Patent races, “me-too” drugs, and generics: A developing-world perspective

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Introduction

In this paper, we consider an issue that has been very important for developing countries in the context of the negotiations leading up to the World Trade Agreement: The international patent system that, in part, determines the supply and cost of new pharmaceuticals in the world.

We take the stylized facts regarding the current system to be as follows. Most of the research and development that leads to a flow of new drugs is undertaken by a small group of large multinational firms, owned principally by investors in developed countries. The firms compete with each other, and when one of them achieves a “breakthrough” leading to the discovery of a significant new drug, the others try to quickly produce their own versions of the new drug. Although they are based on the same breakthrough (hence the expression “me too”), the new versions are sufficiently different in some ways from the original one so that they can be patented in their own right.

Patent legislation in the developed countries ensure that the firms owning the patents have a monopoly in the markets for the drugs in question for a period of (typically) twenty years, although for breakthrough drugs the period of effective patent protection is smaller as there is a substantial lag between the time when the relevant patent is registered and the time when the drug can be marketed. When the patent on the breakthrough drug expires, other firms are free to use the technology to produce a generic version of it. Typically, because generic versions of brand-name drugs must be
aggressively marketed, the market for the generic version tends to be dominated by a single seller for a period of time after the patent has expired.

In the past, many developing economies have had different patent regimes, often involving weaker forms of patent legislation, and shorter periods of protection, than in the developed countries. Following the WTO negotiations (and specifically, after the conclusion of the TRIPS agreement), the rules in most developing countries now are similar to those in the developed world, with stronger and longer-lasting forms of patent protection than before. A key feature of the patent legislation in most countries is that it prohibits “parallel imports”, defined as imports of (legally produced) pharmaceuticals from countries in which they are priced lower than in the importing country (except with the permission of the patent owner in the importing country). Thus the patent owner in each country faces no competition from independent imports.

Economic efficiency in this system depends in a complex way on the length of the period of patent protection, the rules that determine “how different” a new version of a drug has to be in order to be patented as a different drug, and on the nature of competition among different versions of a drug, and (after expiry of the breakthrough patent) between generics and brand name drugs. As has been well described in the literature, economic efficiency in this market involves a tension between static efficiency (which is promoted by pricing drugs at their marginal cost of production once they have been invented) and dynamic efficiency (ensuring that the expected profitability of inventing new drugs is high enough, which requires prices above marginal production cost). The tension arises because the implicit optimum is inherently second-best in comparison with one in which marginal-cost pricing is used to attain static efficiency, and incentive to undertake
research and development is provided through public subsidies. Thus, to the extent that the strengthening of the international patent system in the TRIPS negotiations can be given a rationale in terms of economic efficiency, it would be that, by increasing the potential profitability of the world-wide marketing of new drugs, it enhanced dynamic efficiency in that it provided stronger incentives for the pharmaceutical companies to undertake R&D.

In this paper, we argue that this rationale is very tenuous. Specifically, we show that under reasonable assumptions, other methods to enhance the profitability of pharmaceutical R&D (such as providing for longer periods of patent protection, or changing the rules for granting patents on drugs that are similar to existing ones) are more efficient in the conventional sense. Moreover, because the larger static efficiency losses under the new system affect individuals in low-income countries, they will, other things equal, have a highly unfavourable impact on the global distribution of real income.

The paper is organized as follows. In the next section, we specify the model and solve for the equilibrium configuration on the assumption that TRIPS rules are in force, so that patent protection is similar in both developed and developing countries. In the following section, we find the solution under the alternative assumption that developing countries have patent legislation that allows generics to compete with the breakthrough drug from the outset. We show the difference this makes to the returns to pharmaceutical research, and to the consumer surplus in developed and developing countries.

The model and the solution with WTO

Our analysis is based on a three-stage model of the life-cycle of a breakthrough drug, starting from the time it is first marketed. In the first stage, the firm that has
developed it, firm A, has a high degree of monopoly power, as there is, by definition, no other “similar” drug (no other drug in the same “therapeutic class”).

During the first stage, competing firms are working on developing their own drugs in this therapeutic class. The first stage comes to an end when additional versions of the drug have been patented and begin to compete with the original one. We represent these “me too” versions by a single drug, developed and produced by firm B, and assume that during this stage, firms A and B engage in a form of Bertrand competition (with differentiated products). The third stage begins when the patent on the breakthrough drug has expired. At this point, a single generic competitor G enters the market, changing the nature of the competition.

