Better than a compromise, a third way: Using patent pooling to accelerate access to vaccines and treatments against Covid-19

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Better than a compromise, a third way: Using patent pooling to accelerate access to vaccines and treatments against Covid-19*

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Abstract

In the debate on intellectual property rights induced by the Covid-19 pandemic, vaccines and treatments are typically referred to as simple products whose manufacturing specifications need only to be shared in order to increase production capacity and accelerate access to all, more specifically to low-income populations in the developing world. We contribute to this debate by taking into account the fact that the manufacture of innovative vaccines and treatments can involve multiple technologies whose patents are held by several entities. We propose an economic approach that it is more balanced than the polar options – on which the debate has focused – of either maintaining or suspending patents, without being reduced to a simple compromise between these two extremes. This "third way" is grounded in a model for the characterization of the performance of a patent pool mechanism, whose objective is to maximize access to medicinal products by licensing multiple technologies as a bundle to downstream manufacturers. The outcomes of the nonprofit patent pool are compared with those of two benchmark scenarios where either patent holders license their technologies separately, or where a profit-maximizing patent pool is involved. The analysis highlights the positive role that a non-profit organization such as the Medicines Patent Pool can play in the global governance of responses to the pandemic.

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1 Introduction

In 2021, efforts and strategies to address the COVID-19 pandemic have gone global. The development of several effective vaccines in record time against SARS-CoV-2 offers the prospect of an end to the crisis, with significant progress also being made in the treatment and management of patients with severe forms of the disease. However, the emergence and spread of more contagious variants of the virus implies that no country can address the pandemic alone, and that life will return to normal only when all countries are free of outbreaks. Access to vaccines and treatments in developing countries, as well as in developed countries, is therefore a major concern of the international community.

The progress of vaccination campaigns in different parts of the world reveals significant geographic disparities. While in North America, as in many European countries, vaccination campaigns started as early as December 2020, the majority of African countries did not start vaccinating their populations until March 2021. By the summer of 2021, while the highest-income countries report that they have vaccinated more than 70% of their adult population, the low-income countries have vaccinated less than 1% of their population (Sen-Crowe et al., 2021; Padma, 2021).

The success of immunization campaigns depends on an extensive range of complementary factors, none of which should be overlooked. For example, on the demand side, it has been documented that vaccine hesitancy results in large quantities of doses that go unused before the expiry date (Arezki, 2021). On the supply side, a challenge is to install sufficient production facilities for vaccines to be rolled out at scale and deployed in the shortest possible time by governments, so that population-wide coverage can result in herd immunity and stop transmission (Wouters et al., 2021; Guzman et al., 2021). Similar issues relate to the provision of new treatments that protect against most severe forms of the disease and reduce the risk of hospitalization. These treatments are all the more necessary in developing countries where health systems are fragile and hospital space is limited (Gupta, 2021 ; Sanders, 2021).

In this context, the role of patents, often seen as a barrier to accelerating the manufacturing of vaccines and treatments, and to their diffusion in the developing world, has been debated within the World Health Organization (WHO), the World Intellectual Property Organization (WIPO),

and the World Trade Organization (WTO).[1] By granting a monopoly (of limited duration) to its holder, a patent rewards the innovator for its research and development efforts which, in the biopharmaceutical domain, typically take a long time, involve high risks, and require costly investments. However, this reward comes at a cost to society, as monopolistic behavior results in a reduced quantity of products sold at higher prices in comparison to a hypothetical situation where the innovation is made freely available in the public domain. On these grounds, an official request was filed by India and South Africa in October 2020 with the World Trade Organization (WTO) for a temporary waiver of all intellectual property rights (IP) rights relating to Covid-19 technologies. The initiative, supported by some 100 countries, aimed at facilitating the use of technologies for the accelerated manufacturing of innovative vaccines and treatments by producers of biosimilars and generics, and their timely diffusion in the developing world.

The patents that protect the intellectual property of technologies in relation to vaccines can be held by several companies, universities, or research organizations. This situation occurs in the case of tozinameran, the first messenger ribonucleic acid (mRNA) vaccine against Covid-19, commercialized under the brand name Comirnaty, which was authorized for emergency use by the US Food and Drug Administration (FDA) in December 2020. Developed by the biotech company BioNTech and manufactured in partnership with Pfizer, the vaccine is protected by fourteen patents (or patent families) whose holders include, in addition to BioNTech, the biotech companies Acuitas Therapeutics, Arbutus Biopharma, and Protiva Biotherapeutics, the Trustees of the University of Pennsylvania, and the translational research organization TRON (for translational oncology) of Johannes Gutenberg University Mainz.[2]

Patents in relation to the technologies needed to supply treatments can also be held by multiple entities. This occurs in the case of drugs that combine several molecules and are often described as therapeutic "cocktails". For example, the combination of two molecules, baricitinib and remdesivir, was authorized for emergency use by the FDA in November 2020 for the treatment of patients with respiratory failure. The first of these molecules is protected by two patents, and the second molecule by eight patents, which were filed in the US by Eli Lilly and Gilead, respectively.[3]

[1] See, for example, the news released jointly by WHO, WIPO, and WTO, dated 24 June 2021: https://www.who.int/news/item/24-06-2021-directors-general-of-who-wipo-and-the-wto-agree-on-intensified-cooperation-in-support-of-access-to-medical-technologies-worldwide-to-tackle-the-covid-19-pandemic

[2] For detailed information on the patent status of COVID-19 vaccines worldwide, see the MPP's patents database VaxPAL: https://medicinespatentpool.org/what-we-do/vaxpal

[3] Outside the United-States, baricitinib is protected by 54 patents, and remdesivir by 246

In a range of industries connected to information technology (software, telecoms, electronics ...), where innovation efforts generate extensive patent families, the holders of property rights frequently collaborate in the form of patent pools. These organizations, which often relate to a technological standard (e.g., Bluetooth, RFID, MEPG, 5G), aim at facilitating the coordination of multiple contributors and at reducing transaction costs with technology users.[4]

In the health sector, the view that pooling intellectual property rights might accelerate the development of innovative medicines was discussed in the context of the SARS-CoV-1 crisis in 2002-03, the H5N1 bird flu pandemic in 2005, and the H1N1 swine flu pandemic in 2009. With the support of the United Nations, the Medicines Patent Pool (MPP) was founded in 2010 in order to "improve health by providing patients in low- and middle-income countries with increased access to quality, safe, efficacious, more appropriate and more affordable health products medical products."[5] The MPP seeks voluntary licenses from pharmaceutical companies and biotechnologies that hold patents necessary for the marketing of specific drugs, before reselling (combinations of) sublicenses to downstream generic producers. Because it operates as a one-stop shop, the MPP strengthens legal certainty for generic manufacturers (a single license for all necessary technologies reduces the risk of infringement proceedings), prevents possible patent holdup situations (when the holder of an essential patent charges unreasonably high royalties), and lowers transaction costs (by reducing the number of contract negotiations).[6] As the operations of the MPP are based on voluntary licensing, this is more conducive to a transfer of manufacturing know-how – as a complement to intellectual property – than when a government issues a compulsory license which, by definition, allows a company to supply a product without the consent of the patent holder (Garrison, 2020).

In March 2020, the MPP expanded its mandate – which had been limited to HIV, tuberculosis and hepatitis C treatments – to include any health technology that could contribute to the global response to COVID-19. In May 2020, the MPP became part of the Covid-19 Technology Access Pool (C-TAP), initiated by WHO for the sharing of intellectual property, knowledge and data with quality-assured manufacturers. Although no vaccine producer contributed to the C-TAP (Billette

patents (for more information see www.drugpatentwatch.com/subs/generic/BARICITINIB and www.drugpatentwatch.com/subs/generic/REMDESIVIR, respectively).

[4]See Lerner et Tirole (2007) for an authoritative discussion of public policies towards patent pools and their economic effects.

[5]Statutes of the Medicines Patent Pool, dated July 8, 2010 (modifications adopted on Septembre 22, 2017; October 23, 2018; April 27, 2020). See: https://medicinespatentpool.org/who-we-are/statutes-by-laws-policies.

[6]The benefits of operating a patent pool in the health domain have have been discussed in the literature prior to the foundation of the MPP (see, for example, Verbeure, 2009).

de Villemeur, Dequiedt, and Versaevel, 2021a, 2021b), in June 2021 the MPP took part in the creation of a South African consortium in order to establish the first transfer hub for mRNA vaccine technology.[7] Located at Afrigen Biologics and Vaccines in Cape Town, the hub involves WHO, the Biologicals and Vaccines Institute of Southern Africa (Biovac), the South African Medical Research Council (SAMRC) and Africa Centres for Disease Control and Prevention (Africa CDC).[8] Similar projects are under preparation that involve partners in Latin America.[9] These initiatives, which make possible the emergence of industrial sites that implement good manufacturing practices, for additional mRNA vaccine production capacity to be made available in low- and medium-income countries, might facilitate in principle the negotiation of future agreements between the MPP and holders of patents for next-generation vaccine technology.

In November 2020, eighteen producers of medicinal products (generics and biosimilars), including several leading Indian companies, pledged to contribute to the MPP's effort to accelerate access to COVID-19 treatments (most being still in development at the time) in low- and middle-income countries.[10] A year later, two first licensing agreements were signed by the MPP and producers of COVID-19 treatments. The first of these agreements, announced in October 2021, is for molnupiravir, an investigational oral antiviral developed and manufactured in partnership by Merck and Ridgeback Biotherapeutics in the US. The active pharmaceutical ingredient of this drug is protected by patents held by Emory University, and several manufacturing processes are protected by patents held by companies such as Fermenta Biotech and Optimus Pharma in India (Abinader, 2021a, 2021b). A second licensing agreement, concluded in November 2021, relates to PF-07321332, another investigational oral antiviral developed by Pfizer in the US. When used to treat COVID-19, this molecule is administered in combination with ritonavir, another approved molecule – for the treatment of HIV infections – whose intellectual property is held by AbbVie, another US company.[11] Furthermore, the Swiss company Roche, that markets tocilizumab (a monoclonal an-

[7]Despite the support of no less than 41 countries, the C-TAP did not receive any contributions until November 2021 (Clark et al., 2021), when the Spanish National Research Council (CSIC) provided a Covid-19 serological antibody technology (https://www.who.int/news/item/23-11-2021-who-and-mpp-announce-the-first-transparent-global-non-exclusive-license-for-a-covid-19-technology).

[8]For more information on this South African consortium, see: https://www.who.int/news/item/30-07-2021-new-consortium-working-to-boost-vaccine-production-in-south-africa

[9]For more information on a Latin American initiative, see: https://www.paho.org/en/news/21-9-2021-paho-selects-centers-argentina-brazil-develop-covid-19-mrna-vaccines

[10]For a press release, see: https://medicinespatentpool.org/news-publications-post/covid-19-generic-pledge-press-release

[11]For press releases that relate to the two licensing agreements, see: https://medicinespatentpool.org/news-publications-post/mpp-msd-new-license-announcement-molnupiravir and https://medicinespatentpool.org/news-

tibody), has announced it is open to collaborating with the MPP if the company's own attempts to identify qualified industrial partners for the production of biosimilars prove unsuccessful.[12]

The MPP possesses constitutive characteristics that distinguish it from most patent pools in relation to information technology. It is not a collaborative agreement between pharmaceutical companies, but a non-profit foundation whose mission is to improve access to essential medicines in low- and middle-income countries. Thus, the objective of the MPP is not maximizing the profits of its contributing patent holders, but rather maximizing the quantities delivered to populations in need of medicines.

In this paper, we adapt a model by Shapiro (2001) to characterize the price, quantity, and social welfare outcomes of operating a patent pool that, as in the case of the MPP, does not behave as a profit-maximizing entity. The model includes two vertically connected markets: an intermediate market, where licenses for complementary technologies are supplied to manufacturing firms; and a final market, where licensees manufacture and sell a homogeneous pharmaceutical product (a generic or biosimilar). Each license transacted in the intermediate market generates the payment of a royalty by the licensee for each unit of product sold in the final market. We focus on a scenario where all licenses are "packaged" together to be supplied as a bundle by a patent pool, whose profit is transferred to the patent holders. We assume that the objective of the patent pool is to promote access to the medicinal product in the final market, implying that the price of licenses – more precisely, the amount of royalties – in the intermediate market should be reduced as much as possible, subject to the constraint that participation in the mechanism by patent holders is not discouraged.

We compare the economic performance of the non-profit patent pool against that of two benchmark scenarios, where 1) the licenses necessary to manufacture and sell the pharmaceutical product are marketed separately and non-cooperatively by the patent holders to maximize their individual profits, and 2) the patent pool coordinates the pricing of these same licenses to maximize the joint profits of the participating patent holders. We show that the larger the number of patent holders, the higher the social value generated by a non-profit patent pool compared to the baseline

publications-post/pfizer-and-the-medicines-patent-pool-mpp-sign-licensing-agreement-for-covid-19-oral-antiviral-treatment-candidate-to-expand-access-in-low-and-middle-income-countries

[12]For a monograph on "Roche Position on Enabling Access through Collaborations and Patent Pools", see: https://assets.cwp.roche.com/f/126832/fd4b786871/roche_position_on_enabling_access_through_collaboration.pdf

situations. These results are all the more relevant in the context of the SARS-CoV-2 health crisis, as the IP rights attached to pharmaceutical products in relation to Covid-19 are typically held by multiple entities. It should be noted, however, that in our model the patent pool does not adversely affect the financial performance of the patent holders – who receive the profit generated by the licenses – in comparison to the maximum private profit that each of them would earn by marketing its license separately.

The formal analysis aims to enhance our understanding of the mechanisms that can be put in place in a pandemic context for the management of intellectual property, in order to accelerate the production of pharmaceutical products, and their dissemination on a global scale. The analysis also complements the existing economic literature by highlighting the positive effect of patent pooling on social welfare, to the benefit of populations in low- and middle-income countries, when the mechanism involves a non-profit organization.

In our approach, we assume that the patent holders do not contemplate starting a new organization that competes with the non-profit patent pool by also commercializing the licenses as a bundle, but with the objective of maximizing their joint profits, as in the second reference scenario. This is because the existence of constraints (e.g., dealing with governance issues, the regulatory context), some of which being specific to the multiple entities that hold intellectual property, can make it difficult to start – at least in the short term – the in-depth transformation of the existing business model that starting such an organization would cause. In particular, this transformation would entail the payment of installation costs for a new structure. Contrary to the situation of a non-profit patent pool such as the MPP, this new structure would hardly be eligible for external budgetary allocations financed by taxes or philanthropy.[13]

The paper is organized as follows: Section 2 presents the model specifications. Section 3 details two pricing policies of reference where patent holders commercialize their technology licenses separately (section 3.1), and when a patent pool is involved in order to maximize the joint profits of patent holders (section 3.2). Section 4 investigates the scenario of a non-profit patent pool whose objective

[13]In our model, introducing the assumption that the pharmaceutical industry can start a new for-profit patent pool, in charge of coordinating choices of license prices, would amount to modifying the participation constraint attached to IP holders when they contribute to the non-profit patent pool. More specifically, the latter patent pool would then have to transfer the profit obtained in the second benchmark scenario (coordination of license prices to maximize joint profits), reduced by the costs incurred for the installation of the new for-profit structure, instead of an amount set equal to the total profit obtained in the first benchmark scenario (where patent holders market licenses separately and non-cooperatively). In these circumstances, the social welfare contribution of the non-profit patent pool would be reduced to the avoided costs associated with setting up the for-profit organization.

is to maximize the quantities marketed in the final market. Section 5 considers the particular case of a linear demand to generate simple analytical expressions which are easily comparable between different pricing policies. Section 6 concludes the paper.

2 The Model

As in Shapiro (2001), we assume that n technology providers, indexed by i in $\{1, \ldots, n\}$, with $n \geq 1$, each hold a single patent. The patented technologies, which relate to active ingredients and excipients, or to formulation processes, are all necessary for the manufacture of a homogeneous pharmaceutical product – a treatment or a vaccine – with determined chemical or biological characteristics. In the biopharmaceutical context, such patents are most often held by pharmaceutical companies, biotechnology firms, research units, or universities.

Each patent can be licensed in an intermediary market for technology, at a marginal cost $c_i \geq 0$ incurred for trading and administering the intellectual property. The buyers of these technologies are symmetric manufacturing companies, which supply a generic (chemical molecules) or biosimilar (biological molecules) version of the treatment or vaccine[14] in a final market, at a marginal cost $\alpha \geq 0$ of production and distribution. The final market is assumed to be perfectly competitive, for simplicity.

The latter specification, which facilitates the comparison of several scenarios, implies that the share of industry profits accruing to producers of generics or biosimilars is normalized to zero. As for final market buyers of the pharmaceutical product, they can be public organizations (governments, hospitals, ...), private entities (clinics, pharmacies, ...), or individual consumers.[15] Their demand is described by the monotone decreasing function $Q(P)$, where $Q \geq 0$ is the total demanded quantity, and $P \geq 0$ is the price of the product.

[14] Vaccines are generally categorized as biological medicinal products, which can in principle entail the production of biosimilars. However, given the manufacturing process specific to mRNA vaccines, it is also possible to classify the latter products among chemical molecules, which can therefore lead to the production of generics (see Niazi, 2021).

[15] In low-income countries, out-of-pocket spending on healthcare is higher than publicly funded spending (WHO, 2019).

3 Benchmark Scenarios

In this section, we consider two benchmark scenarios as described in Shapiro (2001), one decentralized and the other centralized – in both cases under the assumption of profit maximization – for the trading of licenses in the intermediate market for technology.

3.1 For-profit decentralized marketing of licenses

For a first benchmark scenario, suppose that each of the patent holders is active in the intermediate market for technology. The individual profit to patent holder i, resulting from marketing a license, is

$$\pi_i^{MM} = \left(p_i^{MM} - c_i\right) Q\left(P^{MM}\right),$$

where the price p_i^{MM} (lowercase notation)[16] of license i is paid by all downstream firms for each unit of pharmaceutical product they sell in the final market, and the price P^{MM} (uppercase notation) of this product is equal to the sum of license prices and of the producers' marginal cost, namely $\sum_{i=1}^{n} p_i^{MM} + \alpha$, as implied by the perfect competition assumption (no commercial margin). For each patent holder's individual profit to be maximized, by marketing a license without coordinating with technology providers (decentralized approach), the price of each license must satisfy the first-order condition

$$Q\left(P^{MM}\right) + \left(p_i^{MM} - c_i\right) \frac{dQ\left(P^{MM}\right)}{dp_i} = 0,$$

and, using symmetry, the sum of the n latter equations can be written as

$$nQ\left(P^{MM}\right) + \sum_{i=1}^{n} \left(p_i^{MM} - c_i\right) \frac{dQ\left(P^{MM}\right)}{dp_i} = 0.$$

As $P^{MM} = \sum_{i=1}^{n} p_i^{MM} + \alpha$, we know that $\sum_{i=1}^{n} p_i^{MM} = P^{MM} - \alpha$ and $dQ\left(P^{MM}\right)/dp_i = dQ\left(P^{MM}\right)/dP$, so that the preceding equation can be rewritten as

$$nQ\left(P^{MM}\right) + \left(P^{MM} - (\alpha + c)\right) \frac{dQ\left(P^{MM}\right)}{dP} = 0,$$

where $c = \sum_{i=1}^{n} c_i$ is the sum of the patent holders' marginal costs. A simple reorganization of terms leads to an expression of the percentage markup over total marginal cost generated by selling

[16] Throughout the paper, the price of a license refers to the royalties paid by a technology user to the patent holder for each unit of product sold in the final market.

the pharmaceutical product in the final market, and earned by each patent holder, that is

$$\frac{P^{MM} - (\alpha + c)}{P^{MM}} = \frac{n}{\epsilon_{Q/P}^{MM}},$$

where $\epsilon_{Q/P}^{MM} = -\left(dQ\left(P^{MM}\right)/dP\right)\left(P^{MM}/Q\left(P^{MM}\right)\right)$ is the (absolute value of) the price-elasticity of demand in the final market. The expression of the percentage markup over total marginal cost is thus equal to n times the standard level of the Lerner index in a monopolistic situation.[17] It reflects the fact that each patent holder, by supplying a license separately and non-cooperatively to downstream manufacturers, does not internalize the choices made by the other suppliers of complementary technologies in its individual pricing decision. However, each downstream firm must pay the price of all licenses to manufacture the pharmaceutical product (hence the superscript "MM" which refers to multiple margins). The overall market power of patent holders in the intermediate market therefore results in an inflated markup over total marginal cost in the final market, in proportion to the number of licenses.

In what follows, the joint profits earned by all patent holders in this scenario, that is $\sum_{i=1}^{n} \pi_i^{MM}$, is denoted $\Pi\left(P^{MM}\right)$.

3.2 For-profit centralized marketing of licenses

Suppose for comparison, in a second benchmark scenario, that all technology providers delegate the marketing of licenses to a patent pool. This organization sells all licenses together as a bundle to the manufacturing firms, and transfers its profit entirely, in proportion to marginal costs c_i, to the n technology providers.[18] This profit is equal to

$$\Pi\left(P^{M}\right) = \left(p^{M} - c\right) Q\left(P^{M}\right),$$

where the price p^M (lowercase notation) is paid to the patent pool by all downstream firms for each unit of the pharmaceutical product sold in the final market, and the price P^M (uppercase

[17] Except in the case of an iso-elastic specification, in the final market the price-elasticity of demand depends on the prices of licenses, each considered at the level that satisfies each patent holder's first-order condition for individual profit maximization. In the case of a linear demand, as considered in section 4, the equilibrium price obtained in this first benchmark scenario (with for-profit decentralized trading of licenses) implies a higher price-elasticity (in absolute value) of demand than in the second benchmark scenario (with for-profit centralized trading of licenses), and than in our central scenario where a non-profit patent pool is involved.

[18] The net profit to the patent pool, after transfer payments to the patent holders has occurred, is thus equal to zero. The same outcome would result from the alternative specification where each manufacturing firm pays $p^M - c_i$ directly to the patent holders, and only c_i to the patent pool, for each unit of product sold in the final market.

notation) of this product is equal to $p^M + \alpha$, again as a consequence of the perfect competition assumption. The price of the bundled licenses that maximizes the profit earned in the intermediate market for technology satisfies the first-order condition

$$Q\left(P^M\right) + \left(p^M - c\right)\frac{dQ\left(P^M\right)}{dp} = 0.$$

As $p^M = P^M - \alpha$, and $dQ\left(P^M\right)/dp = dQ\left(P^M\right)/dP$, the first-order condition can be written as

$$Q\left(P^M\right) + \left(P^M - (\alpha + c)\right)\frac{dQ\left(P^M\right)}{dP} = 0,$$

which coincides with the first-order condition of a for-profit monopoly in the final market. Therefore, the markup over total marginal cost in that market, and received by the patent pool on behalf of all technology providers, satisfies the Lerner condition, that is

$$\frac{P^M - (\alpha + c)}{P^M} = \frac{1}{\epsilon^M_{Q/P}},$$

where $\epsilon^M_{Q/P} = -\left(dQ\left(P^M\right)/dP\right)\left(P^M/Q\left(P^M\right)\right)$. Delegating the marketing of technological licenses – which are all needed for a downstream manufacturer to supply the product in the final market – to the patent pool is equivalent to coordinating pricing decisions in the market for technology. The multiple margins of the preceding scenario, where the same licenses are marketed separately and non-cooperatively, are replaced by a single margin (hence the superscript "M") in the present scenario with centralized trading.

In other words, due to the complementarity of the patented technologies, the centralized approach implemented by a for-profit patent pool results in a single license price, which can be lower than the sum of the prices paid in the decentralized approach by the downstream manufacturers for each of the licenses traded decentrally by the n technology providers. Moreover, any price $p^M < \sum_{i=1}^n p_i^{MM}$ in the intermediate market directly implies a lower price in the final market, that is $P^M < P^{MM}$, consequently a higher quantity $Q\left(P^M\right) > Q\left(P^{MM}\right)$, and finally more consumer surplus.[19] The joint profits to patent holders, as generated by delegating of the trading of licenses to the for-profit patent pool, are necessarily greater than the total profit generated by marketing licenses separately

[19]The expression of the markup over total marginal cost in the two benchmark scenarios shows that $P^M < P^{MM}$ if and only if $\epsilon^M_{Q/P} > \epsilon^{MM}_{Q/P}/n$. This condition, for all $n \geq 2$, is verified with standard demand functions, including the iso-elastic case (obviously), or the linear case (see section 4).

and non-cooperatively, formally $\Pi\left(P^{M}\right) > \Pi\left(P^{MM}\right)$.[20] Therefore, social welfare, defined as the sum of total industry profit and consumer surplus, is also higher in this second benchmark scenario.

4 Pricing Policy of a Non-Profit Patent Pool

In this section, we compare on several dimensions – product price and quantity, industry profit, consumer surplus, social welfare – the economic performance of the two benchmark scenarios considered above with that of a third case involving a non-profit patent pool. In the latter scenario, the objective of the patent pool is to maximize access to the pharmaceutical product by reducing the price of licenses (i.e., royalties per unit of product) as much as possible, under the constraint of not discouraging the participation of patent holders.

In this scenario, we suppose that in the intermediate market for technologies the patent pool does not charge the profit-maximizing price p^{M}, for which it substitutes another price, denoted p^{*}, defined as the lowest price that satisfies the profitability constraint

$$(p^{*} - c)\, Q\left(P^{*}\right) \geq \Pi\left(P^{MM}\right),$$

where p^{*}, in the intermediate market, is paid to the patent pool for each unit of the pharmaceutical product sold in the final market, at a price P^{*} equal to $p^{*} + \alpha$, again as a consequence of the perfect competition assumption. In this scenario the price p^{*} charged by the patent pool results in joint profits $\Pi\left(P^{*}\right)$, which are transferred in proportion to marginal costs c_i, to the n technology providers (should the dispersion of marginal costs be relatively low, transfer payments to patent holders would be close to $\Pi\left(P^{*}\right)/n$).[21] Access maximization, under the profitability constraint, implies that joint profits are exactly equal to $\Pi\left(P^{MM}\right)$, as earned in the first benchmark scenario where licenses are marketed separately and non-cooperatively.

We know from the comparison of the two benchmark scenarios in the preceding section that

[20] The strategy set of the for-profit patent pool in the centralized approach includes the possibility of charging a single license price equal to the sum of the equilibrium prices for each licenses in the decentralized approach, implying by a revealed preference argument that $\Pi\left(P^{M}\right) \geq \Pi\left(P^{MM}\right)$. This last inequality is strict, for any $P^{M} < P^{MM}$, as a consequence of the demand function $Q\left(P\right)$ being, by assumption, monotone decreasing for any final-market price $P \geq 0$.

[21] An alternative to transferring joint profits as a proportion of marginal costs, as assumed in this model, is to divide the amount by the number of patent holders. In an extended version of the model, where technology providers are assumed to potentially hold several patents, transfer payments could be made in proportion to the number of contributions to the pool. Layne-Farrar and Lerner (2011) observe that, in the information technology domain, a majority of patent pools actually apply such a rule. This approach simplifies the sharing of joint profits when asymmetric marginal costs are private information.

$\Pi\left(P^M\right) > \Pi\left(P^{MM}\right)$, where $P^M < P^{MM}$ follows from $p^M < \sum_{i=1}^{n} p_i^{MM}$. The profit function $\Pi(P) = (p-c)\,Q(P)$ is (strictly) concave in P, as implied by the (strict) monotonicity of the final-market demand function. The price P is equal to the sum of the price p paid for the use of all technology licenses in the intermediate market, and of the marginal cost α incurred on the supply side of the final market, as a consequence of the perfect competition assumption. The concave function $\Pi(P)$ being maximized at $P^M < P^{MM}$, there exists a unique product price P^* for a unique license price p^* verifying $\Pi(P^*) = (p^*-c)\,Q(P^*) = \Pi\left(P^{MM}\right) < \Pi\left(P^M\right)$. The comparison across scenarios of final-market prices $P^* < P^M < P^{MM}$ implies that $Q(P^*) > Q\left(P^M\right) > Q\left(P^{MM}\right)$, and hence results in higher consumer surplus when a non-profit patent pool centralizes the marketing of licenses than in the two benchmark scenarios. Social welfare is also higher than in the first benchmark scenario with patent holders separately and non-cooperatively charging license prices (although the industry profit is the same, P^* lower than P^{MM} implies a higher consumer surplus), as well as in the second benchmark scenario where the patent pool maximizes joint profits (although the producer surplus is reduced, P^* lower than P^M implies a higher consumer profit, for a positive net effect on social welfare).

The scenario where licenses are delegated to a non-profit patent pool, to maximize access to a generic or biosimilar, therefore makes it possible to reduce the price of the pharmaceutical product and to increase the quantities sold, to the benefit of buyers (i.e., governments, hospitals, patients), without penalizing the financial performance of technology providers. The latter, as patent holders, earn the same joint profits as when all licenses are supplied separately and non-cooperatively.

5 A Linear Example

In this section, we introduce more structure to the model by assuming that the demand function for the pharmaceutical product is linear. This specification facilitates the characterization of the scenario where the objective of a non-profit patent pool is to maximize final-market access, under the constraint of not discouraging participation by patent holders.

We assume that the (inverse) final-market demand function is $P(Q) = max\{0, a - bQ\}$, where a and b are positive parameters, with $a > \alpha + c$. Then, joint profits and the consumer surplus can be rewritten as functions of the product quantity sold in the final market, that is $\Pi(Q) =$

$(a-(\alpha+c)-bQ)\,Q$ and $S(Q)=bQ^2/2$, respectively.[22] Adding the latter two expressions leads to a measure of social welfare function, $W(Q)$. This function is maximized in the hypothetical situation, where the price paid by manufacturers is equal to the total marginal cost $c\,(=\sum_{i=1}^{n}c_i)$ incurred by supplying licenses in the intermediate market for technology, implying that the patent pool's profit is zero. The value of the social optimum is $W^{**}=(a-(\alpha+c))^2/(2b)$.

These specific algebraic expressions make straightforward the calculation of the price charged in the final market, the quantity of products sold, the total industry profit, the consumer surplus, and finally the social welfare in the two benchmark scenarios of section 3, as in the central non-profit patent pool scenario of section 4. The social welfare outcomes, as derived in each scenario, can then be compared with the value of the social optimum, W^{**}, for any number n of patents.

In the first benchmark scenario (section 3.1), where licenses are marketed separately and non-cooperatively by for-profit patent holders, we find[23]

$$P^{MM}=\frac{na+\alpha+c}{n+1},\qquad Q^{MM}=\frac{1}{b}\frac{a-(\alpha+c)}{n+1},$$

$$\Pi^{MM}=\frac{n}{b}\left(\frac{a-(\alpha+c)}{n+1}\right)^2,\qquad S^{MM}=\frac{1}{2b}\left(\frac{a-(\alpha+c)}{n+1}\right)^2,$$

for a social welfare

$$W^{MM}=\frac{2n+1}{2b}\left(\frac{a-(\alpha+c)}{n+1}\right)^2.$$

In the second benchmark scenario (section 3.2), where licenses are marketed as a bundle by a for-profit patent pool, we find

$$P^{M}=\frac{a+\alpha+c}{2},\qquad Q^{M}=\frac{1}{b}\frac{a-(\alpha+c)}{2},$$

$$\Pi^{M}=\frac{1}{b}\left(\frac{a-(\alpha+c)}{2}\right)^2,\qquad S^{M}=\frac{1}{2b}\left(\frac{a-(\alpha+c)}{2}\right)^2,$$

for a social welfare

$$W^{M}=\frac{3}{2b}\left(\frac{a-(\alpha+c)}{2}\right)^2.$$

In the first benchmark scenario, for all $n\geq 1$ the price of the product is higher, and the quantity

[22] For the sake of expositional simplicity, we abuse notation slightly by using the letter Π to describe joint profits as a function of the product quantity Q sold in the final market, unlike in the preceding sections where the argument was the price variable P.

[23] The algebraic steps leading to the expressions of outcomes and to their comparison across scenarios are available from the authors.

sold in the final market is lower, than in the second scenario. When the patent holders do not coordinate their pricing decisions in the intermediate market for licenses, for all parameter values the levels of industry profit, consumer surplus, and social welfare, are lower than in the second benchmark scenario where a single price is charged by the for-profit patent pool, for a license that covers all technologies. For all outcomes considered across the two scenarios, differences are monotonically increasing in n, because the private and social performance in the first case deteriorates as the number of patents increases. On the other hand, the economic performance of the second benchmark scenario does not depend on the number of patents included in the pool. This is because all technologies are marketed as a bundle through a single license, by a monopolistic entity whose choice of price internalizes technological complementarities. The formation of a patent pool – albeit a for-profit one – is therefore all the more justified when intellectual property is distributed over a relatively large set of entities (i.e., companies, universities, research units).

Finally, in the central scenario where the objective of a non-profit patent pool is to maximize access, provided that technology providers keep contributing, we find

$$P^* = \frac{a + n(\alpha + c)}{n+1}, \qquad Q^* = \frac{1}{b}\frac{n(a - (\alpha + c))}{n+1},$$

$$\Pi^* = \frac{n}{b}\left(\frac{a - (\alpha + c)}{n+1}\right)^2, \qquad S^* = \frac{1}{2b}\left(\frac{n(a - (\alpha + c))}{n+1}\right)^2,$$

for a social welfare

$$W^* = \frac{n(n+2)}{2b}\left(\frac{a - (\alpha + c)}{n+1}\right)^2.$$

The comparison of the latter expressions with those of the two benchmark scenarios confirms that, with a non-profit patent pool, the final market price is lower, and hence access is enhanced. For the same industry profit as in the first benchmark scenario (licenses marketed separately and non-cooperatively), and thus lower than in the second benchmark scenario (delegation to a for-profit patent pool), in the central scenario with a non-profit patent pool the consumer surplus and social welfare are higher. Although all licenses are supplied "as a bundle", the economic performance of the latter scenario depends on the number of patents in the pool. The reason is that, in order to satisfy the financial constraint for all technology providers to contribute to the pool, the price of the single license is set at the exact level that induces the same joint profits as in the first benchmark scenario. These joint profits depend not only on the number of licenses supplied separately, but

also decrease if this number of licenses is set higher. When this occurs, the financial constraint is relaxed, and the diffusion of technologies is facilitated in the intermediate market, where the non-profit patent pool can charge a lower license price. It follows that social welfare increases in n (the rise in consumer surplus is greater than the reduction in joint profits).[24]

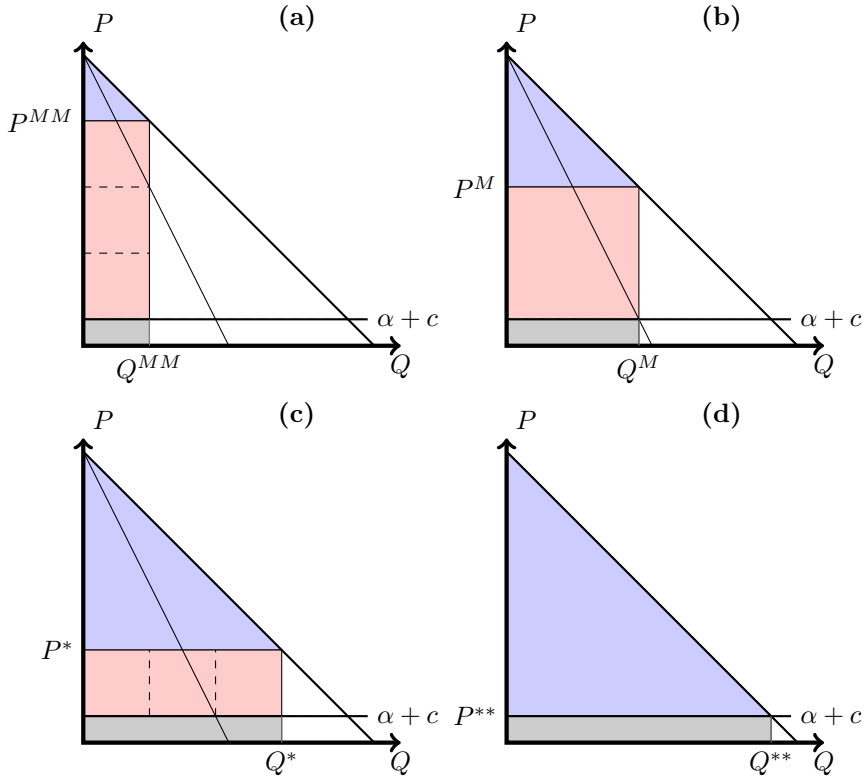

Figure 1: **(a)** First benchmark scenario: profit-maximising patent holders sell licenses separately and non-cooperatively (multiple margins). **(b)** Second benchmark scenario: patent holders delegate the marketing of licenses to a profit-maximising pool (single margin). **(c)** Social welfare is maximised under the constraint that patent holders earn the same joint profits as when licenses are sold separately and non-cooperatively. **(d)** The social optimum.

To illustrate, in Figure 1, the economic performance in the central scenario with a non-profit patent pool (bottom left), is compared with the performance of the two benchmark scenarios (top left and top right) as per Shapiro (2001), and also with the social optimum that results from charging licenses at marginal cost in the intermediate market for technology (bottom right), for the same (linear) inverse demand and constant marginal costs in each quadrant. With only three patents ($n = 3$), social welfare (the sum of joint profits colored in pink and of the consumer surplus in blue) with a non-profit patent pool is clearly greater than in the benchmark scenarios.

[24] More formallly, $d\Pi^*/dn = -(n-1)(a-(\alpha+c))^2 / \left(b(n+1)^3\right) < 0$, and $dS^*/dn = n(a-(\alpha+c))^2 / \left(b(n+1)^3\right) > 0$.

For any number of patents, the social welfare outcomes in the two benchmark scenarios, and in the non-profit patent pool case that we consider, can be assessed relatively to the maximum W^{**}, as obtained when licenses are traded with no margin.

By using the algebraic expressions of W^{MM}, W^{M},and W^{*}, as displayed above, we find

$$\frac{W^{MM}}{W^{**}} = \frac{2n+1}{(n+1)^2}, \quad \frac{W^{M}}{W^{**}} = \frac{3}{4}, \quad \frac{W^{*}}{W^{**}} = \frac{n\,(n+2)}{(n+1)^2}.$$

The first of these expressions decreases in n, the second is constant, the third increases. From a normative viewpoint, in the formal context of this model, the larger the number of patents – and thus of technology providers – the less efficient the separate and non-cooperative marketing of licenses, and the higher the social value of involving a patent pool, even more so when this pool aims at maximizing access in the final market. The latter approach is implementable in practice when each patent provider earns as much profit as when licenses are marketed separately and without coordination. The social performance of this normatively relevant approach is measured by the ratio

$$\frac{W^{MM}}{W^{*}} = \frac{2}{n}\left(1 - \frac{3}{4+2n}\right).$$

From the latter algebraic expression, that relates to the linear demand specification, and for all parameter values, the non-profit patent pool increases social welfare by 60% if $n = 2$, about 114% if $n = 3$, and 167% if $n = 4$. More generally, the pool multiplies social welfare by more than a factor $n/2$ relative to the initial benchmark scenario with multiple margins, for all $n \geq 2$.

The objective we consider in our central scenario, that is to increase access to medicines, coincides with the mission of the Medicines Patent Pool (MPP) mentioned in the introduction. By contracting with multiple licensees for each product included in the pool, the MPP encourages competition in the final market, and makes possible the commercialization of generics or biosimilars at a lower price than if the patent holders were the only suppliers.[25] Even under the profit-maximization assumption (as in the two benchmark scenarios), patent pooling for the marketing of complementary

[25]In an empirical study, with data for the period 2005-2018 relating to 173 pharmaceutical products and 129 countries, Galasso and Schankerman (2020) show that including patents in the MPP increases the likelihood of licensing agreements for the production and marketing of drugs for the treatment of HIV, tuberculosis and hepatitis C. For the period 2010-2028, concerning only anti-retrovirals against HIV, a study by Juneja et al. (2017) offers an estimate of the savings generated by the MPP, in low- and middle-income countries, of the order of USD 2.3 billion. Economic and public health effects generated by the MPP are also quantified by Morin et al. (2021) from case studies on the distribution of drugs against HIV and hepatitis C. Cumulatively, for the period 2017-2032, they predict budgetary savings of around USD 3 billion globally, and a number of averted deaths greater than 150,000, in comparison to a counterfactual scenario without MPP.

licenses as a bundle, on behalf of several patent holders, solves a multiple marginalization problem, and results in a lower cost of accessing technologies in the intermediate market, and of accessing a pharmaceutical product in the final market. Our central scenario, where a non-profit patent pool aims at maximizing access to the pharmaceutical product, provided that patent holders are not penalized relative to the initial benchmark scenario where licenses are marketed separately and non-cooperatively, is more in line with the actual operation of the MPP. It involves a lower final-market price, and a higher volume of quantities, for the same financial returns to patent holders as when they do not partner with a patent pool. The effect on final-market price and quantities, as well as on the consumer surplus and social welfare, increases with the number of patent holders that contribute to the pool.[26]

The linear demand specification leads to explicit algebraic expressions which show that a non-profit patent pool can generate substantial welfare gains, even in the case of a relatively small number of patent holders. This result, in the context of the Covid-19 pandemic, is even more relevant as the IP rights attached to recently approved treatments and vaccines relate to multiple entities (i.e., pharmaceutical companies, biotechnology firms, research units, or universities). Our economic analysis thus reinforces the case for making use of a non-profit organization such as the MPP, for the licensing of technologies necessary for the production and commercialization of generics or biosimilars against COVID-19.

6 Conclusion

A protracted debate has taken place for several months between defenders of a strict application of IP rights and supporters of the view that patents in relation to Covid-19 technologies should be waived – at least momentarily – to accelerate the production and distribution of vaccines and treatments.

The main argument in favor of the status quo is that waiving patents would challenge the business model that has made it possible, in a very short time, to invent new medicines to treat SARS-CoV-2. Weakening the IP rights that relate to Covid-19 would reduce incentives to invest in R&D

[26] In practice, the operating costs of the MPP are financed by external budgetary allocations, received mainly from Unitaid. In the formal context of the non-profit patent pool scenario, this observation amounts to assuming that the total marginal cost of supplying licenses is negligible, or $\sum_{i=1}^{n} c_i \to 0$. This specification implies a reduced final-market price, an augmented volume of consumption, for a higher consumer surplus and social welfare, with unchanged joint profits to patent holders.

efforts necessary to address the emergence of new variants, and to develop new technologies that will be needed to address other pandemics in the future.

On the other hand, supporters of a patent waiver argue that the severity of the crisis justifies any measures allowing for an acceleration of the production of vaccines and treatments that have already been approved. Maintaining IP rights would impede the scaling-up of manufacturing capacity by allowing only the limited number of current suppliers to initiate licensing agreements with manufacturers of generics or biosimilars. This would entail higher prices and thus make access to products more expensive in low- and middle-income countries.

The economic analysis developed in this paper shows that the use of a non-profit patent pool, such as the MPP, can help identify a third way in this debate. As a one-stop shop for technology licenses, a patent pool reduces transaction costs for the conclusion of licensing agreements, increases the legal certainty of these agreements, prevents patent hold-up, and promotes the transfer of scientific and industrial know-how. In addition, a patent pool also generates efficiency gains by coordinating the choices of royalties for complementary technologies. These efficiency gains make it possible for patent holders to earn the same level of joint profits as in a status quo situation where licenses are marketed separately and non-cooperatively. These profits are achieved by a wide diffusion of technologies to producers of generics or biosimilars, in return for low royalties, which lead to reduced final-market prices.

The resulting increase in social welfare is all the more pronounced when patent holders are relatively numerous, as in the case of technologies for the prevention and treatment of COVID-19. The objective of increasing production capacity and facilitating access to the products needed to address the pandemic, without undermining the incentives for manufacturers to engage in research and development, therefore seems achievable.

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