Market Coverage, Price and National Welfare
Under International Exhaustion of Patents

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This paper offers a complete menu of price and welfare ranking of market-based discrimination and parallel imports of drugs (under international exhaustion of patent). It has been shown that the uniform price under parallel imports is unambiguously lower than the discriminatory prices when the poor-country market is fully covered under both market-based discrimination and parallel imports. This is in sharp contrast to the conventional theoretical wisdom, and follows from the fact that under parallel imports a lower quality of drug is innovated by the patent-holder MNC. Thus, parallel imports can, of course, increase market access for the poor, as is often argued in favour of implementing international exhaustion of patents by the developing countries. Conventional welfare results (as in Richardson (2002) for example), however, hold in this endogenous innovation case, except for that market-based price discrimination may raise global welfare even if no markets are dropped as a result of international exhaustion of patent rights (or parallel imports).

JEL Classification: I11, L11, O33, O34

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1. Introduction

The gains from allowing parallel imports of on-patent drugs and medicines that force the patent holder pharmaceutical multinational corporations (MNCs) to charge
uniform price in all markets have been debated over the past few years by researchers as well as policy makers. The general consensus in this regard being that the richer countries primarily gain from such price convergence because otherwise the MNCs would charge higher prices for the patented drugs. This provides incentive for the richer countries to allow parallel imports from the poor countries where the same drugs are sold at lower prices. Thus, as Richardson (2002) demonstrates, when the poor countries are unable to restrict parallel exports the unique Nash equilibrium will be uniform pricing\(^1\): The richer countries undo price discrimination. Of course, the interests of the rich countries may be altogether different if they are exporters of drugs and medicines. On the other hand, poorer countries unambiguously lose from parallel imports allowed by the richer countries, and thus it makes sense for them to prohibit parallel exports. That is, when the poorer countries can restrict parallel exports, market-based (or cross-country) discrimination is the Nash equilibrium pricing [Richardson (2002)]. Of late, Valetti (2006) adds a new dimension to the debate over a global rule on exhaustion of patent rights by establishing an adverse long run effect of parallel imports. As the profit of the MNC is lower under uniform pricing, parallel imports or international exhaustion of patent rights ex ante lowers the level of innovation of a new drug. The corresponding loss of utility all around thus is to be weighed against the utility gains for those who pay lower prices under parallel imports. A similar result is established by Li and Maskus (2006), in the context cost-reducing innovation decision of a MNC: distortions associated with parallel imports reduce its innovation level. They show that reduction in cost-reducing R&D investment depends on transport costs among other things.

For developing and developed countries alike, the more important issue related to parallel imports of pharmaceutical drugs and other health innovations is the market access for their poor patients. It is primarily because of this market access concern that the developed countries are keen on allowing parallel imports, despite in many cases their own pharmaceutical firms emerging losers as a consequence\(^2\). But such a policy of parallel imports while ensures market access for poor in richer countries is

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\(^1\) Jelovac and Bordoy (2005) argue that there may not still be complete price convergence since the consumers in the importing countries may not value the parallel-imported drugs equally as they value the drugs marketed by the MNCs.

\(^2\) National interests regarding parallel imports differ even among the developed or richer countries. Whereas Japan allows international exhaustion, the EU allows regional exhaustion of patented goods. The countries like USA allow only national exhaustion of patents and copyrights, and even incorporate such clauses (the so-called TRIPS-Plus features) in bilateral trade negotiations to protect the interests of their MNC-exporters [Maskus (2000)].
apprehended to deny market access to poor in the poorer countries by raising price there. Thus, parallel imports seem to benefit poor patients in the richer countries at the cost of poor patients in the poorer countries. This apprehension regarding trade off between market access of poor patients in richer and poorer countries follows from the popular belief that arbitrage that parallel imports implies essentially causes discriminatory prices of an innovated drug to converge to a level somewhere in between. But, while in many cases such ranking of discriminatory and uniform prices may seem obvious, that it is not a self-enforcing proposition has recently been demonstrated by Mukherjee and Pennings (2011) in the context of innovation under licensing and decentralized and centralized unions. In the present context of innovation of a pharmaceutical drug and cross-country price discrimination, the adverse innovation effect of parallel imports shown by Valletti (2006) suggests a similar possibility. If, for example, markets are fully covered under parallel imports, and the innovated quality is lower than under discrimination (as shown by Valletti in case of partial market coverage), the uniform price should be lowered to induce the buyers to participate in the market. This is in sharp contrast to the conventional theoretical wisdom that the uniform price (resulting from parallel imports) is higher than at least the lowest discriminatory price. Thus, to the extent to which parallel imports (or international exhaustion of patents) lower prices of drugs all around, it can in fact increase market access for the poor everywhere. This is the main focus of this paper. In other words, in a two-country world with heterogeneous set of buyers distributed uniformly over continuum of incomes and innovation of a quality of a drug by an MNC, which closely resembles the analytical framework of Valletti (2006), the paper examines whether there are equilibria at which price of the drug declines everywhere as a consequence of parallel imports being allowed by the countries. Accordingly, the analysis sheds some light on whether greater market access to an innovated drug can be a plausible explanation of why even some of the low-income developing countries like India allow parallel trade or international exhaustion of patents, which might seem less obvious otherwise.

The paper further investigates into implications of this result for national welfare levels. Since the innovated lower quality of the drug reduces national welfare, does the gain from lower price (and consequent market access) is sufficiently high to provide a normative (or welfare) explanation for why most of the developing countries implement international exhaustion of patents or allow parallel imports? This national welfare analysis again contrasts with Valetti (2006) who restricts himself in deriving the condition for global welfare improvement after allowing PI instead of drawing implications of such under-investment in innovation for national
welfare levels. At the same time, this welfare dimension of our analysis can be seen as examining the robustness of Richardson’s (2002) result when the innovation decision of the MNC is endogenous. This is theoretically interesting because the adverse innovation effect of PI should lower the incentives of the rich countries to undo MBD. In this context, closely following Richardson (2002), we first consider the case where the low-price country (under MBD) cannot restrict parallel exports, and then the case where it can do so by imposing a parallel-export tax. In the latter case, the issue under consideration is whether the country chooses a prohibitive or a non-prohibitive export tax rate.

For the above-mentioned purposes, this paper first extends the adverse innovation effect of parallel imports established by Valletti (2006) to all possible equilibrium configurations including full market coverage equilibrium. In contrast to Valletti’s assumption of all markets being only partially covered under both discrimination and uniform pricing, this paper specifies all equilibrium market-coverage combinations, offers a complete menu of prices and innovation levels under market-based discrimination (henceforth, MBD) and parallel imports (henceforth, PI), and re-states the adverse innovation result. This is done for two reasons. First, as Wauthy (1996) and Acharyya (1998) argue, the extent of market coverage should be an equilibrium outcome of the profit-maximizing behaviour of firm(s) rather than an ex ante restriction. This also contrasts with Malueg and Schwartz (1994) who considered only the possibility of whether all markets are being served depending on the extent of variations in the country-specific maximum willingness-to-pay, but not whether each country market is served fully or partially. But, the extent of intra-country demand dispersion (which in this paper is related to the intra-country income variations) determines whether it is profitable for the MNC to serve all consumers in a particular country or not. Second, since we conceive that lower innovation level under PI may have a favourable impact on market access for poor all around, it is necessary to consider all possible equilibrium market coverage combinations to check whether the market access result is contingent upon a particular choice of market coverage by the MNC.

After specifying all equilibrium market-coverage combinations, the paper then establishes its main result: for a sub-set of these equilibria the uniform price is actually lower than the lowest price charged to poor patients in the poorest country by a discriminatory MNC. The uniform price under PI is unambiguously lower than the discriminatory prices when the poor-country market is fully covered under both MBD and PI. This provides a theoretical basis for the market access argument
mentioned above. But when the poor-country market is fully covered only under MBD, the extent of intra-country demand dispersion determines the ranking of the uniform and the discriminatory prices. The essence of these results is that PI does not necessarily mean a trade off between market access for poor patients in rich and poor countries.