In each stage, the different drugs are marketed throughout the world. For simplicity, we distinguish only two sub-markets, one in the developed world (denoted by \( H \)), one in the developing world (denoted by \( L \)). In each market, individuals buy either one or zero units. Individuals’ willingness to pay for the original breakthrough drug is denoted by \( X \), and ranges from zero to \( X^H \) in \( H \) and from zero to \( X^L \) in \( L \). Again for simplicity, we assume that potential buyers are uniformly distributed on the intervals \( \{X^H, 0\} \) and \( \{X^L, 0\} \), and that the marginal cost of producing any version of the drug once it is developed, is zero. The mass of potential buyers with positive willingness to pay in market \( H \) is normalized to unity; the size of the market in \( L \) is denoted by \( \lambda \) lambda.

A key assumption in the paper is that demand conditions are such that \( X^H > X^L \). We justify this assumption by two considerations. First, incomes are higher in \( H \), so that in general, the willingness to pay for any good, including drugs that contribute to better health, is higher in the developed than in the developing countries. Second, most
individuals in developed countries are covered by some form of health insurance; insurance can either be private or mandated by the government under a social-insurance or national health service model. In developing countries, in contrast, most buyers have to pay out of pocket for the drugs they use.

**Stage 1**

In stage 1, firm $A$ is a monopolist in both markets, and (because demand curves are linear and marginal cost equals zero) sets prices $X^j / 2$, $j = H, L$. (Here and in the rest of the paper, superscripts $H$ and $L$ denote the two markets.) Profits per unit of time are $X^H / 4$ and $\lambda \cdot X^H / 4$ respectively, and consumer surplus in the two markets are $X^H / 8$ and $\lambda \cdot X^H / 8$. Stage 1 lasts from time 0 to $t_1$ which is endogenously determined since it is defined by the time at which drug $B$, the “me too” version of the breakthrough drug $A$, becomes available in the markets. We assume that during stage 1, firm $B$ is engaged in research to produce drug $B$. The intensity of its research effort, measured by its (constant) rate of R&D spending per unit of time, is denoted by $M$. To reflect the fact that drug $B$ has to be sufficiently different from $A$ in order to be separately patentable, we introduce the parameter $s > 1$ which denotes the extent to which drug $B$ is more effective than drug $A$ (for example, by having fewer side effects). We assume that this superior effectiveness is reflected in consumers’ willingness to pay for one unit. Specifically, if a patient has willingness to pay $X$ for a unit of drug $A$, we assume that he/she has willingness to pay $sX$ for a unit of drug $B$.

We specify the process of developing a new drug as one that can be accelerated to some extent by more intensive research, but which requires time in an essential way. The time and resources required also depends on $s$: the higher the quality of the new drug in
comparison with drug $A$, the more time and resources it will require to develop. In particular, we assume that the relation between $M$, $s$, and $t_1$ is given by

\begin{equation}
    s = kM^\alpha \cdot t_1
\end{equation}

where $\alpha < 1$ measures the extent to which the completion time for a drug of quality $s$ can be accelerated by a higher rate of R&D spending, and $k$ is a constant. In full equilibrium, $t_1$ will be determined by this cost function and the expected profitability of marketing drug $B$; the latter depends not only on conditions in stage 1 but also on the nature of competition in stages 2 and 3.

**Stage 2**

Stage 2 lasts from $t_1$ to $t_2$, where $t_2$ is the time when the patient protection on the breakthrough drug $A$ expires; that is, $t_2$ is determined by the common patent legislation in the two markets. In stage 2, firms $A$ and $B$ compete in both markets.

