the world) at the head of the Federal Government's Office of Science and Technology, and massive public infrastructures in the biomedical field, such as the NIH and BARDA. These two institutions operate on a scale that is much larger than in any other country. So Biden certainly does not need to be told by Pfizer's CEO or by the industry press releases that producing a vaccine is a complex matter from the point of view of raw materials, machinery and professionalism.

The issue raised by President Biden is this: whether the only negotiating position of governments over the next 20 years on the technologies that underlie vaccines will be that of signing one purchase contract after another with an oligopoly, which would have enormous power as regards prices, delivery times and control of the value chain without, however, being able to guarantee the

[29] https://www.medrxiv.org/content/10.1101/2021.04.08.21255103v1

vaccination of the entire planet[30]. This would be a self-perpetuating machine for extracting rents for monopoly power, as quantity constraints and prices higher than marginal costs of vaccines would slow down vaccinations, allowing new variants to emerge, which would create the need of further rounds of patented innovations on vaccines, further profits and so on. It will be the SARS Cov2 virus only that will take the "decision" to stop the pandemic, when a highly contagious but mild variant will displace all the other ones. The social opportunity cost of waiting years to vaccinate the world would be several GDP points lost for ever, and directly and indirectly millions of lives (Florio and Pancotti, 2021). All of this could be avoided by forcing the owners of the patents and related IPR to transfer their technologies to any private and public body who is able to safely produce and distribute the vaccines everywhere in the shortest possible time: months not years. Particularly for vaccine production, information currently held as trade secrets is at least as important as that held in patents. For a new technology like mRNA vaccines, active tech transfer is needed in order to really scale production fast and effectively, see Krellenstein and Urrutia (2021). It is apparent that qualified vaccine makers are available in several countries and are trying to get access to the know-how to help produce/distribute the existing vaccines[31].

More in general, the Covid 19 vaccines case study raises the issue of the privatization of knowledge, which begins upstream as a public good and is incorporated downstream into share values. Tracking back the origins of innovation to research supported by governments and tax payers is relatively easy ex-post, for example looking at publications cited by patents or to grants received by companies. However, the rights of tax payers and citizens are not protected without new arrangements (Florio, 2021).

There are two additional economic arguments, suggested by a reviewer, that I cannot develop here, but that are important for future research: firstly, the current arrangements of intellectual property rights create a sizeable economic inefficiency, resulting in redundancy and waste of resources, as well as unnecessary time lags innovation and production[32]; secondly, there is an artificial scarcity of vaccines caused by a system of IPR that does not allow for the scope of production (and distribution) necessary on a planetary scale.

[30] https://www.economist.com/by-invitation/2021/04/20/mariana-mazzucato-jayati-ghosh-and-els-torreele-on-waiving-covid-patents

[31] See, for instance: https://www.politico.eu/article/vaccine-producers-reject-offers-to-make-more-jabs/amp/?__twitter_impression=true

[32] See the opinion of the legal scholar Chris Morten: https://www.commondreams.org/views/2020/09/17/invent-our-way-beyond-covid-19-we-need-open-science

Demand for vaccines, purchasing power (through national governments, but also COVAX), supply of basic inputs and capacity at factories around the world do not match because of a small group of companies were given IPRs beyond their actual contribution to discovery and innovation.

President Biden has blown everyone with his administration statement about a waiver of Covid-19 patents. In fact, the US government potentially has strategic levers and it may plan to use them to sit at the table of the WTO (where patents could be suspended formally via a very complex procedure) and to negotiate from a position of strength in other forums. Will this power be used? This is still an open question. While it is important that the Biden administration has made the statements it has, negotiations may last for months and the resulting waiver, if any, may bear little resemblance to the initial proposal by India, South Africa and other countries. Such waiver was endorsed by the European Parliament (June 10, 2021)[33]:

> In a resolution adopted with 355 votes in favour, 263 against and 71 abstentions, Parliament proposes negotiations start for a temporary waiver of the WTO TRIPS Agreement on patents to improve global access to affordable COVID-19-related medical products and to address global production constraints and supply shortages. MEPs also point to the threat that an indefinite TRIPS Agreement waiver would pose to research finance, in particular for researchers, investors, developers and clinical trials.
>
> Voluntary licencing (when the developer of the vaccine decides to whom and under what conditions the patent can be licensed to enable manufacturing), know-how and technology transfer to countries with vaccine-producing industries are the most important way to scale and speed up global production in the long term, said MEPs.

The European Commission, unfortunately, does not seem in turn to move in the same direction of the European Parliament, hence negotiations at the WTO are in a stalemate. The US government has just announced small amounts of donations of vaccines to low-income countries, de facto considering such donations a higher policy priority than sharing intellectual property rights, advancing deep technology transfer, investing in aid to scale manufacturing, etc.[34]

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[33] https://www.europarl.europa.eu/news/en/press-room/20210604IPR05514/parliament-calls-for-temporary-covid-19-vaccine-patent-waiver

[34] A recent blog from Brook Baker on the Biden administration's efforts in the global arena regarding the pandemic is illustrative of how many in the access to medicines movement see it: https://healthgap.org/bidens-2-7-billion-investment-in-supply-chains-is-a-cynical-boost-to-

Whatever the future of the WTO negotiations and the policies adopted by the US, EU and other governments, there is a policy lesson to be learned after the pandemic: we can do without the old textbook statements on the role of patents in stimulating innovation, if those patents are also based on other patents that result from public research, if private research was co-financed by tax payers, if the business risk was shifted to governments, if clearances from public agencies were granted in record time in an emergency (perhaps with some potential risks shifted to citizens), and if we fail to beat mutant strains in a timely fashion and on a planetary scale. It is not "business as usual". Governments should put their cards in the table and pharmaceutical firms would do better to hire external relations consultants who would suggest that they say: «Mr. President, let's talk about this».

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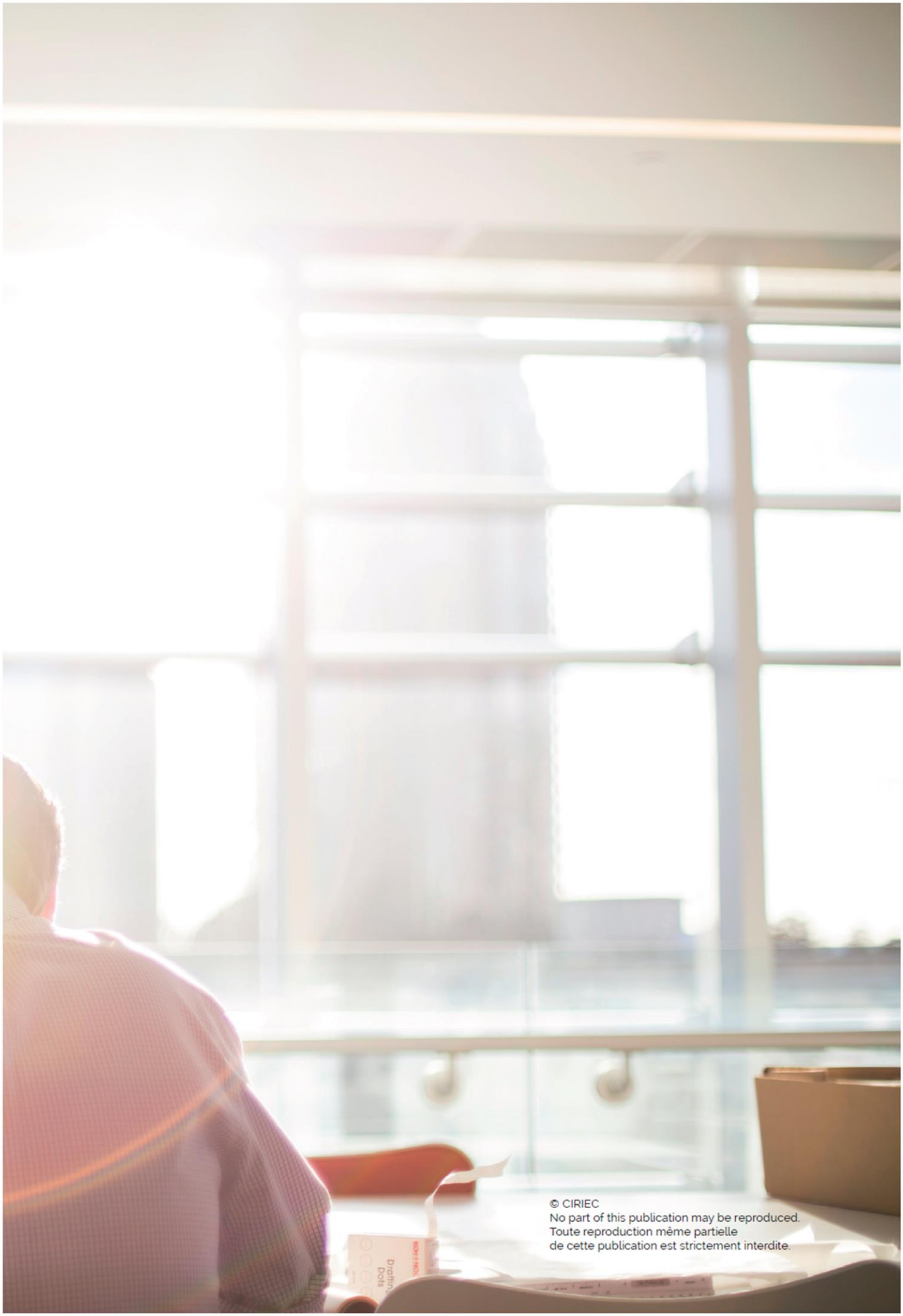

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