The welfare analysis, on the other hand, reveals some interesting policy decisions by countries. First, despite possibilities of a lower uniform price, the poor country unambiguously loses from parallel imports. Thus, international exhaustion of patents allowed by the developing countries cannot perhaps be justified in terms of national welfare gains. Second, the rich country unambiguously gains, so that, as in Richardson (2002), it will undo MBD by allowing parallel imports when the poor country cannot restrict it. Third, global welfare under PI does not necessarily improve over that under MBD. It, in fact, declines unambiguously when the markets are partially covered. This means, the rich country cannot compensate the poor country to make PI globally Pareto superior to MBD. Under full market coverage, global welfare increases only when the market sizes (or intra-country demand dispersions) are sufficiently small in the sense defined later. This result contrasts with Malueg and Schwartz (1994): Market-based price discrimination may raise global welfare even if no markets are dropped as a result of parallel imports (and uniform pricing). This is because the innovation level is lower when parallel imports are allowed by the rich countries. Fourth, when the poor country can restrict parallel exports of the drug to the rich country by imposing an export tax, we show that it does have an incentive to prohibit such parallel exports for all parametric configurations (and, hence, for all combinations of the extent of market coverage). Thus, the second result of Richardson (2002) holds as well.

These results are established in the simplest case of countries having the same and uniform intra-country distribution pattern but different income or demand dispersions. Initially, we also confine ourselves with only two countries to focus on the national welfare levels in a tractable manner. Later we consider a simple three-country extension of the benchmark case to exemplify that a similar extension and generalization to many countries will not affect the main results qualitatively.

The rest of the paper is organized as follows. In section 2 we consider the two-country world economy with uniform income distribution patterns, specify all relevant equilibria and discuss their properties. Section 3 examines the robustness of
the under-investment result for non-uniform income distribution. Finally we conclude in section 4.

2. Unrestricted Parallel Trading
2.1 The analytical framework

Consider a two-country world with a rich or high-income country (H) and a poor or low-income country (L). These countries differ only in respect of the levels of personal income earned by the richest consumers, \( y_H > y_L \), but have the same level of personal income earned by the poorest consumers, \( y \). A consumer country-\( j \) with income \( y \in [\bar{y}, \bar{y}_j] \), \( j = L, H \), allocates his income over a composite consumption good and a drug. The composite consumption good is taken as the numeraire and its price is normalized to unity. Each consumer buys, if at all, only one unit of the drug. The potential buyers in country-\( j \) are distributed uniformly over the relevant income range \([\bar{y}, \bar{y}_j]\) with unit density. Thus, \((\bar{y}_j - y)\) is the extent of (intra-country) demand dispersion.

The drug, which can be of different quality indexed by \( s > 0 \), is developed by a pharmaceutical MNC who has the exclusive right of its production and sales in both these countries. Innovation requires investment of a sum of money \( C \) in R&D that increases at an increasing rate with the target level of innovation:

\[
C = \frac{1}{2}ks^2
\]

where, \( k \) is any positive constant and reflects the rate of change in the marginal cost of innovation. There are no production and distribution costs whatsoever. All consumers everywhere value the innovated quality of the drug as it directly benefits them in terms of better effectiveness of curing the disease for which it is used. Thus it pays for the MNC to develop a higher quality if the additional revenue at least covers the additional investment in R&D. But, though every consumer values a higher quality drug more than a lower quality drug, these valuations varies across consumers with different incomes. More precisely, following the literature on quality choice we assume that richer buyers attach an even higher valuation to a better quality drug relative to a lower quality drug than do the poorer buyers. Assume that such a preference relationship is linear in income and quality\(^3\):

\(^3\) See Shaked and Sutton (1982), for example.
\[ V_j(y, s) = ys \quad \forall \quad y \in [y, \bar{y}_j], \quad j = L, H \]  

(2)

Two comments are warranted at this point. First, this linear preference structure, assumed purely for analytical convenience and tractability in terms of closed-form solutions, satisfies all the desirable properties in a self-selection model like this, such as both the total and marginal utility are increasing in type (here, income), and that they display the single-crossing property\(^4\). Second, since except for the sunk R&D cost, there are no other costs, quality discrimination is not profitable for the monopolist even if it can effectively segment the two country-markets. The MNC will thus develop only one quality for all markets. This result may hold even for positive and increasing (marginal) production costs\(^5\).

Since each buyer buys only one unit of the drug, the net utility equals,

\[ v_j(y, s, P_j) = ys - P_j \]  

(3)

where \(P_j\) is the price of the drug charged in country-\(j\). Note that the prices will differ only when the MNC can practice market-based discrimination (henceforth, MBD). But when the countries allow parallel trade of the drug, arbitrage will cause the drug to be parallely exported from the low-price country to the high-price country, so that the prices will be the same everywhere, \(P_L = P_H\). Of course, for complete convergence of the country-specific prices of the same quality drug when parallel exports and imports are allowed or unrestricted, we must assume that the consumers in the high-price country equally value the drug marketed by the MNC and the one that is parallel-imported.

Assuming zero reservation utility for all, consumers in market \(j\) will not buy the drug if the net utility is negative. Thus, for any innovated quality of the drug, \(v_j(y, s, P^*) = 0\) defines the maximum willingness-to-pay for the drug for consumer with income \(y\) such that the consumer buys the drug only if

\[ P_j \leq ys \equiv P^* \]  

(4)

\(^4\) For a detailed discussion of these properties and their implications, the readers are referred to Cooper (1984).

\(^5\) This is in essence similar to what Acharyya (1998, 2005) had pointed out: when a monopolist chooses what quality (or qualities) to produce from a set of available qualities indexed by \(q \in [0, \bar{q}]\) and incurs zero or slowly rising marginal (production) cost of quality, then it will choose the maximum quality for all types within a country. The only choice left then is the price to be charged.
Given this analytical framework, we now proceed to analyze the alternative trade, intellectual property right and pricing regimes.

2.2 The extent of market coverage

Let $P_{jD}$ and $s_D$ denote respectively the price in country-$j$ market and the innovated quality under MBD. Similarly, let $P_{PI}$ and $s_{PI}$ respectively denote the (uniform) price and the innovated quality when the rich country allows parallel imports (henceforth, PI) and the poor country cannot or does not restrict parallel exports.

Let $y_j^*$ be the marginal consumer in country-$j$ market who derives zero net benefit from the menu $(P_{jD}, s_D)$ offered by the MNC to the potential buyers there. Thus by (4),

$$y_j^* = \frac{P_{Dj}}{s_D} \tag{5}$$

By the tie-breaking rule, the marginal (and indifferent) consumers buy the drug. Since consumers with higher income derive greater benefits by the utility specification in (2), so all these buyers buy the drug as for them the individual-rational constraint (4) is satisfied. But, if $y < y_j^*$, the buyers with smaller income than $y_j^*$ do not buy the drug and the country-$j$ market is partially covered. On the other hand, if $y > y_j^*$, all buyers in country-$j$ buy the drug.

Thus, in case of partial market coverage, given the uniform and unit distribution, the total demand for the drug in country-$j$ market is $(y_j^* - y_j)$. Hence, the profit of the MNC equals,

$$\pi_D = \left[ \sum_{j=L,H} \left( P_{jD} y_j - \frac{P_{jD}^2}{s_D} \right) \right] - \frac{1}{2} k s_D^2 \tag{6}$$

For any innovation level, profit maximization yields the following discriminatory prices:

$$P_{jD} = \frac{1}{2} s_D y_j, j = L, H \tag{7}$$

Substitution of (7) in (5) yields,
y_j^* = \frac{1}{2} y_j

The following lemma then specifies the parametric configurations underlying different combinations of the extent of market coverage at equilibrium under MBD.

**Lemma 1**: Under MBD, the MNC covers

a) each country market partially for all \( y < \bar{y}_L/2 \) and charge prices as specified in (7);

b) poor-country market fully but the rich-country market partially for all \( y \in [\bar{y}_L/2, \bar{y}_H/2] \) and charge prices equal to \( P_{LD} = s_D y \) and \( P_{HD} = s_D \bar{y}_H / 2 \);

c) both the markets fully for all \( y \geq \bar{y}_H / 2 \), if \( \bar{y}_H < 2 \bar{y}_L \), and charge prices equal to \( P_{jD} = s_D \bar{y}_L \).