A consumer in either market will purchase at most one unit of either drug $A$ or drug $B$. For a consumer in market $j$ with willingness to pay of $X$, utility will be given by

\[
U = \begin{cases} 
    sX - P_{B,2}^j, & \text{if buys } B, \text{ the me-too drug} \\
    X - P_{A,2}^j, & \text{if buys } A, \text{ the breakthrough drug} \\
    0, & \text{otherwise}
\end{cases}
\]

for $j=H,L$. (Here and in the following, the superscript denotes the market, the first subscript, $A,B,$ or $G$ [for generic] denotes the drug, and the second subscript denotes the stage of the game.) We assume that the prices are given as the Nash equilibrium of a simultaneous-move price setting game (that is, a Bertrand pricing game). From the demand conditions, it is obvious that $P_{B,2}^j > P_{A,2}^j$, and that those with highest willingness
to pay in each market will buy drug B while the rest will buy drug A. The reaction
functions in each market are (see Appendix 1 for the method of derivation):

\[
\begin{align*}
    P^j_{B,2} &= \frac{X^j (s-1) + P^j_{A,2}}{2}, \\
    P^j_{A,2} &= \frac{P^j_{B,2}}{2s}
\end{align*}
\]

yielding equilibrium prices

\[
\begin{align*}
    P^j_{B,2} &= \frac{2X^j s(s-1)}{4s-1}, \\
    P^j_{A,2} &= \frac{X^j (s-1)}{4s-1}, \quad j=H,L.
\end{align*}
\]

As before, the gross profits of firms A and B, and the consumer surplus of buyers in both
markets can be computed in a straightforward way. Assuming continuous discounting at
an exponential rate $\gamma$, we can also compute the present values of these variables, for
given lengths $t_1$ and $t_2$ of stages 1 and 2.

**Stage 3**

The third stage of the game begins at time $t_2$ when the patent on the breakthrough
drug A expires. At this point, it becomes legal to market a generic version of drug A. We
assume that no R&D is required in order to do this (since the technology inherent in A
can be copied), but that, because of the costs of marketing, there will only be one firm in
each market that distributes the generic version.

In general, while generic versions of previously patented drugs are supposed to be
“bio-equivalent” to the originals, evidence suggests that consumers don’t value them
equally: Even though generic versions are generally sold at lower prices than the brand
name versions, sales of the brand name versions do not go to zero. To reflect this, we
assume that consumers’ willingness to pay for generic and brand name versions are not
the same: Other things equal, consumers value the brand name version somewhat more
highly. To reflect this, we introduce another parameter $\nu < 1$ and specify that a consumer
who values a unit of drug $A$ at $X$ will only value the brand name version at $vX$. Thus, given prices, consumers’ utility in each market is

$$U = sX^j - P_{B,3}^j$$ if buys the me-too drug

$$= X^j - P_{A,3}^j$$ if buys the breakthrough drug

$$= vX^j - P_{G,3}^j$$ if buys the generic drug

$$= 0$$ otherwise

As before, it is easy to show that in equilibrium, $P_{B,3}^j > P_{A,3}^j > P_{G,3}^j$. We again assume that prices in each market are established through a process of Bertrand competition in prices. However, for the generic drug, we assume that arbitrage between the two markets is possible. That is, if copies of the generic drug are sold at lower prices in one market, buyers in the other market are free to import them. Assuming that transport and other costs of arbitrage are zero, this implies that the price of the generic drug has to be the same in both markets, that is, that $P_{G,3}^H = P_{G,3}^L$. Expressions for the equilibrium prices, profits, and consumer surplus are derived in Appendix 1. As before, we can find the present values of all variables for given $t_1$ and $t_2$. To establish the equilibrium value of $t_1$, finally, we write the net profits of firm $B$ as a function of $t_1$. Using standard methods, we then find the value of $M$ and $t_1$ that maximize its net profits.

The counterfactual: A world without TRIPS

Against the background of the baseline case described above, we now turn to the main policy question raised in the introduction: What would be the welfare consequences of a system in which developing countries were not committed to providing the same
level of patent protection as developed countries, but instead were allowed to produce and sell generic versions of patented drugs from the outset?

A full answer would require consideration of both the static and dynamic consequences of changing patent rules. That is, it would need to estimate not only the changes in profits and consumer surplus from the sale of a given breakthrough drug, but would also have to look at the long-term consequences of changes in the profitability of devoting R&D resources to the development of new kinds of drugs. The framework we have outlined above is not sufficient for this purpose, since we have not explicitly modeled the process through which new breakthrough drugs are developed.

To circumvent this problem, we consider instead a somewhat less general problem, namely that of the cost of alternative methods for providing a given level of incentive for the development of breakthrough drugs. We measure this incentive by the combined profits from the sale of breakthrough drugs, and the net profits on the development and sale of the derivative “me too” drugs that result when a new breakthrough drug is introduced. The rationale for this measure is the assumption that at any given time, there are several different firms that are engaged in R&D aiming at developing a given kind of breakthrough drug. However, only one of them will be successful in doing so and obtaining patent protection; the remaining ones will only be able to develop less profitable “me too” versions. But ex ante, it is not known who the successful one will be. Thus, the incentive to engage in R&D will consist in the expected profit of either becoming the patent holder for the new breakthrough drug, or to developing and marketing a “me too” version. Assuming for simplicity that there is symmetry among the contestants, the relevant incentive level is than equal to the sum of
the profits from the breakthrough drug and the net profits from the “me too” drugs. The value of this incentive measure in the baseline case can be computed using the methods outlined in Appendix 1. Our initial approach then is to compute the amount by which the combined incentive changes in a counterfactual experiment in which developing countries are allowed to use generics throughout. One way of compensating for this would of course be direct public subsidies from the public purse. Alternative methods would involve lengthening the period of patent protection in the developed world, or changing the rules governing patentability of me-too drugs.

Equilibrium without TRIPS

In the modified version of the model, the environment in which the three firms (A, B, and G) compete is the same for the developed country market (market H) in all three stages. However, in the developing country market (market L), the breakthrough drug A will no longer be a monopolist in stage 1, but will instead compete with a generic; there will thus be a new equilibrium price $P_{G,1}^L$, with $P_{G,1}^L < P_{A,1}^L$, and firm G will earn some of the profits in market L. Similarly, in stage 2 all three firms will compete in market L to establish prices $P_{B,2}^L > P_{A,2}^L > P_{G,2}^L$. The methods used to establish the equilibrium prices are, in principle, the same as outlined in Appendix 1. As before, the length $t_1$ of the first stage is determined endogenously, in the same way as in the baseline case.

Some numerical illustrations

Preliminary calculations suggest that, as conjectured in the text, allowing developing countries to use liberal rules for the use of generics would be a potentially efficiency-enhancing step.
The simulations underlying Tables 1 and 2 in Appendix 2 were based on a set of assumed parameter values with the following characteristics. The mass of patients with positive willingness to pay (henceforth WTP) for the breakthrough drug A was assumed to be the same in the developed (H) and developing (L) world, but the marginal WTP for each drug, at any quantity, was assumed to be 40% lower in the developing world (i.e., $X^L = 0.6X^H$). The parameters $s$ and $v$ were set at 1.2 and 0.85 respectively. That is, anyone with a positive WTP for the breakthrough drug A had a 20% higher WTP for the improved version (drug B), but a 15% lower WTP for the generic version. The effective period of patent protection $t_2$ was set at 12 years, and competition from the “me too” drug B was assumed to occur 6 years after the launch of drug A (i.e., $t_1$ was set to 6). (As noted in Appendix 2, though we intend to allow $t_1$ to be endogenously determined in later versions of the numerical illustrations, in this version we let it be exogenous.)

The results for the base case are interesting but in some respects unrealistic, perhaps reflecting the inadequacy of our simple form of Bertrand competition as a way of modeling competition among different prescription drugs and generics. Specifically, introduction of competition between the breakthrough drug A and the “me too” version B results, with these parameter values, in a reduction of the price of A in period 2 by almost 90% in both the H market and the L market, and revenue falls by more than 90% (see Table 1 in Appendix 2). Although B, as the most valuable drug, is priced higher than A in either market after it has been introduced, it is priced well below the level at which A was priced when it enjoyed a monopoly in period 1.

In period 3 in the base case, introduction of the generic further lowers the equilibrium prices of A and B. Because we assume that the possibility of effective
arbitrage implies that the price of the generic drug is the same in both markets, the proportional impact of generic competition is most pronounced in market $H$, where prices in periods 1 and 2 are higher than in $L$, reflecting the higher WTP in the $H$ market.

In the counterfactual experiment, the assumption that the generic drug is allowed to compete in the $L$ market from the beginning changes the equilibrium values only in the $L$ market, and only in periods 1 and 2. This results because, in the absence of parallel imports, both drugs $A$ and $B$ can be priced independently in markets $H$ and $L$ in periods 1 and 2, and even though the generic version can be legally sold in market $L$ in periods 1 and 2, it cannot be legally sold in market $H$ until period 3.

The major impact of the generic competition in market $L$ is in period 1, when the price of drug $A$ in the counterfactual case is some 80% lower than in the base case and revenue falls by two-thirds (see Table 2, Appendix 2). In period 2, the difference is much smaller.

Taking the combined present value (the discount rate was set at 5%) of the profits for drugs $A$ and $B$ as the basic measure of target incentive to produce breakthrough drugs, as suggested earlier, in this example over three quarters of the combined profits come from market $H$, the developed world, in the base case. As the model has been constructed, over 40% comes from the “me too” drug $B$, even though it is assumed to be launched in both market six years later than drug $A$.

In the counterfactual case, allowing the marketing of the generic version of the drug from period 1 on reduces the present value of combined profits by about 9%. The reduction is entirely due to a fall in the profits on the breakthrough drug $A$; the present value of worldwide profits on drug $B$ is in fact somewhat higher in the counterfactual
case. By construction, the entire decrease in combined profits occurs in the developing countries. In addition, however, there is a considerable gain to the population in developing countries in the amount of consumer surplus they enjoy. In fact, the present value of the gain in consumer surplus plus the profits of the generic drug companies (we assume that they are owned by developing-country citizens in stages 1 and 2) is more than twice as large as the reduction in drug company profits. That is, for every dollar by which these profits are reduced, citizens of the developing world gain more than two dollars ($2.08). Although the ratio becomes somewhat smaller for assumptions that imply either that the “me too” drug B is more similar to drug A (the value of $s$ is reduced from 1.2 to 1.1), or that the generic drug G is more similar to drug A (the value of $v$ is raised from 0.85 to 0.90), the consumer surplus gain remains quite large relative to the reduction in combined profits (it is 98% and 84% larger, respectively).

Conclusions and future directions

In the introduction, it was suggested that a policy of exempting developing countries from the TRIPS provisions might be a cost-effective measure. Whether this is so depends in part on what is assumed about who compensates the pharmaceutical firms for the loss of revenue.

If it is assumed that it is done taxpayers in the low-income countries, one must take into account that developing countries generally have weak tax systems, implying that the real cost of raising a dollar’s worth of tax revenue has a social cost well in excess of one dollar. However, if the numbers suggested in the previous section are accurate, the measure could be cost-effective even if the marginal excess burden was as high as 85-95 cents or more per dollar of revenue.
If one assumes that compensation is done as a form of foreign aid by developed countries, the measure seems even more likely to be cost-effective. If payment is from taxpayers in the country in which owners of the pharmaceutical companies reside, the measure would be equivalent to a form of foreign aid (that is, donor government funding of goods or services provided by producers in the donor country). A standard result in the analysis of the welfare effects of tied aid is that the real value of such aid is less than its nominal value, since the effect of tying may be to raise the cost. Thus each dollar of aid would be likely to have a real value to the citizens of the receiving country of less than one dollar. In the case of paying for an exemption from the TRIPS agreement, however, the real value is a multiple of the nominal value of the aid: each dollar of aid would yield benefits of that would be perhaps 85-95% higher than their nominal value. Offhand, it is difficult to think of a way of spending foreign aid funds that would yield a higher benefit per dollar of aid.

Taking equity considerations into account is likely to even further strengthen these conclusions. On average, buyers of pharmaceuticals are likely to have lower incomes than the average resident/taxpayer in the developing world, not only because drug expenditure tends to be associated with illness which by itself lowers income, but also because the incidence of illness is likely to be higher in low-income groups than in high-income groups. This consideration would make the measure look even more attractive, whether it were financed by developing-country taxpayers or out of donor funds from the developed countries.
Appendix 1.

In Period 3, when the patent on the breakthrough drug expires, all the three drug varieties are available in the market i.e the breakthrough drug $A$, the me-too drug $B$ and the generic drug $G$. The marginal valuation of patients for the drugs is measured by $X$.

There is a perceived quality difference for the drugs which is measured by the parameters $s > 1$ for the me-too drug and $0 < v < 1$ for the generic drug. The size of Market $H$ is 1 and that of Market $L$ is $\lambda$. Depending on the patient’s choice of drugs, her utility is:

$$U = sX^j - P_{B,3}^j \quad \text{if buys the me-too drug}$$
$$= X^j - P_{A,3}^j \quad \text{if buys the breakthrough drug}$$
$$= vX^j - P_{G,3}^j \quad \text{if buys the generic drug}$$
$$= 0 \quad \text{otherwise}$$

Consider first market $H$. We get three critical values of $X$. These are determined by the patients who are indifferent between buying the me-too drug and the breakthrough drug, the breakthrough drug and the generic drug and the generic drug and not buying any drug. Thus, $X_1, X_2$ and $X_3$ are determined by setting $sX_1 - P_{B,3}^H = X_1 - P_{A,3}^H$; $X_2 - P_{A,3}^H = vX_2 - P_{G,3}^H; \quad vX_3 - P_{G,3}^H = 0$. The proportion of consumers that choose the three drugs will then be given by $(X^H - X_1)/X^H, (X_1 - X_2)/X^H, (X_2 - X_3)/X^H$, respectively. (The analysis for market $L$ is similar.) Given the prices, consumer surplus on purchases of the three drugs are as illustrated in Figure 1 below.
Figure 1: Consumer Surplus in Market H

Valuation per unit in dollars

\[ \text{Profit of Firm B in the two markets, } j = H, L \text{ is} \]

\[
\pi^j_{B,3} = P^j_{B,3} \left( \frac{X^j - X_1}{X^j} \right) \lambda, \quad \text{where } \lambda = 1 \text{ when } j = H \\
= P^j_{B,3} \left( \frac{(s-1)X^j - P^j_{B,3} + P^j_{A,3}}{(s-1)X^j} \right) \lambda
\]

Maximizing with respect to \( P^j_{B,3} \), we get the reaction function

\[
P^j_{B,3} = \frac{X^j(s-1) + P^j_{A,3}}{2}
\]  \(\text{(1)}\)

Profit of Firm A in the two markets is,

\[
\pi^j_{A,3} = P^j_{A,3} \left( \frac{X_1 - X_2}{X^j} \right) \lambda \quad \text{where } \lambda = 1 \text{ when } j = H \\
= P^L_{A,3} \left( \frac{(1-v)P^j_{B,3} - (s-v)P^j_{A,3} + (s-1)P^j_{G,3}}{(s-1)(1-v)X^j} \right) \lambda
\]

Maximizing with respect to \( P^j_{A,3} \), we get the reaction function
\[ P_{A,3}^j = \frac{(1-v)P_{B,3}^j + (s-1)P_{G,3}^j}{2(s-v)} \] (2)

Profit of Firm G is given by the sum of profits in the two markets because once the patent expires, the generic firm is likely to exploit opportunities to gain from arbitrage so that the price of the generic drug is uniform in both the markets.

\[ \pi_{G,3} = P_{G,3} \left( \frac{X_H^H - X_3^H}{X^H} \right) + P_{G,3} \left( \frac{X_L^L - X_3^L}{X^L} \right) \lambda \]

\[ = P_{G,3} \left( \frac{vP_{A,3}^H - P_{G,3}^H}{v(1-v)X^H} \right) + P_{G,3} \left( \frac{vP_{A,3}^L - P_{G,3}^L}{v(1-v)X^L} \right) \lambda \]

Maximizing with respect to \( P_{G,3} \), we get the reaction function

\[ P_{G,3} = \frac{v(P_{A,3}^H X^L + \lambda P_{A,3}^L X^H)}{2M} \quad \text{where} \quad M = X^L + \lambda X^H \] (3)

From (1) and (2), we get

\[ P_{A,3}^j = \frac{(1-v)(X^L (s-1) + P_{A,3}^j)}{2(s-v)} + \frac{(s-1)P_{G,3}^j}{2(s-v)} \]

\[ = \left( \frac{s-1}{N} \right) \left[ 2P_{G,3}^j + (1-v)X^j \right], \quad \text{where} \quad N = 4s - 3v - 1 \] (4)

From (3) and (4), we get

\[ P_{A,3}^H = \frac{(1-v)X^H M[MN - \lambda v(s-1)(X^H - X^L)]}{[MN - v(s-1)X^L][MN - \lambda v(s-1)X^H] - v^2(s-1)^2 \lambda X^H X^L} \]

\[ P_{A,3}^L = \frac{(1-v)X^L M[MN + v(s-1)(X^H - X^L)]}{[MN - v(s-1)X^L][MN - \lambda v(s-1)X^H] - v^2(s-1)^2 \lambda X^H X^L} \]

\[ P_{B,3}^j = \left( \frac{X^j (s-1) + P_{A,3}^j}{2} \right) * \]
\[ P_{G,3} = \frac{\nu(P_{A,3}^H \times X^L + \lambda P_{A,3}^L \times X^H)}{2(X^L + \lambda X^H)} \]

Note that a similar analysis gives the equilibrium results in Period 2 by setting \( \nu = 0 \) and \( P_{G,3} = 0 \).

Appendix 2.

Table 1: Developed countries, Base Case

<table>
<thead>
<tr>
<th>Drug</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Present value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Share</td>
<td>0.500</td>
<td>0.053</td>
<td>0.068</td>
<td></td>
</tr>
<tr>
<td>Revenue</td>
<td>2.500</td>
<td>0.028</td>
<td>0.018</td>
<td>13.265</td>
</tr>
<tr>
<td>Cons. surpl.</td>
<td>1.250</td>
<td>0.014</td>
<td>0.029</td>
<td>6.784</td>
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<tr>
<td>B: Share</td>
<td>0.895</td>
<td>0.905</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revenue</td>
<td>1.130</td>
<td>1.027</td>
<td>15.612</td>
<td></td>
</tr>
<tr>
<td>Cons surpl.</td>
<td>4.803</td>
<td>4.919</td>
<td>72.442</td>
<td></td>
</tr>
<tr>
<td>G: Share</td>
<td>0.016</td>
<td>0.001</td>
<td>0.016</td>
<td>0.013</td>
</tr>
<tr>
<td>Revenue</td>
<td></td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cons. surpl.</td>
<td>0.001</td>
<td>0.013</td>
<td></td>
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</tbody>
</table>

Notes: “Share” is proportion of unit mass of potential buyers opting for each drug. Note that shares do not sum to unity since some potential buyers do not actually buy. “Revenue” and “Cons. Surpl.” is annual revenue and consumer surplus for each drug. “Present value” is discounted present value of revenue and consumer surplus over all three stages. Parameter values are: \( X^H = 10, X^L = 6, s=1.2, \nu=0.85, \lambda = 1 \).
Table 2: Developing countries, Base Case compared to Counterfactual Case.

<table>
<thead>
<tr>
<th>Drug</th>
<th>St 1, B.C.</th>
<th>St 1, C.F.</th>
<th>St 2, B.C.</th>
<th>St 2, CF</th>
<th>PV, B.C.</th>
<th>PV, C.F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Share</td>
<td>0.500</td>
<td>0.905</td>
<td>0.053</td>
<td>0.112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rev.</td>
<td>1.500</td>
<td>0.517</td>
<td>0.017</td>
<td>0.031</td>
<td>7.965</td>
<td>2.925</td>
</tr>
<tr>
<td>CS.</td>
<td>0.750</td>
<td>2.456</td>
<td>0.008</td>
<td>0.037</td>
<td>4.066</td>
<td>13.020</td>
</tr>
<tr>
<td>B: Share</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.895</td>
<td>0.842</td>
</tr>
<tr>
<td>Rev.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.678</td>
<td>0.959</td>
</tr>
<tr>
<td>CS.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.882</td>
<td>2.551</td>
</tr>
<tr>
<td>G: Share</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.048</td>
<td>0.023</td>
</tr>
<tr>
<td>Rev.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.069</td>
<td>0.003</td>
</tr>
<tr>
<td>CS.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.034</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Notes: As for Table 1, except “Rev.” means revenue, “CS” means consumer surplus, “B.C.” and “C.F.” mean base case and counterfactual case, respectively. Stage 3 is not shown as base case and counterfactual case are the same in stage 3. Note that CS includes profits of generic drug producers in stages 1 and 2.

Although in future work, we intend to allow the length of Stage 1 to be endogenously determined, in the simulations underlying Table 2 it was fixed exogenously at 6 years.
References:


