nature biotechnology

Supplementary information https://doi.org/10.1038/s41587-026-03156-7

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In the format provided by the authors and unedited

Supplementary Appendix

The public health impact of the Medicines Patent Pool increases with the fragmentation of intellectual property rights

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February 2026

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1 Setup

We assume, as in Shapiro (2001), that n technology providers, indexed by i in $\{1, \ldots, n\}$, with $n \geq 1$, each hold a single patent. The patented technologies relate to active ingredients and to excipients, or to formulation processes, and are all necessary for the manufacture of a homogeneous pharmaceutical product (a treatment or a vaccine) with determined chemical or biological characteristics.

Each patent can be licensed in an intermediate market for technology, at a marginal cost $c_i \geq 0$ incurred for trading and administering the intellectual property (IP). The buyers of these technologies are symmetric manufacturing companies, which supply a generic (chemical molecules) or biosimilar (biological molecules) version of the product in a final market, at a marginal cost $\alpha \geq 0$ of production and distribution. For simplicity, the latter market is perfectly competitive, implying that the share of industry profits accruing to producers of generics or biosimilars is normalized to zero.

In order to generate analytical expressions, we specify a linear demand function in the final market, in inverse form $P(Q) = max\,\{0, a - bQ\}$, where Q is the total (non-negative) demanded quantity, P is the price of the pharmaceutical product paid by end buyers (e.g., governments, pharmacies, hospitals, patients, etc.), a and b are positive parameters. Denoting by $c = \sum_{j=1}^{n} c_j$ the marginal cost of trading and administering all licenses, we assume throughout that $\alpha + c < a$ for sales in the final market, at any price in the interval $[\alpha + c, a)$, to cover total costs at the industry level.

In the next sections, we derive the model outcomes – the price of products, the quantities sold, and the consumer surplus – in two alternative scenarios. In the first one, the 'separation' scenario, each patent holder maximizes its individual profit by trading separately a license for its own technology. In the 'delegation' scenario, we formalize the functioning of a non-profit patent pool mechanism.

2 The 'separation' scenario

In this baseline scenario, each patent holder (upstream) trades separately and non-cooperatively a license at a profit-maximizing price in the intermediate market for technology. Each of the manufacturing firms (downstream) buys all licenses to manufacture and commercialize the pharmaceutical product in the final market.

Formally, each patent holder i charges a license price p_i to maximize its individual profit

$$\pi_i^{MM}(p_i) = (p_i - c_i)\, Q\left(\sum_{j=1}^{n} p_j + \alpha\right), \tag{1}$$

where the superscript "MM" refers to multiple margins (one for each patent holder), the license price p_i is the royalty for each unit of product sold in the final market, at a price P equal to $\sum_{j=1}^{n} p_j + \alpha$, that is the sum of license prices and of the marginal cost of downstream manufacturers (as a consequence of the perfect competition assumption).

Profit maximization implies that p_i^{MM}, the unique maximizer of the concave profit function, satisfies the first-order condition

$$Q\left(\sum_{j=1}^{n} p_j^{MM} + \alpha\right) + \left(p_i^{MM} - c_i\right) \frac{dQ\left(\sum_{j=1}^{n} p_j^{MM} + \alpha\right)}{dp_i} = 0, \tag{2}$$

and summing the n latter equations, by using symmetry, leads to

$$nQ\left(\sum_{j=1}^{n} p_j^{MM} + \alpha\right) + \sum_{i=1}^{n} \left(p_i^{MM} - c_i\right) \frac{dQ\left(\sum_{j=1}^{n} p_j^{MM} + \alpha\right)}{dp_i} = 0, \tag{3}$$

where $\sum_{j=1}^{n} p_j^{MM} + \alpha = P^{MM}$ so that $dQ\left(\sum_{j=1}^{n} p_j^{MM} + \alpha\right)/dp_i = dQ\left(P^{MM}\right)/dP$. Substituting and reorganizing terms leads to the final-market price

$$P^{MM} = \frac{na + \alpha + c}{n+1}, \tag{4}$$

and to the related quantity

$$Q^{MM} = \frac{a - (\alpha + c)}{b\,(n+1)}, \tag{5}$$

which together result in the consumer surplus

$$CS^{MM} = \int_0^{Q^{MM}} \left[P(Q) - P^{MM}\right] dQ = \frac{1}{2b}\left(\frac{a-(\alpha+c)}{n+1}\right)^2. \qquad (6)$$

In what follows, we also refer to the total profit earned by patent holders in this 'separation' scenario, that is $\Pi\left(P^{MM}\right) = \sum_{i=1}^{n} \pi_i^{MM}\left(p_i^{MM}\right)$, whose closed-form expression is $(n/b)\left((a-(\alpha+c))/(n+1)\right)^2$, as derived by using (1), together with (4) and (5).

3 The 'delegation' scenario

In this scenario, constructed to formalize the functioning of the Medicines Patent Pool, all patent holders delegate the marketing of their license to a non-profit patent pool. This organization resells all licenses as a bundle in the intermediate market for technology, and transfers all royalties, net of marginal costs, to the patent holders. It charges the lowest possible 'package' sublicense price, under the constraint that each patent holder earns at least the same profits as in the 'separation' scenario – unlike in Shapiro (2001) where the patent pool is assumed to maximize profit. All manufacturing firms pay this sublicense price and supply the product in the final market.

Formally, the patent pool charges the lowest 'package' sublicense price p that verifies

$$(p-c)\, Q(p+\alpha) \geq \Pi\left(P^{MM}\right), \qquad (7)$$

where $P = p + \alpha$ (again as a consequence of the perfect competition assumption), and $\Pi\left(P^{MM}\right)$ is the total profit earned by patent holders in the 'separation' scenario.

The profit $(p-c)\, Q(p+\alpha)$, earned by the pool and transferred to the patent holders, is (strictly) concave in p. It reaches its maximum, $\left(p^M - c\right) Q\left(p^M + \alpha\right) = (a-(\alpha+c))^2/(4b)$, at $p^M = (a+\alpha+c)/2$. This maximum profit coincides with the boundary value $\Pi\left(P^{MM}\right)$ if $n=1$, and is strictlty higher otherwise. Therefore, there exists a unique $p^* < p^M$ such that (7) holds with an equality sign, in reduced form $p^* = (a-\alpha+nc)/(n+1)$, for all $n \geq 2$. Then $P^* = p^* + \alpha$ leads to the final-market price

$$P^* = \frac{a+n(\alpha+c)}{n+1}, \qquad (8)$$

and to the related quantity

$$Q^{*}=\frac{n\left(a-(\alpha+c)\right)}{b\left(n+1\right)}, \tag{9}$$

which together result in the consumer surplus

$$CS^{*}=\int_{0}^{Q^{*}}\left[P\left(Q\right)-P^{*}\right]dQ=\frac{1}{2b}\left(\frac{n\left(a-(\alpha+c)\right)}{n+1}\right)^{2}, \tag{10}$$

which can be easily compared with the expression in (6).

4 Comparison

It follows from (4) and (8) that $P^{*}\leq P^{MM}$, and from (5) and (9) that $Q^{*}\geq Q^{MM}$, with and equality sign if and only if $n=1$. The 'delegation' scenario results in reduced prices and augmented quantities in the final market compared to the 'separation' scenario, even when the pool is constrained to transfer the same level of total royalties to patent holders.

Market access thus improves, as measured synthetically by the difference in consumer surpluses across the two scenarios. It follows from (6) and (10) that

$$CS^{*}/CS^{MM}=n^{2}. \tag{11}$$

If $n=1$, the 'separation' and 'delegation' scenarios coincide, as the pool behaves in the same way as a single patent holder in the market for technology. Otherwise, for all $n\geq 2$, in the 'delegation' scenario the patent pool internalizes technological complementarities by reselling all licenses as a bundle, and thereby susbtitutes a single margin for the multiple ones that uncoordinated patent holders generate in the 'separation' scenario. The effect on the final-market price and quantity results in the consumer surplus to increase more than proportionally with n, a measure for IP rights fragmentation in this model.

The consumer surplus generated in the two scenarios can also be compared with a normative theoretical benchmark, in which the industry – the upstream patent holders, the intermediary patent pool and the downstream users – provide maximum access to the product without earning a negative gross profit (i.e., total revenues minus all variable costs). This outcome results from equating the final market price P with the total marginal cost of supplying licenses and of manufacturing the product, that is $P^{**} = \alpha + c$, at which is sold the quantity $Q^{**} = (a - (\alpha + c))/b$.

In this benchmark case, which does not depend on n, the consumer surplus is

$$CS^{**} = \int_0^{Q^{**}} \left[P(Q) - P^{**}\right] dQ = \frac{1}{2b}\left((a - (\alpha + c))\right)^2. \tag{12}$$

We compare of the consumer surplus of the 'separation' and 'delegation' scenarios, in (6) and (10) respectively, with the maximum level in (12), to find

$$CS^{MM}/CS^{**} = \left(\frac{1}{n+1}\right)^2, \tag{13}$$

and

$$CS^{*}/CS^{**} = \left(\frac{n}{n+1}\right)^2. \tag{14}$$

The latter two expressions depend only on n, and coincide only if $n = 1$. The first ratio is monotone decreasing, and the second ratio is monotone increasing, in $n \geq 1$. In the main body of the paper, all three ratios in (11), (13), and (14) are graphed in Figure 2.

For other comparisons with the outcomes of a third scenario, where the patent pool is assumed to behave as a profit-miximizing organization, see Billette de Villemeur, Dequiedt, and Versaevel (2023).

5 References

Billette de Villemeur, E., Dequiedt, V., and Versaevel, B., 2023, "Better than a compromise, a third way: Using patent pooling to accelerate access to vaccines and treatments against Covid-19," available at: https://mpra.ub.uni-muenchen.de/117765/

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