**Proof**: First two claims follow from the profit-maximizing choice of the extent of market coverage as specified in (8). Finally, since \( y < \bar{y}_L \), so the case where the rich-country is fully covered is relevant (i.e., \( y \geq \bar{y}_H / 2 \)) if \( \bar{y}_H / 2 < \bar{y}_L \Rightarrow \bar{y}_H < 2 \bar{y}_L \).

When the countries allow parallel trade, the MNC is forced to charge a uniform price \( P_{PI} \). Let \( y^{**} \) denote the marginal consumers in each country market who derive zero net benefit from the menu \( (P_{PI}, s_{PI}) \) offered by the MNC to all the potential buyers:

\[
y^{**} = \frac{P_{PI}}{s_{PI}}
\]

\( ^6 \) Since the lowest income level is assumed to be same everywhere \( (\bar{y}_j = y \forall j = H, L) \), the MNC charges the same price in both the countries when both markets are fully covered. This becomes a trivial case since there will be no incentive for either country to allow parallel imports, and thus is not considered in price and welfare comparisons later. Full coverage of both markets would have been a meaningful case in the present context if, for example, \( \bar{y}_L < \bar{y}_H \), as in Acharyya and Garcia-Alonso (2012).
For the same reason as already spelled out above, if \( y < y^{**} \) both the markets are partially covered. In that case, the profit of the MNC equals,

\[
\pi_{pl} = P_{pl} \left[ \frac{y_L + y_H}{4} \right] - \frac{2P_{pl}^2}{s_{pl}} - \frac{1}{2} k s_{pl}^2
\]  
(10)

Proceeding as before, the profit-maximizing uniform price, for any given choice of innovation, equals:

\[
P_{pl} = \frac{1}{4} (y_L + y_H) s_{pl}
\]  
(11)

\[\Rightarrow y^{**} = \frac{1}{4} (y_L + y_H)
\]  
(12)

It is now readily verifiable that if \( y_L < y^{**} \), i.e., \( 3 \bar{y}_L < \bar{y}_H \), the MNC does not serve the poor-country market. Otherwise, for smaller cross-country demand dispersions, i.e., for \( \bar{y}_H \in (\bar{y}_L, 3 \bar{y}_L) \), both the markets are served. Therefore,

**Lemma 2:** Under PI, for all \( \bar{y}_H \in (\bar{y}_L, 3 \bar{y}_L) \), the MNC serves both the markets, with each country market partially covered for all \( y < y^{**} \) and both the markets fully covered otherwise, where, \( y^{**} = (\bar{y}_L + \bar{y}_H)/4 \).

In rest of the analysis we will assume that \( \bar{y}_H < 2 \bar{y}_L \), which means, first, both the countries will be served under PI, and second, both the markets may be fully covered under MBD. The different combinations of market coverage at different equilibria and the corresponding parametric configurations are illustrated in Figure 1.

Thus, there are four relevant cases and correspondingly four possible sets of equilibrium price, innovation and welfare levels. The first case is what has been discussed in Valletti (2006). The last of these cases, however, is trivial. Since the lowest willingness-to-pay is assumed to be the same in the two countries, under full coverage of both the markets the MNC charges the same price \( s_D y \) everywhere even without parallel imports being allowed by the countries. That is, when \( \bar{y} \geq \bar{y}_H / 2 \), MBD is simply not profitable. In rest of our analysis we abstract from this trivial case. We will distinguish between the choices in case II and case III (from those in case I) by putting a hat and a tilde over them respectively.
2.3. Innovation and Prices

In the first of the three non-trivial cases illustrated in Figure 1 above, where the intra-country demand dispersion is very large, and as a consequence, both the markets are partially covered under both the price regimes, the innovation levels can be found by maximizing (6) and (10) for the corresponding price choices defined in (7) and (11) respectively. More precisely,

\[
\begin{align*}
\pi_D^e &= \frac{1}{4k}(y_L^2 + y_H^2) \\
\pi_P^e &= \frac{1}{8k}(y_L + y_H)^2
\end{align*}
\]  

When the intra-country demand dispersion is moderately large (\(y_L / 2 \leq y < y^{**}\)) and thus under MBD the MNC fully covers the poor-country market but partially covers the rich-country market, the price charged in the former equals \(\hat{s}_D y\) and consequently the profit-maximizing choice of the quality of the drug equals,
The innovation levels and prices in other cases can similarly be derived. The equilibrium values of prices and innovation levels for different parametric configurations are reported in Table 1. As shown in the appendix, the underinvestment result of Valletti (2006) holds for all relevant range of demand dispersion. But the gap between the innovation levels under MBD and PI declines with the decline in the extent of the intra-country demand dispersion (or the intra-country income disparity), i.e., with higher \( y \) for any given \( \bar{y}_j \).

### Table 1: Equilibrium Price and Innovation Levels

<table>
<thead>
<tr>
<th></th>
<th>Case I ( y &lt; \frac{1}{2} y_L )</th>
<th>Case II ( \frac{1}{2} y_L \leq y &lt; y^{**} )</th>
<th>Case II ( y^{**} \leq y &lt; \frac{1}{2} y_H )</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBD</td>
<td>( s_D = \frac{1}{4k} \left( y_L + y_H \right)^2 )</td>
<td>( s_D = \frac{1}{8k} y_L \left( y_L + y_H \right)^2 )</td>
<td>( s_D = \frac{1}{8k} y_H \left( y_L + y_H \right)^2 )</td>
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<td></td>
<td>( P_{LD} = \frac{1}{8k} \left( y_L y_H \right)^2 )</td>
<td>( P_{LD} = \frac{1}{2k} y_H \left( y_L y_H \right)^2 )</td>
<td>( P_{LD} = \frac{1}{2k} y_H \left( y_L y_H \right)^2 )</td>
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<tr>
<td></td>
<td>( P_{HD} = \frac{1}{8k} \left( y_L y_H \right)^2 )</td>
<td>( P_{HD} = \frac{1}{2k} y_H \left( y_L y_H \right)^2 )</td>
<td>( P_{HD} = \frac{1}{2k} y_H \left( y_L y_H \right)^2 )</td>
</tr>
<tr>
<td>PI</td>
<td>( s_{PI} = \frac{1}{8k} \left( y_L + y_H \right)^2 )</td>
<td>( s_{PI} = \frac{1}{8k} \left( y_L + y_H \right)^2 )</td>
<td>( s_{PI} = \frac{1}{k} \left( y_L + y_H - 2y \right) )</td>
</tr>
<tr>
<td></td>
<td>( P_{PI} = \frac{1}{32k} \left( y_L + y_H \right)^3 )</td>
<td>( P_{PI} = \frac{1}{32k} \left( y_L + y_H \right)^3 )</td>
<td>( P_{PI} = \frac{1}{k} y^2 \left( y_L + y_H - 2y \right) )</td>
</tr>
</tbody>
</table>
This is illustrated in Figure 2. Under full market coverage of the poor country, $s_D y$ and $\frac{y_H}{2} s_D$ are the prices charged by the MNC when MBD can be practiced whereas $s_{PI} y$ is the global uniform price when PI is allowed by the rich country. Thus, for any given innovation level, as $y$ rises, the extent of the market (and hence the profit of the MNC) shrinks. Thus, the MNC lowers the innovation level as shown in Figure 2 for all $y \geq \frac{y_L}{2}$ under MBD and for all $y \geq y^{**}$ under PI.

The price comparison, on the other hand, is ambiguous. In case I where both the markets are partially covered under both the regimes, the global uniform price is greater than the lowest discriminatory price $P_{LD} \forall y_H \in [\frac{y_L}{2}, 2y_L]$. But when the poor-country market is fully covered under MBD (i.e., $y \geq \frac{y_L}{2}$), the discriminatory price there rises with $y$.

However, $\forall y \in (\frac{y_L}{2}, y^{**})$, the markets are still partially served under PI so that the (global) uniform price remains invariant with respect to the extent of demand dispersion (see Table 1). For all $\frac{y_H}{2} > y \geq y^{**}$, the markets are fully covered so that the uniform price rises with $y$ just as the discriminatory price charged in the poor country, though of course at a different rate. For this range of values of $y$, it is readily verifiable that,

![Figure 2: Parallel Imports and Under-Investment in R&D](image-url)
\[ \tilde{P}_{LD}^e - \tilde{P}_{Pl}^e = \frac{1}{4} y \left[ y_H - 2y \right]^2 > 0 \]

Therefore, by the continuity property of the equilibrium prices, \( \tilde{P}_{LD}^e(y) \) and \( \tilde{P}_{Pl}^e(y) \), there exists a \( y^* \in (\frac{y_L}{2}, y^{**}) \) such that \( \tilde{P}_{LD}^e(y = y^*) = \tilde{P}_{Pl}^e(y = y^*) \). Hence, for all \( y \geq y^* \), the global uniform price is lower than the discriminatory prices contrary to the conventional theoretical wisdom. This is what we anticipated earlier. The intuition behind this result is simple. When it is profitable for the MNC to serve the entire market in the poor country under PI, it must lower the price below the discriminatory price \( P_{LD}^e \) to induce the poorest buyers there since the innovated drug is now of a lower quality variety. That is, the uniform price under PI is lower than the discriminatory prices because of the adverse R&D effect of PI. The complete ranking of prices is illustrated in Figure 3 and the algebraic details are provided in the appendix.

**Figure 3**: Discriminatory and Global Uniform Prices
The above results are summarized in the following proposition:

**Proposition 1:**

a) Parallel imports unambiguously lower the innovation level and the consequent quality of the drug for all relevant parametric configurations and the extent of market coverage.

b) The global uniform price under parallel imports is unambiguously lower than the country-specific discriminatory prices when the poor-country market is fully covered under both MBD and PI regimes (i.e., for all \( y \geq y^{**} \)). But when this market is fully covered only under MBD (i.e., \( \frac{\bar{y}_L}{2} \leq y < y^{**} \)), there exists a \( y^* \in (\frac{\bar{y}_L}{2}, y^{**}) \) such that the uniform price under PI is lower than the discriminatory prices for all \( y \geq y^* \).

**Proof:** Follows from the above discussion.

Thus, parallel imports can, of course, increase market access for the poor, as is often argued in favour of implementing international exhaustion of patents by the developing countries. In the next section, we examine whether this market-access gain can be so high to provide a normative justification for such a policy as well.

### 2.4 Welfare Properties of Parallel Imports

From the preference structure and the consumer set defined here, it appears that there are three sources of a change in consumer gains and national welfare as the price regime changes from MBD to global uniform pricing. First is the level of innovation. Since all buyers value higher innovation and consequently a better quality of the innovated drug, national welfare levels rise with the innovation level. Second source of gain is a decline in price. The lower is the price of the drug, higher is the surplus for the intra-marginal consumers, for any given quality of the drug. Third source is the greater market coverage. If price of the drug declines or a better quality drug is innovated, and initially all the potential buyers were not served, more lower-income buyers are brought into the market who did not find it worthwhile to buy the drug earlier. Conversely, if the price of the drug rises or a lower quality of it is innovated, a few buyers drop out of the market and the national welfare declines. Of course, change in the profit of the MNC constitutes the other part of the change in national welfare for its native country. However, in our national welfare calculations below,
we neglect this component for two simple reasons. First, this helps us avoid the issue of location of the MNC. Second, the debates over the costs and benefits of parallel imports primarily concern how the users of drugs and medicines are affected by such a policy regime. However, the MNC profit is included when the global welfare is calculated later.

Thus, national welfare levels here are simply the sum of net welfare derived by all consumers who participate in the market:

\[ W_j = \int_{y_j^*}^{y_j} (y_j - P_j) dy \]

where, \( y_j^* \) be the marginal consumer in country-\( j \) market. The values of national welfare levels in each of the sub-cases discussed above are shown in Table 2 below.

Consider first the welfare of the poor country. In the first case, where the markets are partially served under both MBD and PI, parallel imports lower the quality of the innovated drug and raise the price. Thus, whereas some low-income buyers in the poor country are now driven out of the market, those who still buy the drug are worse-off due to lower innovated quality and higher price. So on all accounts the national welfare under PI declines below that under MBD.

In the second case, parallel import lowers national welfare through under-investment and smaller market-coverage. Though the uniform price is lower for some parametric values in this case, the consequent gain in net utility is not sufficient to compensate for the utility losses (see appendix). Finally, in the third case where the poor-country market is fully covered under both MBD and PI, there would be no market coverage effect on the national welfare. But once again, the utility loss due to under-investment under PI is larger than the utility gain due to lower (uniform) price, thereby lowering national welfare of the poor country. Thus, PI is unambiguously welfare reducing for the low-income country. The welfare loss under PI, the magnitude of which declines, however, with the fall in the demand dispersion (\( \bar{y}_L - \bar{y} \)), is shown in Figure 4.

\[ \text{Alternatively, we can think of MNC belonging to the rich country, but its government puts a very low or zero weight on MNC’s profit.} \]
Table 2: National and Global Welfare Levels

<table>
<thead>
<tr>
<th>Case I</th>
<th>Case II</th>
<th>Case II</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y &lt; \frac{1 - y_L}{2}$</td>
<td>$\frac{1}{2} y_L \leq y &lt; y^{**}$</td>
<td>$y^{**} \leq y &lt; \frac{1}{2} y_H$</td>
</tr>
</tbody>
</table>

### MBD

<table>
<thead>
<tr>
<th>$W_{LD}$</th>
<th>$W_{HD}$</th>
<th>$GW_D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{1}{32k} \bar{y}_L (\bar{y}_L + \bar{y}_H)$</td>
<td>$\frac{1}{32k} \bar{y}_H (\bar{y}_L + \bar{y}_H)$</td>
<td>$\frac{1}{16k} (\bar{y}_L + \bar{y}_H)^2$</td>
</tr>
<tr>
<td>$\frac{1}{8k} (\bar{y}_L - \bar{y})^2 (\bar{y}_H + 4\bar{y}_L - 4\bar{y}^2)$</td>
<td>$\frac{1}{32k} (\bar{y}_H + 4\bar{y}_L - 4\bar{y}^2)$</td>
<td>$\frac{1}{32k} (2\bar{y}_H + 4\bar{y}_L - 4\bar{y}_L y)(\bar{y}_H + 4\bar{y}_L - 4\bar{y}^2)$</td>
</tr>
</tbody>
</table>

### PI

<table>
<thead>
<tr>
<th>$W_T$</th>
<th>$W_R$</th>
<th>$GW$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{1}{256k} (\bar{y}_L + \bar{y}_H)^2 (3\bar{y}_L - \bar{y}_H)^2$</td>
<td>$\frac{1}{256k} (\bar{y}_H + \bar{y}_L)^2 (3\bar{y}_H - \bar{y}_L)^2$</td>
<td>$\frac{1}{128k} (\bar{y}_L + \bar{y}_H)^2 (3\bar{y}_L + 3\bar{y}_H - 2\bar{y}_L \bar{y}_H)$</td>
</tr>
<tr>
<td>$\frac{1}{2k} \frac{\bar{y}(\bar{y}_L - \bar{y})^2 (\bar{y}_L + \bar{y}_H - 2\bar{y})}{\bar{y}}$</td>
<td>$\frac{1}{2k} \frac{\bar{y}(\bar{y}_H - \bar{y})^2 (\bar{y}_L + \bar{y}_H - 2\bar{y})}{\bar{y}}$</td>
<td>$\frac{1}{2k} \frac{\bar{y}(\bar{y}_L + \bar{y}_H - \bar{y}_L \bar{y}_H y)(\bar{y}_L + \bar{y}_H - 2\bar{y})}{\bar{y}}$</td>
</tr>
</tbody>
</table>

On the other hand, since the global uniform price is always lower than the discriminatory price charged to the buyers in the rich country by the MNC, parallel import raises the national welfare of the rich country over and above the level under MBD primarily through the favourable price effect. The utility gain consequent upon the lower price over-compensates the utility losses from under-investment for those who participate in the market under both the price regimes. These welfare results mean that the rich country will undo price discrimination by allowing parallel imports of the drug when the poor country cannot restrict it. Thus the Richardson (2002) result extends to this case of endogenous investment decision with under-investment in R&D under PI compared to that under MBD.
Let us now turn to the efficiency property of this global-uniform pricing equilibrium. Since the poor country unambiguously loses, uniform price under PI can at most be potentially Pareto efficient provided, of course, the rich country gains from PI more than the poor country loses from it. In such a case, there is a scope for the rich country to compensate the poor country for its losses through transfers (such as contributions to the Global Fund launched by the United Nations) and still gain from PI. From such a perspective it is worthwhile to examine whether uniform pricing under PI improves the global welfare. The following Lemma makes a definite statement in this regard.

**Lemma 3:** Let $GW_D \equiv W_{LD} + W_{HD}$ and $GW \equiv W_L + W_H$ denote global welfare levels (including the MNC profit) under MBD and PI respectively. Then,

$$GW_D > GW \quad \forall \ y < \hat{y}$$

$$GW_D < GW \quad \forall \ y \in [\hat{y}, \frac{1}{2} y_H)$$

where, $\frac{1}{2} y_L < \hat{y} < y^{**}$. 

\[ Figure 4: \text{Welfare Ranking of MBD and PI} \]
Thus, global-uniform pricing under PI does not necessarily improve global welfare. Only for small demand dispersions (or large values of $\gamma$), global welfare is larger under PI than under MBD. Therefore:

**Proposition 2:**

a) When the poor country cannot restrict parallel exports of the patented drug sold by the MNC, the rich country will undo MBD by allowing parallel imports. A lower quality of the drug will be innovated and sold at the same price in every country by the patent-holder MNC.

b) Parallel imports and the consequent global uniform pricing will be (potentially) Pareto-efficient only when the demand dispersions are small in the sense that $\gamma \in [\hat{\gamma}, \gamma_H / 2)$.

**Proof:** The first part of the proof follows from the observation that the rich country always gains from parallel imports. The second part follows from Lemma 3.

### 3. Robustness

#### 3.1 More than two countries

To check whether the above results depend on the two-ness of the world economy, I consider a simple extension of the world economy to three-country case, which can of course be further extended to include more countries in the same manner as outlined below. In addition to the poor and rich countries as defined above, consider a middle-income country having the same lowest income level $\gamma$ but a highest income level $\gamma_M \in (\gamma_L, \gamma_H)$. The other characteristics of the taste heterogeneity of the potential buyers in this country are the same as those specified above in the benchmark case. For this extended world economy, I discuss only those sub-cases (as distinguished in terms of the value of $\gamma$ or the magnitude of demand dispersions) where the above-derived unorthodox price and welfare results hold.
Proceeding as before it is readily verifiable that under MBD the MNC serves all these markets partially $\forall \ y < \bar{y}_L/2$; serves the low-income country market fully and the other two partially $\forall \ y \in [\bar{y}_L/2, \bar{y}_M]$; serves the low and middle income countries fully and the rich-country market partially $\forall \ y \in [\bar{y}_M/2, \bar{y}_H/2]$; and serves all the markets fully $\forall \ y > \bar{y}_H/2$. On the other hand, under PI, all the markets are partially covered $\forall \ y > y^{***} \equiv \frac{\bar{y}_L + \bar{y}_M + \bar{y}_H}{6}$, and fully covered otherwise. Since, $\bar{y}_L/2 < y^{***}$, so all the markets are partially covered under both the pricing regimes $\forall \ y < \bar{y}_L/2$. In this particular case the innovation and welfare levels are as follows:

$$s_D^e = \frac{1}{4k} \left[ -y_L^2 - y_M^2 - y_H^2 \right]$$  

(17)

$$s_{PI}^e = \frac{1}{12k} \left[ y_L - y_M - y_H \right]^2$$

(18)

$$G_{WD} = \frac{1}{16k} \left[ y_L^2 + y_M^2 + y_H^2 \right]^2$$

(19)

$$GW = \frac{1}{144k} \left[ y_L + y_M + y_H \right]^2 \left[ 5y_L^2 + 5y_M^2 + 5y_H^2 - 2y_Ly_M - 2y_Ly_H - 2y_My_H \right]^2$$

(20)

The under-investment result is immediate from the comparison of the innovation levels:

$$s_D^e - s_{PI}^e = \frac{1}{6} \left[ (\bar{y}_M - \bar{y}_L)^2 + (\bar{y}_H - \bar{y}_M)(\bar{y}_H - \bar{y}_L) \right] > 0$$

On the other hand,

$$G_{WD} - GW = \frac{1}{36k} \left[ y_L^2 + y_M^2 + y_H^2 - y_Ly_M - y_Ly_H - y_My_H \right] > 0$$
Thus, in this case of partial coverage of all the markets, parallel imports lower the innovation level. It is also globally Pareto inefficient as in the two-country case discussed above.

To demonstrate now the favourable price effect of PI, consider the case where \( y \in [y^*, (y^*_L + y^*_H) / 2] \). Note that \( y^* \) is greater than \((y^*_M / 2)\) if \((y^*_H - y^*_M)\) is greater than \((y^*_M - y^*_L)\). For such a parametric configuration, the presumed values of \( y \) means that whereas only the low and middle income countries are fully covered under MBD by the MNC, all the three markets are fully covered under PI. Proceeding as before, the equilibrium prices under the two alternative pricing regimes equal:

\[
P_{LD}^e = P_{MD}^e = y s_D^e = \frac{1}{4k} y \left[ 2 y_H + 4 y_L + 4 y_M - 8 y_L y - 8 y^2 \right]
\]

\[
P_{IH}^e = \frac{1}{k} y^2 \left[ y_L + y_M + y_H - 3 y \right]
\]

When it is profitable for the MNC to cater the low and middle incomes country markets fully, as in this particular case, it charges the same price \( y s_D^e \) in these markets for any given innovated quality since the lowest income (and hence the willingness-to-pay) is the same. A higher price \( y s_D^e / 2 \), however, is charged to the buyers in the rich country, for the same quality of the drug. That is, due to smaller demand dispersion in the low and middle income countries, it does not pay for the MNC to discriminate between these two markets. But relatively larger demand dispersion in the rich country makes it profitable to price out some low-income potential buyers there and thus discriminate against the buyers who buy the drug relative to those in the other two countries. We can label this pricing choice of the MNC as the regional uniform pricing or partial discrimination.

It should then be obvious that since a lower quality of the drug is innovated under PI, the global uniform price that the MNC charges under PI to induce the potential buyers with the lowest income \( y \) (since in this case full coverage of the low-income country is profitable) must be smaller than the price the MNC would charge when a higher quality is innovated under partial discrimination in the sense defined above.
The following algebraic expression specifies the magnitude of this equilibrium price difference:

\[
P_{pL}^e - P_{pL}^e = P_{MD}^e - P_{pL}^e = \frac{1}{4k} \left[ \frac{y^2}{y_H} + 4y_L^2 \right] > 0
\]

These two cases are sufficient to illustrate how do the results specified in Propositions 1 and 2 in the context of a two-country world can extend to the three-country, and in a similar fashion to the many-country, world.

### 3.2 Export Tax and Parallel Imports

So far we have assumed that the government in the low-income country cannot prohibit parallel exports of the drug to the rich (and middle income) country. But trade restrictions such as an export tax can be effectively used to restrict and even prohibit parallel exports provided of course there are strict monitoring and prohibition of illegal exports and smuggling. Richardson (2002) in his homogeneous good framework argued that when the low-income countries can restrict parallel exports, the MBD will be the (Nash) equilibrium pricing. In this section I examine whether this result extends to this vertically differentiated good case. In the analysis below, we refer back to the benchmark model of two-country world and assume \( k = 1 \) for the innovation technology defined in (1) to keep the algebra simple but without any loss of generality.

Suppose the L-government imposes an ad valorem export tax at the rate \( t \) that maximizes the country’s welfare. The potential competitive local parallel exporters now buy the drug at the price \( P_L \) sold by the MNC in this country and then exports it at the price \((1 + t) P_L\) to the rich country. Thus, when the rich country allows unrestricted parallel imports of the drug from the low-income country, the MNC cannot charge the rich-country buyers more than \((1 + t) P_L\), the price that they have to pay for the parallel imported drug. However, we assume that when the rich country buyers face the same price for the drug sold by the MNC in the rich country and the parallel imported drug, they buy the drug sold by the MNC\(^8\). Thus, for any

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\(^8\) This choice is assumed here simply as a tie-breaking rule but can be justified by the buyers’ perception that parallel imported drug is not a perfect substitute of the original drug sold by the MNC. Readers are referred to Jelovac and Bordoy (2005) and Maskus (2001) for a similar argument.
given tax rate, the MNC sells the drug at the price \((1 + t) P_L\) in the rich country in which case no drug is actually (parallel) exported. Thus, the threat of parallel exports now though restricts the MNC’s ability to discriminate, it does not force it to charge the same price everywhere as when the L-government allows free parallel exports.

The MBD regime and the choices remain the same as before. Thus, we need only to analyze the export tax and PI regime, denoted by \(T\), where the L-government first chooses the optimal tax rate and then the MNC chooses the innovation level and the price of the drug to be sold in the low-income country market, \(P_{LT}\). We solve this sequential game by backward induction method. Given any choice of the export tax rate \(t\) by the L-government, the following profit maximizing choices of the innovation and the price level by the MNC, when it serves the low-income country market, are readily verified:

\[
\hat{s}_I^* = \frac{y_L^* + (1 + t)\hat{y}_H^*}{4[1 + (1 + t)^2]}, \quad (23)
\]

\[
P_{LT}^* = \frac{y_L^* + (1 + t)\hat{y}_H^*}{8[1 + (1 + t)^2]}, \quad (24)
\]

The extent of market coverage in the two countries equal \([\hat{y}_L - \hat{y}_L(t)\]\) and \([\hat{y}_H - \hat{y}_H(t)\]\) where \(\hat{y}_j(t), j = L, H\), is the marginal consumer in country-\(j\) who is indifferent between buying and not buying:

\[
\hat{y}_L(t) = \frac{\overline{y}_L + (1 + t)\overline{y}_H^*}{2[1 + (1 + t)^2]}, \quad \hat{y}_H(t) = (1 + t)\hat{y}_L(t) \quad (25)
\]

Of course, the innovation and price levels specified in (23) and (24) will be the profit-maximizing choices of the MNC only for all \(\overline{y} < \hat{y}_L(t)\). Otherwise the MNC covers the low-income country market fully (though still caters the high-income country partially for any positive export tax rate). The choices then can be readily verified as:
\[
\delta^e_T = \left[ \bar{y}_L y - y^2 + (1 + t)\bar{y}_H y - (1 + t)^2 y^2 \right]
\]

\[
\tilde{p}_{LT}^e = \left[ \bar{y}_L y - y^2 + (1 + t)\bar{y}_H y - (1 + t)^2 y^2 \right]
\]

A few comments are warranted at this point. First, \( \hat{y}_L(t) \) varies inversely with the tax rate. This has two implications. The low-income country market will be served by the MNC as long as \( \hat{y}_L(t) < \bar{y}_L \). Since \( \hat{y}_L(t) \) is decreasing in the tax rate and \( \hat{y}_L(0) \equiv y^{**} \), so \( \hat{y}_L(t) < \bar{y}_L \) \( \forall \ t > 0 \) if \( y^{**} < y_L \). Hence, by the condition stated in Lemma 2, viz. \( \bar{y}_H < 2\bar{y}_L \), the MNC serves the low-country market for any export tax rate imposed by the L-government. On the other hand, for any given \( y \), whether the MNC covers the low-income country market fully or not depends on the tax rate itself. Define a tax rate \( \hat{\iota}(y) \) such that \( y = \hat{y}_L(\hat{\iota}) \). Thus, the L-government can induce the MNC, if it prefers to, to cover the entire market by choosing a tax rate at least equal to \( \hat{\iota}(y) \), and since \( \hat{y}_L(t) \) varies inversely with the tax rate, this critical tax rate would be higher the smaller is the value of \( y \) (i.e., the higher is the demand dispersion in the low-income country). This is shown in Figure 4 by the downward sloping curve. Second, since for any given choice of the price at which the drug is to be sold in the low-country, \( P_L \), the price at which the MNC sells the drug in the rich country when its government allows parallel import of the drug increases monotonically with the export tax rate, there exists a tariff rate that enable the MNC to charge the same price that it would charge under MBD. I label this tariff rate as prohibitive tariff rate and understandably its value differs according to whether under MBD the MNC covers the low-income country fully or partially. In particular, let \( \hat{\iota}_P \) and \( \tilde{\iota}_P \) be such that,

\[
(1 + \hat{\iota}_P)P_{LD}^e = P_{HD}^e \quad \Rightarrow \quad \hat{\iota}_P = \frac{y_H - y_L}{y_L}
\]

\[
(1 + \tilde{\iota}_P)\tilde{p}_{LD}^e = \tilde{p}_{HD}^e \quad \Rightarrow \quad \tilde{\iota}_P = \frac{y_H - 2y_L}{2y_L}
\]

These prohibitive tariff rates are shown by the vertical and downward-sloping curves respectively in Figure 5. The relative positions and slopes of the \( \tilde{\iota}_P \)-constraint (reflecting the relationship \( 2(1 + \tilde{\iota}_P)y = \bar{y}_H \)) and the curve labeled \( y = \hat{y}_L(\hat{\iota}) \) are readily verifiable and thus a detailed discussion on this is avoided.
Since, as established earlier, the low-income country unambiguously loses when the rich country allows parallel imports, the L-government will gain by imposing the prohibitive tax rate on parallel exports, \( \hat{t}_p \) or \( \tilde{t}_p \) as defined above according as the relevant value of \( y \), relative to allowing free parallel exports. And for such a prohibitive tax rate, the H-government’s choice of allowing parallel imports is inconsequential. The issue is then whether there exists any non-prohibitive tax rate that raises the low-income country’s welfare over and above the level corresponding to the prohibitive tax rate, which, in turn, is equal to the level realized under MBD. If so, the L-government chooses that non-prohibitive tax rate, and then analyzing the choice of the H-government over allowing PI or MBD is meaningful.

Refer back to the Figure 5. Since \( \forall \ y < \bar{y}_L / 2 \), the relevant prohibitive tax rate \( \hat{t}_p \) is less than the critical rate \( \hat{t} \), so for this range of demand dispersion only Region I is relevant for discussion. For any \( t \geq \hat{t}_p \), as in Regions II, III and IV, the MNC the charges the same set of discriminatory prices \( P_{LD}^{e} \) and \( P_{HD}^{e} \), realizing the same welfare levels for the two countries. Now, for all such combinations of \( y \) and the tax rate in Region I, the following results hold as elaborated upon in the appendix:
The innovation level rises with the tax rate for the simple reason that higher taxes enable the MNC to discriminate more between the consumers in the low-income and rich countries and earn higher profits. The welfare level of the low-income country, on the other hand, varies with the innovation level and the extent of market coverage, when the MNC partially covers the low-income country market (i.e., for any choice of the tax rate \( t < \hat{i} ( \underline{y} ) \)):

\[
\hat{W}_{LT} = \frac{1}{2} \hat{s}^e \left[ \hat{y}_L - \hat{y}_L(t) \right]^2
\]

Given that \( \hat{y}_L(t) \) is decreasing in the tax rate, by (30a) it immediately follows that,

\[
\hat{W}_{LT}(t) < \hat{W}_{LT}(\hat{i}_P) \quad \forall \; t \leq \hat{i}_P
\]  
(31)

Therefore,

**Lemma 4:** For all \( \underline{y} < \underline{y}_L / 2 \), the L-government imposes the prohibitive export tax rate \( \hat{i}_P \).

**Proof:** See appendix. □

But for higher demand dispersion in the low-income country, i.e., for \( \underline{y} \geq \underline{y}_L / 2 \), the MNC fully covers this market under MBD (i.e., when the rich country does not allow parallel imports) so that \( \tilde{i}_p ( \underline{y} ) \) is now the relevant prohibitive export tax. There are now two relevant sub-cases. First is the sub-case of moderately high demand dispersions, \( \underline{y} \in [\underline{y}_L / 2, \underline{y}_*^* ) \), and the other is the sub-case of very small demand dispersions, \( \underline{y} \in [\underline{y}_*, \underline{y}_H / 2 ) \). Since for all such moderately high demand dispersions \( \hat{i}_P ( \underline{y} ) > \hat{i} ( \underline{y} ) > 0 \), the L-government can influence the MNC’s choice of the extent of market coverage by its own choice of a non-prohibitive tax rate. Precisely, when the rich country allows parallel imports and demand dispersions are
moderately large in the sense that \( \bar{y}_L / 2 \leq y < y^{**} \), for all non-prohibitive tax rate \( t < \hat{i}(y) \), the MNC partially covers the low-income country market, and fully covers this market otherwise. On the other hand, for very small demand dispersions, \( y \in [y^{**}, \bar{y}_H / 2) \), the MNC fully covers the low-income country market regardless of the export tax rate when the rich country allows parallel imports. Hence, the welfare levels realized for the low-income country for different parametric configurations are as follows:

\[
\tilde{W}_{LT} = \begin{cases} 
\frac{1}{2} \tilde{s}_L \left[ \bar{y}_L - \hat{y}_L(t) \right] & \forall \; t < \hat{i}(y) \; \text{and} \; y \in \left[ \frac{1}{2} \bar{y}_L, y^{**} \right] \\
\frac{1}{2} \tilde{s}_L (y_L - y) & \forall \; t \geq \hat{i}(y) \; \text{and} \; y \in \left[ \frac{1}{2} \bar{y}_L, y^{**} \right] \\
\frac{1}{2} \tilde{s}_L (y_L - y) & \forall \; t > 0 \; \text{and} \; y \in \left[ y^{**}, \frac{1}{2} \bar{y}_H \right]
\end{cases}
\]

Thus, for any given value of \( y \), and hence the extent of demand dispersion, the welfare level of the low-income country when the rich country allows parallel imports and the MNC covers its market fully, \( \tilde{W}_{LT} \), varies proportionately with the innovation level. Given the profit-maximizing level of innovation by the MNC as specified in (26), it is readily verifiable that, given \( y \), the innovation level, and hence the low-income country’s welfare, is maximum for the prohibitive tax rate \( \tilde{t}_p(y) \). Therefore, for all \( y \in [y^{**}, \bar{y}_H / 2) \), since the MNC serves all the consumers in the low-income country regardless of the rate of export tax, the L-government imposes \( \tilde{t}_p(y) \) to maximize the national welfare, \( \tilde{W}_{LT} \). On the other hand, for moderately high demand dispersions, since \( \hat{i}_p > \tilde{t}_p(y) > \hat{i}(y) \) and \( \hat{W}_{LT}(t) \) is increasing in the tax rate \( \forall \; t \leq \hat{i}_p \), the L-government’s choice of the export tax rate depends on the value of \( \hat{W}_{LT}(\hat{i}) \) relative to that of \( \hat{W}_{LT}(\tilde{t}_p) \). That is, the choice of the tax rate essentially boils down to choice between \( \hat{i}(y) \) and \( \tilde{t}_p \). The following lemma specifies this choice:

\textbf{Lemma 5:} \( \hat{W}_{LT}(\hat{i}) < \hat{W}_{LT}(\tilde{t}_p) \; \forall \; y \in \left[ \frac{1}{2} \bar{y}_L, y^{**} \right] \).
Proof: See appendix. □

Therefore,

**Proposition 3:** Regardless of the size of its market (or the demand dispersion), \( \bar{y}_L - y \), the L-government prohibits parallel exports. The H-government’s choice is thus inconsequential.

**Proof:** Given (32), the result follows directly from Lemmas 4 and 5 and that \( \tilde{w}_{LT} \) is maximum for the prohibitive tax rate \( \tilde{t}_p(y) \). □

That is, when the L-government imposes an export tax to restrict the parallel exports of the drug from the low-income to the rich country, the MBD will be the equilibrium price regime since its choice of prohibitive rate of tax makes inconsequential the parallel imports allowed by the rich country. Thus, the Richardson (2002) result once again extends to all parametric configurations.

### 4. Conclusion

By extending the earlier work of Valletti (2006) to all plausible parametric configurations this paper shows that though the under-investment result always holds, the innovation level for a drug varies with the extent of (intra-country) demand dispersion (and hence the extent of market coverage). But, the uniform price (when parallel trade of the patented drug is allowed by the countries) may be lower than the discriminatory prices contrary to the conventional theoretical wisdom. Despite such a possibility, however, the poor country always loses and the rich country always gains from parallel trading. Moreover, global welfare (including MNC profit) may fall as well implying that parallel trading of a patented drug may not even be a potentially Pareto superior regime compared to price discrimination.

Similar welfare properties of parallel imports hold when the poor-country government imposes a non-prohibitive export tax to (partially) restrict parallel exports of the patented drug to the rich country. Thus, when the poor country is not constrained politically or otherwise, it will undo global uniform price by **prohibiting** parallel exports of the drug regardless of the parametric configurations. Thus, MBD
will be the equilibrium pricing rule. This result reinstates Richardson (2002) result in this case of endogenous R&D investment.

Appendix:

1. Under-investment under parallel imports

From (13) and (14), it follows that, for \( \frac{1}{2} y_L < \frac{1}{2} y_L \),

\[
\frac{s_D^e - s_{pi}^e}{k} = \frac{1}{4} y_L + \frac{1}{4} y_H - \frac{1}{8} y_L - \frac{1}{8} y_H - \frac{1}{4} y_L - \frac{1}{4} y_H > 0 \quad (A.1)
\]

On the other hand, for \( \frac{1}{y_L} \leq \frac{1}{2} y_L \), given the values of innovation levels as specified in Table 1 in the text, it is sufficient to note the following:

\[
\frac{\partial s_D^e}{\partial y} = \frac{1}{k} (y_L - 2y) < 0 \quad (A.2)
\]

\[
s_D^e (y = y^{**}) = \frac{1}{16k} \left[ 3y_L^2 + 3y_H^2 + 2y_L y_H y_L \right] \quad (A.3)
\]

Since for this range of income levels, the innovation level under parallel imports remains the same as before, so

\[
s_D^e (y = y^{**}) - s_{pi}^e = \frac{1}{16k} (y_H^2 - y_L^2) > 0
\]

implies that \( s_D^e > s_{pi}^e \) \( \forall \frac{1}{2} y_L < \frac{y}{2} y_L \).

Finally, note that for \( \frac{y^{**}}{y_L} < \frac{1}{2} y_L \),

\[
\frac{\partial s_{pi}^e}{\partial y} = \frac{1}{k} \left[ (y_H + y_L) - 4y \right] = \frac{1}{k} (y_H - 2y) - \frac{1}{k} (y_L - 2y) < 0 \quad (A.4)
\]

Given (A.2) this means that innovation level under parallel imports falls faster than that under MBD as \( y \) rises, as shown in Figure 2 in the text. On the other hand,

\[
s_{pi}^e \left( y = \frac{1}{2} y_H \right) = s_D^e \left( y = \frac{1}{2} y_H \right) = \frac{1}{2k} y_H y_L
\]
Hence, \( s_D^e > s_P^e \) for \( y^{**} < y < \frac{1}{2} y_H \).

II. The extent of market coverage and discriminatory and uniform prices

First of all, note that, \( \forall y < \frac{y_L}{2} \), discriminatory price in the low-income country would always be smaller than the uniform price, though the magnitude of the difference depends on how large is \( y_H \) relative to \( y_L \). This is readily verified from the following set of values:

\[
P_{LD}(y_L = y_H) = \frac{1}{4k} y_L^3 = P_{PI}(y_L = y_H) \tag{A.5}
\]

\[
P_{LD}(2y_L = y_H) = \frac{5}{8k} y_L^3 < \frac{27}{32k} y_L = P_{PI}(2y_L = y_H) \tag{A.6}
\]

Moreover,

\[
\frac{\partial P_{LD}}{\partial y_H} = \frac{y_L}{4k} > 0, \quad \frac{\partial P_{PI}}{\partial y_H} = \frac{3}{32k} [y_L + y_H]^2 > 0 \tag{A.7}
\]

\[
\frac{\partial P_{LD}}{\partial y_H} - \frac{\partial P_{PI}}{\partial y_H} = -\frac{1}{32k} \left[ y_L^2 + y_H^2 + (y_H - y_L)^2 \right] < 0 \tag{A.8}
\]

Hence, \( P_{PI} > P_{LD} \) \( \forall y_H \in [y_L, 2y_L] \), given \( y < \frac{1}{2} y_L \).

On the other hand, \( \forall y \in [y_L/2, y^{**}] \), using the value of \( y^{**} \) in (12) and the values of the prices given in Table 2, it is readily verifiable that

\[
P_{LD}(y = y^{**}) = \frac{3}{64k} [y_L + y_H]^3 > \frac{1}{32k} [y_L + y_H]^3 = P_{PI}(y = y^{**}) \tag{A.9}
\]

Since, as demonstrated above, \( P_{LD} = P_{PI} \) for \( y = \frac{y_L}{2} \), by (A.8) and the properties of \( P_{LD}(y) \) and \( P_{PI}(y) \) functions, \( y > \frac{y_L}{2} \) we arrive at the ranking of the discriminatory and uniform prices as illustrated in Figure 3 in the text.
III. Welfare Properties of Parallel Imports

In case I, as specified in Table 2, it can be readily verified that both $W_H$ and $W_{HD}$ are monotonically increasing in $y_H$ at an increasing rate but $W_H$ rises faster than $W_{HD}$. Since $W_H = W_{HD}$ for $y_H = y_L$, so $W_H > W_{HD}$ over the relevant range, i.e., $\forall y_H \in (y_L, 2y_L]$. Alternatively, using Scientific Workplace, it can deduced that,

$$W_{HD} - W_H = \frac{1}{256} (y_H - y_L)(y_H + 13y_H y_L + 3y_H y_L - y_L) > 0 \quad (A.10)$$

Hence, the rich country unambiguously gains from parallel imports when markets are only partially covered under both MBD and PI.

When only the low-income country market is fully covered under MBD but both markets are still partially covered under PI (case II), first of all note that, welfare of the low-income country monotonically declines as $y$ rises,

$$\frac{\partial W_{LD}}{\partial y} = \frac{(y_L - y)(y_H^2 + 4y_H y_L - 4y_L^2) + 2(y_L - y)(y_L - 2y)}{4k} < 0 \quad \forall \ y > \frac{1}{2} y_L$$

(A.11)

and,

$$W_{LD}(y = y^*) - W_L(y = y^*) = \frac{1}{128k} \left( 3y_H^2 + 3y_L^2 + 2y_H y_L \left( y_H^2 + 3y_L^2 \right) - \frac{1}{256k} \left( y_H + y_L \right)^2 \left( 3y_L - y_H \right)^2 \right. = \frac{1}{256k} \left( 5y_H^4 + 9y_L^4 + 26y_H y_L^2 + 8y_L y_H^2 \right) > 0 \quad (A.12)$$

Therefore, as argued in the text, since $W_{LD} > W_L \ \forall y \leq y_L / 2$, and $W_L$ remains invariant with respect to changes in $y$ \forall $y < y^*$, so by (A.11) and (A.12) it follows that $W_{LD} > W_L \ \forall y \in \left[ y_L / 2, y^* \right]$. For even smaller demand dispersion, welfare under parallel imports decline as well and attains the same value at $y = y_H / 2$ as the welfare under MBD. Thus, the welfare of the low-income country unambiguously declines under parallel imports for all relevant demand dispersions.
On the other hand, it is straightforward to check that in Case I, parallel imports improve the welfare of the rich country:

\[ W_H - W_{HD} = \frac{1}{256} \left( y_H - y_L \left( y_H^3 + 13y_H^2 y_L + 3y_H y_L^2 - y_L^3 \right) \right) > 0 \]

For moderate demand dispersion (case II), \( W_{HD} \) monotonically declines but \( W_H \) remains invariant with the increase in \( y \). But since,

\[ W_H (y = y^*) - W_{HD} (y = y^*) = \frac{1}{256} \left( 5y_H^4 + 9y_L^4 + 26y_H^2 y_L^2 + 3y_L^2 y_H^2 \right) > 0 \]

so \( W_{HD} > W_H \) \( \forall y \in \left[ \frac{1}{2} y_L, y^* \right] \).

For even smaller degree of demand dispersion (case III), \( W_H \) monotonically declines as well with the increase in \( y \), but is still greater than \( W_{HD} \) except for \( y = \frac{y_H}{2} \). Hence, parallel imports unambiguously raise the welfare of the high-income countries for all relevant demand dispersions.

IV. Innovation levels under an export tax

From Eq. (23) in the text,

\[ \frac{\partial \delta_T^e}{\partial t} = \frac{y_L + (1+t)y_H - (1+t)y_L}{2 \left[ 1 + (1+t)^2 \right]^2} \]  
(A.13)

Hence, \( \frac{\partial \delta_T^e}{\partial t} > 0 \) \( \forall t \leq \frac{y_H - y_L}{y_L} \equiv \hat{t}_p \). On the other hand, subtracting (23) from (13) yields,

\[ \delta_D^e - \delta_T^e = \frac{1}{4} \left[ y_L + y_H \right] - \frac{1}{4} \left[ y_L + (1+t)y_H \right] = \frac{1}{4} \left[ (1+t)y_L - y_H \right]^2 \]  
(A.14)
Thus, $s_d^x > \delta_i^x \forall \ t \neq i_P$, as in (30b) in the text.

V. Proof of Lemma 4

For all $y < \bar{y}_L / 2$, the MNC serves both the markets partially under MBD as established in Lemma 1. Thus, the relevant prohibitive tax rate is $\hat{i}_P$ defined in (28). Since $\hat{i}_P < \hat{i}(y) \forall \ y < \bar{y}_L / 2$, so for all non-prohibitive tax rate $t < \hat{i}_P$, the low-income country market is partially covered by the MNC when the rich country allows parallel imports. Thus, $\hat{W}_{LT}(t)$ is realized, which, by (31), is maximum at $t = \hat{i}_P$. Hence the claim. □

VI. Proof of Lemma 5: $\hat{W}_{LT}(\hat{i}) < \hat{W}_{LT}(\hat{i}_P) \forall \ y \in [\frac{1}{2} \bar{y}_L, y^{**})$.

By definition, $\hat{i}(y)$ is such that,

$$y = \frac{y_L + (1 + \hat{i})y_H}{2[1 + (1 + \hat{i})^2]} \equiv \hat{y}_L(\hat{i})$$

which solves $\hat{i}$ as $^9$

$$(1 + \hat{i}) = \frac{-y_H + \sqrt{y_H^2 + 8y_Ly - 16y^2}}{4y} \quad (A.15)$$

Substitution of this value in $\hat{W}_{LT}(\hat{i}) = \frac{1}{8}[\bar{y}_L - \hat{y}_L(\hat{i})]^p \left[\frac{y_L + (1 + \hat{i})y_H}{1 + (1 + \hat{i})^2}\right]^p$ yields,

$$\hat{W}_{LT}(\hat{i}) = \frac{1}{16} (\bar{y}_L - y)^2 \left[\frac{-y_H + \sqrt{y_H^2 + 8y_Ly - 16y^2}}{4y_Ly + y_H^2 + y_H^2 8y_Ly - 16y^2} \right] \quad (A.16)$$

On the other hand, using (26), (29) and (32), we obtain,

$$\hat{W}_{LT}(\hat{i}_P) = \frac{1}{8} (\bar{y}_L - y)^2 (4y_Ly - 4y^2 + y_H^2) \quad (A.17)$$

$^9$ We consider only the positive root.
Suppose, \( \hat{W}_{LT}(\hat{t}) > \tilde{W}_{LT}(\tilde{t}_P) \). Hence, by (A.16) and (A.17),

\[
8 \overline{y}^2 + \overline{y}_H \sqrt{\overline{y}_H^2 + 8 \overline{y}_L y - 16 \overline{y}_L^2} > 4 \overline{y}_L y + \overline{y}_H^2
\]

\[
\Rightarrow 64 \overline{y}_H^4 - 64 \overline{y}_L \overline{y}_H^3 + 16 \overline{y}_L^2 \overline{y}_H^2 < 0 \Rightarrow (\overline{y}_L - 2 \overline{y}_H)^2 < 0
\]

which cannot be true. Thus, \( \hat{W}_{LT}(\hat{t}) < \tilde{W}_{LT}(\tilde{t}_P) \) as stated in Lemma 5 in the text.

References:


