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Garcia-Alonso, Maria D C and Acharyya, Rajat (2011) Parallel imports, drug innovation and international patent protection: a policy game. *Journal of International Trade and Economic Development*, 21 (6). pp. 865-894. ISSN 1469-9559.

DOI

<https://doi.org/10.1080/09638199.2010.541273>

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Parallel imports, drug innovation and international patent protection: a policy game*

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November 15, 2010

Abstract

We consider a policy game between a high-income country hosting a drug innovator and a low-income country hosting a drug imitator. The low-income country chooses whether to enforce an International Patent Regime (strict IPR) or not (weak IPR) and the high-income country chooses whether to allow parallel imports (PI) of on-patent drugs or market based discrimination (MBD). We show that, for a moderately high imitation cost, both (Strict IPR, PI) and (Weak IPR, MBD) emerge as the Subgame Perfect Nash Equilibrium (SPNE) policy choices. For relatively smaller imitation costs, (Weak IPR, MBD) is the unique SPNE policy choice. The welfare properties reveal that although innovation may be higher at the (Strict IPR, PI) policy regime, the market coverage and national welfare of the low-income country, and the total welfare are all lower. This opens up the efficiency issue of implementing TRIPS and at the same time allowing international exhaustion of patent rights.

JEL Classification: D4, L1, I1.

Keywords: Income Inequality; Intellectual Property Rights; India; TRIPS; Parallel Imports; Pharmaceuticals;

*We would like to acknowledge financial support from the British Academy Grant number SG-50473 and the University of Kent Small Faculty Grants. We thank Kaushik Basu, Sugato Bhattacharyya, Javier Coto, Jagjit Chadha, Martin Jensen, Sugata Marjit, Indrajit Ray, Mathan Satchi and seminar participants at University of Birmingham, University of Kent, Centre for Studies in Social Sciences, Kolkata and Imperial College for their comments and suggestions on an earlier version of the paper. We would also like to thank two anonymous referees for their helpful suggestions. The usual disclaimer applies, however.

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1 Introduction

Compliance with the trade-related aspects of intellectual property rights (TRIPS), which requires prohibition of imitation of patented drugs, is meant to accelerate drug innovation to benefit developing and developed countries alike. However, developing countries argue that TRIPS implementation will lead to closing down of business for a significantly large number of their firms¹ and loss of market access for poor patients as a consequence of monopoly pricing of drugs by the patent-holder multinational corporations (MNCs).

Interestingly, the possibility of cross-country price discrimination by patent-holder MNCs under TRIPS has raised similar concerns of accessibility to new drugs for the poor in the rich world as well. Article Six of TRIPS addresses these concerns, whereby countries can allow parallel imports (PI) of an on-patent drug from the low-priced low-income countries without the permission of the patent-holder MNC.² A conflict of interest among poor patients and innovator, however, has led to a wide variation in the national rules for exhaustion among the rich drug-importing and drug-exporting countries [Maskus (2001)]. For the developing world, whereas a product patent regime may deny market access for the poor, the situation is apprehended to be worsened further by PI allowed by the rich countries. Price convergence induced by PI will increase drug prices in the poorer countries.³ At the extreme, the MNC may not cater to the poor countries at all [Malueg and Schwartz (1994)]. In addition, since PI adversely affects innovation [Valletti (2006)], there is a conflict between implementing strict IPR and allowing PI in terms of generating incentives for innovation. Therefore, what appears is that benefits of TRIPS – both product patent and flexible clauses and exceptions like PI – are neither unequivocal nor uniform across nations.

To capture the above conflict of interests across different nations, this paper considers a policy game between a low-income and a high-income country and evaluates the choice over a strict and a weak IPR regime in the former and over the alternative rules of exhaustion of patent rights in the latter in terms of national welfare levels that incorporate the effects of these policies on both market access for poorer buyers and the incentives to innovate. Since TRIPS exceptions allow country-specific variations in the implementation of an IPR regime [Abbott (2001), Correa (2000a)], TRIPS compliance is still an option for many developing countries. In addition, developing countries can

¹The available evidence suggests that TRIPS will not have a significant positive impact on innovation in the developing world [Primo Braga (1990), Chadha (2008), Lall (2003) and, Ramani and Maria (2005)].

²Under such a provision the exclusive right to sell by a patent-holder exhausts after the drug is marketed. This is different from imitation of the patented drug, which is the production and sale of drugs closely similar to the patented drug without the permission of the patent holder.

³See Danzon (1998), Maskus (2001) and Richardson (2002).

use compulsory licensing (CL) by which a non-patentee can obtain license and compete with the patent-holder by paying a nominal (or often non-existent) royalty to the patent-holder through the national government. This provides another motivation for considering a policy choice over a strict and a weak IPR regime. On the other hand, our welfare analysis is motivated by the recognition in Article 7 of TRIPS that the protection and enforcement of TRIPS should be "conducive to social and economic welfare".

In the literature on imitation and innovation, two recent papers have some relevance for our analysis. First, Kovac and Zigic (2007) examine the optimal trade policy choice when a quality-leader developed-country firm faces the threat of imitation from a follower developing-country firm in a vertically differentiated developing country market. They argue that an optimal tariff imposed by the developing country government encourages imitation, and when marginal efficiencies of firms' investment in qualities is small, it can even lead to quality reversals (or leapfrogging). However, when quality reversals do not occur, the tariff policy lowers welfare below the free trade level. The other analysis is that of Sohn (2007) that argues that by welfare criterion, imitation may be weakly regulated. The investment to innovate shrinks when the innovator faces the threat of imitation by his rival, but there is also the benefit arising from cost reduction through imitation. Thus, although imitation weakens the incentive for (cost-reducing) innovation, it can benefit the society on the whole. This result has some direct relevance in the present context. However, none of these papers have put their analyses in the specific context of pharmaceutical industry or products that are subject to PI.

The existing literature on PI, innovation and welfare, on the other hand, has evolved under the implicit assumption of strict IPR regime across the globe. Thus, the impact of the threat of imitation on the choice of rich countries over allowing PI or not has not been addressed. Valetti (2006), however, has some relevance for the issues that we address here. Using the assumption of partial coverage of markets, he considers the impact of PI on innovation. As the profit of the MNC is lower under uniform pricing, PI or international exhaustion of patent rights *ex ante* lowers the level of innovation of a new drug.^{4,5}

To best of our knowledge, the only paper that links these two literatures and provides a benchmark for the present paper is that of Ichino (2004). He considers a policy game between a low-income country choosing over allowing

⁴This analysis has been extended to all equilibrium market-coverage combinations (including full coverage of all country-markets) by Acharyya (2008a). It has been established that the global welfare under PI is lower than that under market based discrimination when the markets are partially covered. On the other hand, under full market coverage, the global welfare under PI increases only when the market sizes (or intra-country demand dispersions) are sufficiently small.

⁵Li and Maskus (2006) are also concerned with the interaction of incentives to innovate and PI. They design a model of process innovation in which the innovator decides whether or not to supply their good via a distributor to another country, the distributor may in turn decide to compete with the innovator firm in its own domestic market if PI is allowed. The paper analyzes the impact of banning PI on the decisions of the firms. In their model, the government in the non innovator country is not policy active.

or not allowing piracy and a high-income country choosing over allowing or not allowing PI. In such a context, the possibility of piracy significantly alters the welfare effect of PI. Whereas piracy is a dominant strategy for the low-income country, the choice of PI by the high-income country depends on the population density in the low-income country and the difference in the highest income parameter across countries. However, by assuming exogenously given quality, Ichino's analysis neglects the adverse effect of both PI and piracy (or imitation) on the quality of the product. Given the adverse innovation effect of PI on innovation, the incentive for poorer countries to allow imitation when the rich country allows PI may be smaller since those who buy the innovated drug are strictly worse off. Our paper takes account of the adverse innovation effects of PI and imitation (or weak IPR regime).

There are other dimensions in which the present analysis differs from that of Ichino (2004). First, observing the price-setting power of the Indian pharmaceutical firms even for the imitated drugs, we assume a single potential imitator instead of perfectly competitive imitators.⁶ Second, we consider a leader-follower structure in the innovation-imitation subgame similar to Kovac and Zigic (2007). However, we do not allow quality reversal through imitation as there is no such evidence even for Indian pharmaceutical firms who have the technical and manpower skills. That is, we assume that pharmaceutical industries in different countries differ in their ability to produce innovative drugs. Third, we assume that the imitator must incur in a fixed cost so as to be able to imitate. This opens up a wider strategy set for the innovator as we define below.

The structure of the model is as follows. We characterize the two-country global economy, a high-income country (H) and a low-income country (L). There are both intra and cross country income disparity. Consumers in each country in an interval are located according to their respective income levels. A key assumption is that the intervals are not too far apart and that the richest consumer in H is richer than the richest consumer in L. The utility of the representative consumer is increasing in the quality level of the drug and decreasing in its price. The firm in country H is assumed to have the technology to innovate a new drug. The firm in country L only has the technology to produce an imitation, and can operate only when the L-government enforces a weak-IPR regime. The sequence of events in the policy game played by the governments is as follows. First, national governments simultaneously choose their policy regimes. For H, where the innovator firm is based (the higher income country), the policy choice consists of allowing PI or letting the firm implement market based price discrimination (hereafter, MBD). For L, where only imitation is possible, the policy choice consists of allowing imitation (weak IPR) or not (strict IPR). Second, the H-firm determines the quality of the innovation. Under a weak IPR regime in the low-income country, this innovating

⁶Even under the Patent Act 1970 that allowed imitation, reverse engineering and patents for new processes in India until it was being replaced by the Patent Act 1999, the imitating firms could enjoy positive supernormal profits. One reason for this may be the fixed costs involved in imitation and reverse engineering which restricted entry.

firm decides upon whether to accommodate or deter entry of the potential local imitator in L. If it decides to deter entry, it innovates a limit quality.⁷ Third, the L-firm determines the quality of the imitation (if accommodated). Fourth, the innovator and imitator set their prices. Finally, the consumers in each country decide whether to buy the drug and, if relevant, which one to buy.

Within this framework, we obtain the following results. First, for moderately high fixed costs of imitation in the sense defined later, we have multiple subgame perfect Nash equilibrium (henceforth, SPNE) policy pair: (Weak IPR, MBD) and (Strict IPR, PI). Second, for relatively lower fixed cost (Weak IPR, MBD) emerges as the unique SPNE. Thus, at a SPNE, regardless of the level of fixed cost of imitation, entry deterring strategy and limit quality are never realized because the low-income country never implements a weak IPR when the innovator is expected to deter entry. Third, the welfare properties of the two SPNE reveal that although innovation may be higher at the (Strict IPR, PI)-SPNE than at the (Weak IPR, MBD)-SPNE regime depending on the cross-country income disparity, the market coverage and national welfare of the low-income country and the total welfare all are lower. This opens up the efficiency issue of implementing TRIPS (or strict IPR) and at the same time allowing international exhaustion of patent rights since the optimal response of high income countries (where MNC are based) to TRIPS implementation would be to allow PI.

The nature of SPNE policy choices, multiple or unique, provides a theoretical support for the historically observed policy choices in the developed and developing countries. A SPNE policy choice (multiple or unique) always involves a weak IPR implemented by the low-income country. The result also provides an explanation for the interests of the rich countries in enforcing product patents and at the same time allowing international or regional exhaustion of patent rights. The potential threat of imitation induces the high-income country not to allow international exhaustion of patents (and thus not to allow PI), because the full potential benefits from PI cannot be realized. But, when the threat of imitation is eliminated through implementation of a strict (and uniform) IPR regime across the globe under the WTO commitments, the potential benefits from PI can be fully realized and this is more desirable than MBD for the rich country.

One of the possible SPNE we obtain here that involves the rich country allowing PI and the low-income country respecting TRIPS could be related to results obtained Grossman and Lai (2008). They analyze countries with different abilities to innovate (North and South) choosing policies on price caps and PI. They conclude that a North country might use PI as a means to discourage price caps in the South country. Similarly, the choice to give patent protection will have an impact on the ability of the innovator to set high prices in the South country.⁸

⁷In the vertical differentiation literature, firms usually commit to quality levels and then compete in prices [Shaked and Sutton (1982)]. Donnenfeld and Weber (1995) and, Lutz (1997) consider limit qualities set by incumbent firms to deter entry.

⁸Grossman and Lai (2008) use a general equilibrium dynamic model of innovation where

The rest of the paper is organized as follows. Section 2 discusses the basic assumptions and structure of our analytical framework. The firm strategies and innovation choices are derived in section 3. Section 4 examines the SPNE policy choices. Section 5 discusses the properties of the two SPNE policy choices, and re examine the policy choices considering compulsory licensing allowed by the low-income country and the possibility of transport costs. Finally, concluding remarks are made in section 6.

2 The analytical framework

Consider a two-country world, with two countries as rich or high-income country (H) and a poor or low-income country (L). These countries differ in a number of ways. First, though personal income is uniformly distributed in each country j ($j = H, L$) over the relevant income range $[\underline{y}_j, \bar{y}_j]$ with unit density for each income level, both the richest and poorest consumer in country H have a higher level of income than those in country L , i.e., $\bar{y}_H > \bar{y}_L$ and $\underline{y}_H > \underline{y}_L$. A consumer in country- j with income y buys, if at all, only one unit of the drug. Thus, $[\bar{y}_j - \underline{y}_j]$ is the extent of (intra-country) demand dispersion when the markets are fully covered. The second way in which our two countries differ is the ability of their pharmaceutical industry to perform basic R&D research. There is a pharmaceutical firm located in the H -country which develops a new drug with quality $s^* > 0$. Innovation requires investment of a sum of money C in R&D that increases at an increasing rate with the target level of innovation:

$$C = \frac{1}{2}(s^*)^2 \quad (1)$$

We also have a pharmaceutical firm in country L , but this firm is unable to improve on the quality produced by the innovator firm. However, once the imitation technology has been acquired at a cost F , this firm can produce a drug of any quality $s < s^*$. To simplify the analysis, we assume there are no production and distribution costs whatsoever for any of the two firms.

As we will see, as long as \underline{y}_j is sufficiently small relative to \bar{y}_j so that it pays for a patent-holder MNC to only partially cover both these markets, these assumptions really do not matter for our results. All that matters is that the richest buyers in the H -country are richer than the richest buyers in the L -country (i.e., $\bar{y}_H > \bar{y}_L$), but not too rich in the sense $\bar{y}_H < 3\bar{y}_L$. We will confine ourselves in this paper to partial coverage of both markets. The reason for this is that the increased market access argument for imitation and PI makes sense when initially the markets are not fully covered.

new varieties are introduced. Their model shares some similarities with ours. We also allow the North to prohibit PI. However, the choice on the side on the poor country is whether or not to abide by TRIPS agreement to give patent protection to the North firm. Such choice will indeed have an impact on the ability of the innovator firm to set high prices in the Southern country, similarly to price caps being set.

Finally, the differences in the pharmaceutical industries result in differences in the policies available for implementation in each of the two countries. Whereas an IPR regime is strictly enforced and monitored in the H-country, the L-country government may choose to implement a weak IPR regime, which would allow imitation. On the other hand, the H-country must choose whether or not to allow PI of the drug innovated by its own firm and sold in the L-country. If PI are not allowed, the innovator firm will be able to price discriminate across countries.

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. This means that the marginal willingness-to-pay for quality varies across different income levels in each country.⁹ We assume that such a preference relationship is linear in income and quality so that if a consumer purchases a drug of quality s^* , she gets a gross utility

$$V_j(y, s^*) = ys^* \quad \forall y \in [\underline{y}_j, \bar{y}_j], j = L, H. \quad (2)$$

The net utility, assumed to be additively separable, equals,

$$v_j(y, s^*, P_j) = ys^* - P_j^*, \quad (3)$$

where P_j^* is the price of the s^* quality drug charged in country- j .

We consider the following timing for the decisions taken by the agents in our model, first, welfare maximizing governments in countries H and L simultaneously choose whether or not to allow PI and whether or not to implement strict IPR respectively. Second, the firm in the H-country decides the quality of the drug. Third, the firm in the L-country chooses the quality of the imitated drug, thereafter, the innovator and the imitator simultaneously set their prices. Finally, the consumers in each country decide whether to buy the drug, and in if relevant which one to buy.

In what follows, we obtain the innovation, price and national welfare levels under each of the four possible combination of policy regimes: strict-IPR regime in both countries with and without PI allowed by the H-country, and a weak-IPR regime in L-country with and without PI allowed by the H-country. Finally, we will discuss SPNE strategy choices for the governments.

Using backwards induction, we start with the decisions faced by consumers in each country. First, note that, regardless of whether the H-country government allows PI or not, consumers there can only consume the drug innovated by the patent protected innovator, that is, exports of the imitated drug to the H-country are not possible. Hence, their purchase decision is determined by the non-negative value of net-utility $v_H(y, s^*, P_H^*)$ as defined in expression (3). However, for the consumers in L-country the choice is two-fold, if a weak IPR regime is implemented and if the innovated drug is locally imitated. First

⁹We follow Acharyya and Garcia-Alonso (2006, 2008). Gabszweicz and Thisse (1979) and Shaked and Sutton (1982) relate the differences in marginal willingness-to-pay for quality to differences income levels. Mussa and Rosen (1978) however link them to taste diversity.

is whether to participate in the market, and second is which drug, original innovated one or the locally imitated one, to buy. These decisions are dictated by the following individually rational (IR) and self-selection (SS) or incentive-compatible constraints respectively:

$$v_L(y, s, P) = ys - P \geq 0, \quad (4)$$

$$v_L(y, s^*, P_L^*) \geq v_L(y, s, P) \implies ys^* - P_L^* \geq ys - P, \quad (5)$$

where, P is the price of the locally imitated and produced drug and P_L^* is the price charged by the innovator in the L-country. Of course, the SS constraint is relevant only if the imitator firm enters. A strict IPR regime will prevent imitation. In addition, given our assumption of fixed costs of acquiring an imitation technology, the innovator might choose to deter entry. In both these cases, only the IR constraint that ensures the non-negative value of net-utility $v_L(y, s^*, P_L^*)$ will matter.

We must also restrict the choice set for innovated quality to $(0, 1)$ such that the profit maximizing quality $s^* < 1$. This will ensure that whenever the IR constraint is satisfied (4), the budget constraint $P \leq y$ is satisfied as well.¹⁰ In the section that follows, we will analyze the firms profit maximizing choices given the different policy scenarios, Table 1 summarizes the equilibrium prices and quality levels for each case.

3 Firm strategies under alternative policy regimes

3.1 Strict IPR and market based price discrimination

Let P_{jD}^* and s_D^* denote the price in country- j and the innovated quality under MBD respectively. Let y_{jD}^* be the marginal consumer in country- j who derives zero net benefit from the price, quality menu (P_{jD}^*, s_D^*) offered by the MNC to the potential buyers there. Using the IR constraint, we obtain the marginal (and indifferent) consumer's income level

$$y_{jD}^* = \frac{P_{jD}^*}{s_D^*}. \quad (6)$$

Consumers with higher income will buy the drug as for them the IR constraint is also satisfied. Thus, if $\underline{y}_j < y_{jD}^*$, the buyers with smaller income than y_{jD}^*

¹⁰In the literature on quality choice, it is generally assumed that a small proportion of income is spent on the quality differentiated good so that the purchasing power constraint is implicitly assumed to be non-binding (see Tirole (1992)). But, our linearization of marginal willingness-to-pay in (2) does not allow us to assume a non-binding purchasing power constraint. However, instead of considering a separate purchasing power constraint, we set $s^* < 1$, as suggested by an anonymous referee, so that the IR constraint (2) implies the purchasing constraint. See Acharyya (2005, 2008b) for an explicit purchasing power constraint and how such a constraint by itself provides a scope to a monopolist to discriminate.

do not buy the drug and country- j is partially covered. On the other hand, if $\underline{y}_j > y_{jD}^*$, all buyers in country- j buy the drug, and the markets are fully covered. Thus, in case of partial market coverage, given the uniform and unit distribution, the total demand for the drug in country- j is $[\bar{y}_j - y_{jD}^*]$. Hence, the profit of the MNC equals,

$$\pi_D^* = \sum_{j=L,H} \left[P_{jD}^* \bar{y}_j - \frac{P_{jD}^{*2}}{s_D^*} \right] - \frac{1}{2} s_D^{*2}. \quad (7)$$

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

$$P_{jD}^* = \frac{1}{2} s_D^* \bar{y}_j, \quad j = L, H. \quad (8)$$

Substitution of (8) in (6) yields,

$$y_{jD}^* = \frac{1}{2} \bar{y}_j. \quad (9)$$

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

Lemma 1 *Under MBD, when the L-country implements a strict IPR regime, the MNC covers*

- i) each country market partially for all $\underline{y}_j < \frac{1}{2} \bar{y}_j$, $j = H, L$*
- ii) country- i market fully but country- j market partially for all $\underline{y}_i > \frac{1}{2} \bar{y}_i$ and $\underline{y}_j < \frac{1}{2} \bar{y}_j$, $i \neq j = H, L$, $\underline{y}_H \in [\frac{1}{2} \bar{y}_L, \frac{1}{2} \bar{y}_H]$.*
- iii) both markets fully for all $\underline{y}_j > \frac{1}{2} \bar{y}_j$, $j = H, L$.*

All these claims follow from the profit-maximizing choice of the extent of market coverage as specified in (9). From now, we will assume that the intra-country income disparity is sufficiently large in the sense that $\underline{y}_j < \frac{1}{2} \bar{y}_j$, $j = H, L$. Hence, at equilibrium both country markets are only partially served, because otherwise the often quoted market-access argument in favour of a weak IPR regime in the L-country does not make sense ex ante.

It is now straightforward to obtain the profit maximizing quality level:

$$s_D^* = \frac{1}{4} [\bar{y}_L^2 + \bar{y}_H^2], \quad (10)$$

3.2 Weak IPR and market based price discrimination

Under a weak IPR regime in the L-country, a local producer learns about the production technology by investing a sum F and chooses an inferior quality of the drug, $\tilde{s}_D \in [0, \tilde{s}_D^*)$, where \tilde{s}_D^* denotes the quality of the drug innovated by the MNC under the threat of imitation. We will observe that the lower price

of the imitated drug, \tilde{P} , compared to that charged by the MNC, \tilde{P}_{LD}^* induces some of the low-income buyers, who would otherwise buy the original drug, to switch to the imitated drug. This, in turn, forces the MNC to lower the price of the innovated drug. Alternatively, the MNC may deter entry by setting a limit quality, provided that it is profitable to do so. As we will see later, such a decision to deter entry depends on the level of fixed cost.

We start with the case when the imitator enters and the innovator MNC accommodates entry, given the IR and SS constraints, defined in (4) and (5), the market demand in the L-country for the imitated and innovated varieties is as follows. All consumers with income $y \in [\tilde{y}_D, \tilde{y}_{LD}^*]$ buy the imitated drug whereas all buyers with income $y \geq \tilde{y}_{LD}^*$ buy the original drug, where $\tilde{y}_D = \frac{\tilde{P}_D}{\tilde{s}_D}$ and $\tilde{y}_{LD}^* = \frac{\tilde{P}_{LD}^* - \tilde{P}_D}{\tilde{s}_D^* - \tilde{s}_D}$. Note that as a tie-breaking rule, we assume that the indifferent buyer with income \tilde{y}_D buys the original innovated drug. Hence, assuming $\tilde{y}_D > \underline{y}_L$ the demands in the low income country for the imitated and innovated drugs are $[\tilde{y}_{LD}^* - \tilde{y}_D]$ and $[\bar{y}_L - \tilde{y}_{LD}^*]$ respectively. Profit

maximization yields the following prices and the quality level for the innovator and imitator:

$$\tilde{P}_{LD}^* = \frac{1}{4} \tilde{s}_D^* \bar{y}_L, \quad (11)$$

$$\tilde{P}_{HD}^* = \frac{1}{2} \tilde{s}_D^* \bar{y}_H, \quad (12)$$

$$\tilde{P}_D = \frac{1}{14} \tilde{s}_D^* \bar{y}_L. \quad (13)$$

The above results in the following levels of innovated and imitated quality

$$\tilde{s}_D^* = \frac{1}{48} [12\bar{y}_H^2 + 7\bar{y}_L^2], \quad (14)$$

$$\tilde{s}_D = \frac{4}{7} \tilde{s}_D^*. \quad (15)$$

It is easy to check that the MNC innovates a lower quality under the threat of imitation. The reason for this is simple. The price competition from the imitator forces the MNC to lower the price of the innovated drug and since innovation is costly, it saves upon the innovation cost by innovating a lower quality. However, it is easy to prove that the lower price compensates the effect of the lowered quality resulting in greater coverage of the L-country market by the MNC, i.e., $y_{LD}^* - \tilde{y}_{LD}^* > 0$. That is, the MNC now caters to an additional $(y_{LD}^* - \tilde{y}_{LD}^*)$ number of poorer buyers whom it would exclude from the market under a stronger IPR. We summarize the results in the following lemma.

Lemma 2 *When the innovator accommodates entry under a weak IPR regime in the L-country, the threat of imitation lowers both the innovation level and the price, but raises the extent of market coverage at the low-end of the L-country market compared to a stronger IPR regime.*

Note that buyers even poorer than those served by the MNC, viz., with income $y \in [\tilde{y}_D, \tilde{y}_{LD}^*]$ can also access the drug, albeit the inferior quality imitated one.

The greater market coverage by the MNC is the competitive effect of a weak IPR regime. Of course, the above analysis presumes that it is worthwhile for the lower income country firm to enter the market and imitate the innovated drug by incurring the fixed cost. If entry occurs, the profits realized for the innovating MNC and the imitating local firm are the following:

$$\tilde{\pi}_D^* = \frac{1}{2} (\tilde{s}_D^*)^2. \quad (16)$$

$$\tilde{\pi}_D = \frac{1}{48} \tilde{y}_L^2 \tilde{s}_D^*. \quad (17)$$

For the local firm entry is worthwhile only if the cost of imitation is sufficiently low,

$$F < \bar{F}_D = \tilde{\pi}_D. \quad (18)$$

For higher fixed costs of imitation, entry is blockaded and a weak IPR regime would not pose any threat to the innovator. When entry is blockaded, the MNC innovates the same quality s_D^* as it would under a strict IPR and prices out the poorer buyers in the L-country market having income less than y_{LD}^* . However, even if entry is not blockaded it may still be profitable for the MNC strategically deter entry. Realizing that the local imitator's potential profit (obtained in (17)) varies directly with the innovated quality \tilde{s}_D^* , the MNC can innovate a lower limit quality \tilde{s}_{Dl}^* which, for any given F , deters entry by pushing the net potential profit for the local imitator to zero. From (18), using (17), such a limit quality equals,

$$\tilde{s}_{Dl}^* = \frac{48}{\tilde{y}_L^2} F. \quad (19)$$

Since in our assumed timing of decisions, the quality levels are committed (sequentially) by the innovator and the imitator *before* the prices are chosen, by innovating this entry-detering limit quality the MNC can charge the monopoly prices in the two markets in the same way as it would under a stronger IPR regime, i.e., $\tilde{P}_{jD}^l = \frac{1}{2} \tilde{s}_{Dl}^* \bar{y}_j$, $j = H, L$. Two observations are in order, which we state in the lemma that follows.

Lemma 3 *Under a [weak IPR, MBD] policy regime, if the innovator chooses to deter entry, it innovates a lower quality and charges a lower price. The quality and price declines are proportional such that the L-country market is covered to the same extent as under a strict IPR regime.*

Proof. See appendix ■

Note that, given Lemmas 2 and 3, under a [weak IPR,MBD] policy regime, market coverage in the L-country is less when the entry is deterred than when it is accommodated. This brings out the essential difference between the entry-accommodating and the entry-detering strategies. Under the entry-accommodating strategy, the MNC responds to the weak IPR regime by innovating a smaller quality but by lowering (the post entry duopoly) price more than proportionately so that it actually covers a greater fraction of the L-country market. On the other hand, under the entry-detering strategy, by committing to an even lower quality, despite lowering the (monopoly) price proportionately and thus serving the same number of buyers in the L-country as under a stronger IPR regime, the MNC squeezes the potential price-cost margin for the imitator sufficiently to make entry unprofitable for any fixed cost of imitation.

All these discussions are, however, relevant only if it is worthwhile for the MNC to deter entry. The following lemma proves that this will not be the case under the present policy regime.

Lemma 4 *Under a [weak IPR,MBD] policy regime, the innovator will always accommodate entry. On the other hand, entry is blockaded if $F > \bar{F}_D$.*

Proof. See appendix. ■

That is, if it is worthwhile for the local imitator to enter, the MNC always accommodates. Essentially, we show that entry deterrence is only worthwhile for too high a fixed cost, but, for that fixed cost the local imitator itself chooses not to enter (i.e., entry is blockaded).

3.3 Strict IPR and parallel imports

Suppose the H-country allows PI of the drug from the L-country. Arbitrage then forces the MNC to charge a uniform price P_p^* across countries. Let y_p^* denote the marginal consumers in each country market who derive zero net benefit from the menu (P_p^*, s_p^*) offered by the MNC to all potential buyers:

$$y_p^* = \frac{P_p^*}{s_p^*}.$$

As already discussed, if $y < y_p^*$, both markets are partially covered. In that case, the profit of the MNC equals,

$$\pi_p^* = P_p^* [\bar{y}_H + \bar{y}_L] - \frac{2(P_p^*)^2}{s_p^*} - \frac{1}{2}s_p^{*2}. \quad (20)$$

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

$$P_p^* = \frac{1}{4} [\bar{y}_H + \bar{y}_L] s_p^*, \quad (21)$$

resulting in indifferent consumer at

$$y_p^* = \frac{1}{4} [\bar{y}_H + \bar{y}_L]. \quad (22)$$

Note that by our earlier assumption that $\underline{y}_L < \frac{1}{2}\bar{y}_L$, the MNC serves both markets partially under PI, provided, of course, the L-country market is served at all, which requires that $3\bar{y}_L > \bar{y}_H$. In rest of our analysis, we will assume that the cross-country income disparity is not too large so that under PI the MNC serves both countries.

Under these assumptions, the innovation level is:

$$s_p^* = \frac{1}{8} [\bar{y}_H + \bar{y}_L]^2, \quad (23)$$

Note that $s_p^* < s_D^*$, which is the under-investment result of Valletti (2006): PI lower the innovation level.¹¹

3.4 Weak IPR and parallel imports

Finally, we consider the case where the L-country does not enforce a strict IPR regime and the H-country allows PI of the original drug from the L-country. Let \tilde{P}_p^* and \tilde{P}_p be the prices of the original and imitated drug, and \tilde{s}_p^* be the level of quality of the innovated drug when entry is accommodated. Proceeding as before, it is straightforward to check that, when entry is accommodated, consumers in the H and L-country having at least income levels $\tilde{y}_{Hp}^* = \frac{\tilde{P}_p^*}{\tilde{s}_p^*}$ and $\tilde{y}_{Lp}^* = \frac{\tilde{P}_p^* - \tilde{P}_p}{\tilde{s}_p^* - \tilde{s}_p}$ respectively purchase the innovation. The imitated drug, on the other hand, is bought by the consumers in the L-country having at least the income level $\tilde{y}_p = \frac{\tilde{P}_p}{\tilde{s}_p}$ (lower than \tilde{y}_{Lp}^*). Given this, the entry accommodating profit-maximizing innovated and imitated quality level equal

$$\tilde{s}_p^* = \frac{7}{96} (\bar{y}_H + \bar{y}_L)^2, \quad (24)$$

$$\tilde{s}_p = \frac{8}{11} \tilde{s}_p^*. \quad (25)$$

resulting in profit level for the innovator

$$\tilde{\pi}_p^* = \frac{1}{2} (\tilde{s}_p^*)^2. \quad (26)$$

¹¹This result has been generalized in Acharyya (2008) for all possible parametric configuration – very large, moderately large, small and very small intra-country demand dispersions – resulting in unilateral and universal partial and full market coverages as equilibrium outcomes.

Note, that once again, the level of innovation is smaller than that under a strict IPR regime (with PI), $\tilde{s}_p^* < s_p^*$. On the other hand, the local imitator enters the market for all $F < \bar{F}_p$, where \bar{F}_p is such that

$$\bar{F}_p = \tilde{\pi}_p = \frac{7}{4(48)^2} (\bar{y}_H + \bar{y}_L)^4 \quad (27)$$

under an entry-detering strategy the MNC innovates the limit quality \tilde{s}_{pl}^* such that $\tilde{\pi}_p - F = 0$:

$$\tilde{s}_{pl}^* = \frac{96}{(\bar{y}_H + \bar{y}_L)^2} F. \quad (28)$$

Lemma 5 *Under a [weak IPR,PI] policy regime, the MNC deters entry by setting a limit quality \tilde{s}_{pl}^* specified in (28) for all $F \in (F_{p,root}^*, \bar{F}_p]$. On the other hand, entry is blockaded if $F > \bar{F}_p$, and accommodated if $F < F_{p,root}^*$, where*

$$F_{p,root}^* = \left[\frac{12 - \sqrt{95}}{4(48)^2} \right] (\bar{y}_H + \bar{y}_L)^4. \quad (29)$$

Proof. See appendix. ■

Once again, imitation by a local firm lowers the profit of the MNC. However, there is one essential difference. Under MBD, although the MNC was forced to compete with the local imitator in the L-country, it could still charge monopoly price in its own country. Now, under PI, a uniform price must be charged in both the markets. Thus, the prospect of imitation lowers the MNC's profit in both markets. Setting the limit quality to deter entry would enable the MNC to charge the (non-discriminatory, uniform) monopoly price. At the same time, there are profit losses from setting the lower limit quality. This is due to the smaller market coverage compared to that under entry accommodation because the price in the L-country is raised more than proportionately. Since the magnitude of this loss varies inversely with the level of limit quality and hence with the value of F . For sufficiently large values of F , profit gains outweigh profit losses and thus entry deterrence becomes relatively profitable.

4 Policy choices

We now consider the SPNE policy choices. Each government maximizes national welfare, which is simply the sum of the domestic consumers surplus and the profit of its native firm. For the L country, the imitator's profit (net of the fixed imitation cost) matters only when a weak IPR is implemented there and entry is accommodated by the drug innovator. Otherwise, national welfare in country L is simply the domestic consumers surplus, for any given price-quality menu chosen by the innovator. For example, the national welfare levels in countries L and H when a weak IPR is implemented in the L-country and entry

is accommodated by the drug innovator are (other welfare levels can be similarly defined)

$$\widetilde{W}_{LD} - F = \int_{\widetilde{y}_{LD}^*}^{\widetilde{y}_D} (\widetilde{s}_D y - \widetilde{P}_D) dy + \int_{\widetilde{y}_D}^{\widetilde{y}_L} (\widetilde{s}_D^* y - \widetilde{P}_D^*) dy + \widetilde{\pi}_D - F, \quad (30)$$

$$\widetilde{W}_{HD} = \int_{\widetilde{y}_{HD}^*}^{\widetilde{y}_H} (\widetilde{s}_D^* y - \widetilde{P}_{HD}^*) dy + \widetilde{\pi}_D^*. \quad (31)$$

As evident from the above discussions, the level of fixed cost of imitation influences the firm strategies. The SPNE policy choices thus vary accordingly. However, we will confine ourselves to the range of fixed costs for which entry is not blockaded, i.e., it is worthwhile for the potential imitator to enter the market under a weak IPR when the MNC does not deter entry. Since $\overline{F}_D < \overline{F}_P$ for the relevant range of incomes, it is enough to assume,

$$F < \overline{F}_D. \quad (32)$$

On the other hand, although $F_{p,root}^* < \overline{F}_P$, $F_{p,root}^*$ may be greater than \overline{F}_D for some high cross-country income differences as illustrated in Figure 1.¹² In that case, given the assumption in (32), the parametric values for which $F_{p,root}^*$ is greater than \overline{F}_D will mean that the MNC will accommodate entry under both MBD and PI. Thus, (as specified in the Lemma 6 below) when the levels of highest incomes in the two countries are such that

$$F_{p,root}^* < \overline{F}_D, \quad (33)$$

we have only two distinctly different cases which we refer to in the Lemma 6 as Cases I and II. Otherwise, we have only one of these cases, or to be more precise, the case which we label below as Case II. Figure 2 provides a visual reminder of the optimal strategy of the innovator regarding entry deterrence for the different levels of fixed imitation costs.

[INSERT FIGURE 1 HERE]

[INSERT FIGURE 2 HERE]

Lemma 6 *When the L-government implements a weak IPR regime, under the assumptions (32)-(33), the relevant parametric configurations that lead to two different payoff structures of the policy game are as follows. For all F such that,*

Case I: $\overline{F}_D > F > F_{p,root}^$. The MNC accommodates entry under MBD and deters entry under PI. Thus, either \widetilde{W}_{jD} or $\widetilde{W}_{jp}(\widetilde{s}_{pl})$ $j = L, H$, are realized according as the policy choice of the H-country.*

¹²The diagram is drawn letting $t = \frac{\widetilde{y}_H}{\widetilde{y}_L}$ for the relevant range of cross-country difference is thus given by the interval $[1, 3]$ for the parameter t . For the purposes of the graphical representation, we normalize \widetilde{y}_L to unity. This does not affect any of the results.

Case II: $F_{p,root}^* > F > 0$. The MNC accommodates entry under both MBD and PI. The welfare levels realized are either \widetilde{W}_{jD} or \widetilde{W}_{jp} , $j = L, H$

Proof. Follows directly from Lemmata 2-5 and the discussions above. ■

The two cases specified in the above lemma exhaust all the possibilities regarding the implications of the policy game between the governments, irrespective of how large the cross-country income differences are within the limit for which both the markets are served by the MNC. Note that $F < F_{p,root}^* < \overline{F}_D$ would correspond to Ichino's (2004) policy game, extended to endogenous innovation decision. Figure 3 represents the payoff matrix for countries to summarize the notation for all the possible welfare levels under Lemma 6. Table 2 provides the expressions for each of those welfare levels. By simply comparing the different welfare levels we immediately obtain the results that follow in the paper.¹³

[INSERT FIGURE 3 HERE]

Lemma 7 Under MBD, the L-country unambiguously gains from weak IPR whereas the H-country unambiguously loses.

It is straightforward to prove that $\widetilde{W}_{LD} - \overline{F}_D > W_{LD}$. Since the net welfare is monotonically decreasing in F and the least value in the relevant range is $\widetilde{W}_{LD} - \overline{F}_D$, then,

$$\widetilde{W}_{LD} - F > W_{LD} \quad \forall F \in [0, \overline{F}_D]. \quad (34)$$

It is also straightforward to prove that

$$\widetilde{W}_{HD} < W_{HD}. \quad (35)$$

The gain from a weak IPR regime when entry is accommodated comes from two sources. First, it is the greater market coverage: the MNC caters for some poorer consumers whom it would not cater for under a stronger IPR, and the even poorer buyers, who can still not buy the original drug, can now buy the low-priced imitated drug. Second, it is the decline in the price of the original drug for all other buyers, which being more than proportional to a lower quality of the original drug, raises the net surplus for all infra-marginal buyers. This is an interesting result which provides a theoretical justification for the poorer countries' reluctance to implement strict IPR regime.

However, the welfare of the H-country is strictly lower under a weak IPR because imitation lowers profit of the MNC and also welfare of the consumers in the H-country because of the lower innovated quality. The price decline cannot compensate the buyers in the H-country for the lower quality as it does in the L-country because the buyers there have a higher marginal willingness to pay for higher quality.

¹³The details of calculations and plotting of expressions for the different welfare expressions, using the whole range of relevant parameters, can be obtained from the authors upon request.

Lemma 8 *Under strict IPR, the L-country unambiguously gains from MBD whereas the H-country unambiguously loses.*

Note that the quality of the innovated drug is now lower whereas the (uniform) price is higher than the discriminatory price charged to buyers in the L-country. Thus, whereas some low-income buyers in the L-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 for the L-country. On the other hand, the source of gain from PI for the H-country is the price reduction and the consequent greater market coverage since by (9) and (22), $y_H^* - y_p^* = \frac{1}{4} [\bar{y}_H - \bar{y}_L] > 0$. As shown in Figure 4, this is large enough to outweigh the welfare losses arising out of lower innovation and lower profit for its MNC. This welfare result captures the popular belief that PI benefit only the richer countries.

[INSERT FIGURE 4 HERE]

We can now examine SPNE policy choices for each possible level of fixed costs already referred to as Case I and Case II. The following proposition summarizes our results:

Proposition 1 *In the above policy game, there are two SPNE policy choices – (Strict IPR, PI) and (weak IPR and MBD) – for high fixed costs of imitation (Case I: $\bar{F}_D > F > F_{p,root}^*$) for which entry is deterred under PI when a weak IPR regime is implemented in the L-country. For low fixed cost of imitation (Case II: $F_{p,root}^* > F > 0$) for which entry is accommodated under PI, (weak IPR and MBD) emerge as the unique SPNE policy choices.*

First, in Case I, it can be checked that (Strict IPR, PI) is a SPNE policy regime. To see this, first of all note from Lemma 8 that when the L-country implements a strict IPR regime, allowing PI is the best strategy for the H-country. On the other hand, note that $\bar{W}_{Lp}(\tilde{s}_{pl})$ is monotonically increasing in the fixed cost of imitation (see Table 2) and is strictly less than W_{Lp} for F close to \bar{F}_p . For $F = \bar{F}_p$, entry is blocked so that essentially the weak IPR regime with entry deterrence boils down to the strict IPR regime. But, as F falls below \bar{F}_p , entry is feasible, and the MNC deters entry by the limit quality which is strictly lower than the innovation level under strict IPR with PI. As argued earlier in Lemma 3, it also lowers its (discriminatory) monopoly price but only proportionately to cover the L-country market to the same extent as it would under a stronger IPR. Thus, the market coverage under a weak IPR (with entry deterrence) is the same as that under a stronger IPR when the H-country allows PI. But the lower quality reduces welfare more than the lower price raises it for the infra-marginal buyers because they have successively greater marginal willingness-to-pay for higher qualities. That is, lower innovation hurts these buyers more than lower price benefits them. Overall the welfare falls below

what the L-country could get under a stronger IPR. Moreover, this net welfare loss is successively higher, the smaller is the level of fixed cost of imitation. Hence,

$$\widetilde{W}_{Lp}(\widetilde{s}_{pl}) < W_{Lp} \forall F < \overline{F}_D. \quad (36)$$

Thus, the L-country should choose a strict IPR regime when the H-country allows PI. This makes (Strict IPR and PI) a SPNE policy pair.

Second, still in Case I, strict IPR is not a strictly dominant strategy for the L-country government because by Lemma 7, country L's welfare is higher under weak IPR when the H-country chooses MBD. In addition, it is possible to prove that $\widetilde{W}_{HD} > \widetilde{W}_{Hp}(\widetilde{s}_{pl})$. Figure 5 illustrates how this indeed holds.¹⁴ Hence, (weak IPR and MBD) is also a SPNE in case I. This is an interesting but not counter-intuitive result. Implementing a weak IPR is worthwhile for the L-country when the H-country chooses MBD because entry of the local imitator is not deterred by the MNC in this subcase. And given the potential threat of imitation (because it is not worthwhile for the MNC to deter entry), the H-country government realizes that the full benefits of PI cannot be obtained. Thus, the threat of imitation induces the H-country to allow MBD which though lowers the market coverage in the H-country, results in higher innovation and therefore, improved health-care quality. But, if the H-country can eliminate the threat of imitation by ensuring implementation of a stronger IPR regime, then the full benefits of PI can be realized (despite a lower innovation level) and allowing PI is chosen over MBD, resulting in the other SPNE. These multiple SPNE brings out the conflicting interests of the developing and the developed world in implementing TRIPS. The implementation of strict IPR is not a unique optimum choice of the low-income countries. But if this is no longer a policy choice for them as a consequence of WTO commitments, then it is in the best interest of the richer countries like the EU and Japan to allow PI through regional or international exhaustion of patent rights.

[INSERT FIGURE 5 HERE]

Now, consider Case II where entry of a local imitator under a weak IPR regime in the L-country is always accommodated by the MNC regardless of whether the H-country allows PI or not. First of all, note that since now the MNC accommodates the local imitator, when the H country chooses PI, there is scope for welfare gain for the L-country from a weak IPR. Though under a weak IPR the MNC lowers its innovation level compared to that under a stronger IPR (i.e., $\widetilde{s}_p < s_p$), by Lemma 4, it covers a larger market in the L-country. The buyers who would have purchased the drug even under a stronger IPR (i.e., those with income y_p^* and higher) would lose no doubt because their higher marginal willingness to pay for a higher quality means that they are hurt more

¹⁴In Figure 5, we actually use a sufficient condition. As $\widetilde{W}_{Hp}(\widetilde{s}_{pl})$ reaches a maximum at F'' , it is enough to show that $z = \widetilde{W}_{HD} - \widetilde{W}_{Hp}(\widetilde{s}_{pl}) \Big|_{F=F''} > 0$ for the whole range of incomes.

by the lower innovation than they are benefitted from the price decline. But the poorer buyers who are now served by the MNC (i.e., those with income higher than \hat{y}_p^* but lower than y_p^*) will unambiguously gain. The other two sets of agents who gain from implementation of a weak IPR when the H-country chooses PI, are those who buy the imitated drug and the local imitator itself as it earns strictly positive (net) profit. Thus, we can expect an overall welfare increase unless the welfare loss from lower innovation is too large. It can be checked, however, that for the relevant range of fixed costs, viz. $F \in [0, F_{p,root}^*]$, and for all relevant range of cross-country income differences, the L-country unambiguously gains from the weak IPR when the H-country allows PI. That is, the welfare loss from lower innovation is outweighed by the gains.

This welfare ranking rules out (strict IPR, PI) as a SPNE in case II since weak IPR is now a strictly dominant strategy for the L-country (similar to what Ichino (2004) observed). Therefore, the existence of a SPNE in this case II boils down to the best-response of the H-country when a weak IPR is implemented in the L-country. A simple comparison of welfare levels for the relevant range of parameters shows that the H-country gains from allowing MBD instead of PI when the L-country implements a weak IPR regime, hence (weak IPR and MBD) emerges as the unique SPNE policy regime.

The nature of SPNE policy choices, multiple or unique, reveals an interesting feature: Entry deterring limit quality is never realized at the SPNE. Because, the threat of entry deterrence makes a weak IPR regime suboptimal for the L-country regardless of whether the H-country chooses MBD or PI, and thus forces it to implement a stronger IPR regime whenever it is relatively profitable for the MNC to deter entry by innovating a limit quality.

5 Discussions

In this section we discuss, first, the welfare and efficiency properties of the two SPNE policy choices derived above, and second, a special case of the above policy game where the choice of the L-government is over allowing and not allowing compulsory licensing. We also briefly discuss how our results may change if there is a transport cost in parallel trading that prohibits full convergence of prices across countries.

5.1 Properties of SPNE policy choices

What appears from Proposition 1 is that the obligations of countries as members of the WTO to implement the TRIPS has two implications. First, in the context of multiple SPNE – (Strict IPR, PI) and (Weak IPR, MBD) – as in Case I, TRIPS is essentially an instrument of equilibrium selection. Second, when (Strict IPR, PI) is not a SPNE, such as in case II, TRIPS enforces policy regimes which would not have been (non-cooperatively) chosen by the countries. Under these circumstance, it is interesting to compare the efficiency and welfare properties of (Strict IPR, PI) being enforced by the TRIPS with the other SPNE

policy choice. We make comparisons of the two SPNE policy choices in terms of four key variables: the extent of market coverage, the level of innovation, national welfare levels, and global welfare level (Tables 1 and 2 summarize equilibrium quality, price and welfare levels).

First, it is readily verifiable that the MNC covers a smaller segment of the L-country market and a larger segment of the H-country market at the (strict IPR, PI)-SPNE than at the (weak IPR, MBD)-SPNE.¹⁵ Moreover, the buyers in the L-country even poorer than \tilde{y}_{LD}^* can also buy the drug, albeit the imitated one, at the (weak IPR, MBD)-SPNE.

Second, recall that under MBD, the threat of imitation and ensuing competition with the local imitator induces the MNC to innovate a lower quality. Also, under a strict IPR, price arbitrage has similar adverse innovation effect. However, whether imitation has a stronger disincentive for innovation compared to that of PI or not when both policies are combined depends on the cross-country income disparity. It can be checked that, for cross-country income differences sufficiently large in the sense that $\bar{y}_H > 1.8\bar{y}_L$, innovation level is higher at the (Weak IPR, MBD)-SPNE than under (Strict IPR, PI).

Turning to the national welfare levels, recall that we have already established that the L-country unambiguously loses at the (strict IPR, PI)-SPNE compared to the other SPNE (see equation (36)). For the H-country, on the other hand, welfare increases at the WTO-compliant SPNE, i.e., $\widetilde{W}_{HD} < W_{Hp}$. Finally, it is possible to prove that the total or global welfare under a (strict IPR, PI) is unambiguously lower than that under (weak IPR, MBD). Thus, the WTO-compliant SPNE is not even globally welfare improving over the other SPNE.

These results clearly bring out the implications of enforcing the (strict IPR, PI)-SPNE through member countries' obligation to implement the TRIPS. More precisely,

Proposition 2 *In the above context, implementation of a strict IPR regime by WTO commitments make the poor country unambiguously worse off in terms of both market coverage and national welfare. The level of innovation may be lower as well when cross country income disparity is large enough in the sense defined above. The rich country unambiguously gains but the welfare gain is smaller than the welfare loss suffered by the poor country.*

To prove the above it is sufficient to note that when the L-country implements strict IPR regime under WTO commitment, the H-country chooses PI. Thus, WTO commitments enforce (Strict IPR, PI) regime regardless of whether it is a SPNE policy regime or not.

Indeed it is also possible to prove that (weak IPR, MBD) results in the highest level of global welfare relative to all the other possible policy regimes (subgame perfect or not).

There is an interesting link to the empirical work of Chaudhuri et al. (2006).

¹⁵Simply note that $y_P = \frac{1}{4}(\bar{y}_L + \bar{y}_H) > \frac{5}{12}\bar{y}_L = \tilde{y}_{LD}^*$ and $y_P = \frac{1}{4}(\bar{y}_L + \bar{y}_H) < \frac{1}{2}\bar{y}_H = \tilde{y}_{HD}^* = y_{HD}^*$.

In our paper, introduction of TRIPS under PI implies an increase in the price of the MNC product being sold abroad of around 343% under price arbitrage (this increase is consistent with Chaudhuri, Goldberg and Jia (2006)). The introduction of TRIPS under MBD would generate a lower increase in prices. However, even for the biggest income difference allowed in our model the price increase would be around 278%. However, for us the most relevant price comparison is that between the two SPNE outcomes: (Strict IPR, PI) and (Weak IPR, MBD). It is possible to prove that this will most likely lead to the highest price increases.

5.2 Compulsory licensing versus parallel imports

In this section we examine CL as an alternative to allowing imitation. A large number of countries had allowed CL in the pre-TRIPS era and a strong case has often been made in favour of its continuation under the new IPR regime [Correa (2000b)]. Given this perspective, suppose instead of the choice over a stronger and a weak IPR regime, the L-country has a choice over allowing or not allowing a CL. The important difference is regarding the profit of the local firm in the developing country and consequently the welfare of the L-country. The local firm with CL can now produce the patented drug without incurring any significant development cost, F . But it has to pay a royalty to the local authority which is then transferred to the patent holder. Suppose, as a benchmark case, the royalty is a fixed sum, R , decided by the L-country government. The innovator's net profit under CL equals $\tilde{\pi}_D^* + R$ or $\tilde{\pi}_p^* + R$ whereas the local firm's profit equals $\tilde{\pi}_D - R$ or $\tilde{\pi}_p - R$ according as the H-country does not and does allow PI. For the L-country government, the choice now is not just over whether to provide CL to the local firm or not, but also over the royalty amount. By Lemma 3 and 4, it is immediate that in case the L-country government provides CL, it would set the royalty levels below \bar{R}_i , $i = D, p$, where \bar{R}_i is such that $\tilde{\pi}_i = \bar{R}_i$. Note that given Propositions 1 and 2 above, the L-government can ensure a higher welfare level by setting any royalty less than $F_{p,root}^*$. However, since $\frac{\partial W_L}{\partial R} < 0$, so the L-government will set $R = 0$. The policy game thus boils down to case II discussed above with (CL, MBD) as the unique SPNE policy choice.

5.3 Transport Costs

Transport costs will prevent price equalization even under PI. Following the iceberg model of transport costs, suppose a δ fraction of output is lost in transit. Thus, per unit of the drug parallelly imported δP revenue is lost. To make up for this, the parallel exporters would charge $(1 + \delta)P$. This enables the MNC to charge $(1 + \delta)P$ in the H-country and P in the L-country for the innovated drug. This will increase the MNC's profits and innovated quality under PI. If transport cost are high enough the PI and MBD cases would be the same.

Since entry is deterred by the innovator only under PI, and profit level of the innovator under PI rises with the transport cost in PI and approaches to the profit level under MBD, we can expect entry being accommodated even under

PI for a high enough transport cost. This will mean a higher welfare for the L-country.

For consumers in the H-country two opposing effects would be at work: price decline under PI (compared to MBD) would be less but quality reduction would be less as well. There would be a critical δ^* for which $(1 + \delta^*)P_L^D = P_H^D$. Thus, the H-country will benefit from allowing PI only if the transport cost is not too high: $\delta < \delta^*$.

6 Conclusion

We have examined a policy game between a low-income and a high-income country over patent protection and international exhaustion of patent rights (or parallel imports) of an on-patent drug. The policy choices are shown to depend on the level of fixed cost of imitation by a local firm in the low-income country. For a moderately high fixed cost for which entry is not blockaded but is deterred under PI when the low-income country implements a weak IPR, both (Strict IPR, PI) and (Weak IPR, MBD) emerge as the SPNE policy choices. In such a context, the WTO commitment to implement a strict IPR regime appears as a mechanism for equilibrium selection as it enforces the (Strict IPR, PI). The low-income country, however, suffers a welfare loss from implementation of such a SPNE policy regime, which is even larger than the welfare gain for the high-income country. For relatively smaller fixed cost, (Weak IPR, MBD) emerges as the unique SPNE policy choice, because now that the MNC always accommodates the local imitator, it is worthwhile for the low-income country to implement a weak IPR regardless of the policy choice of the high-income country.

Our paper contains a number of simplifying assumptions. To obtain closed-form solutions needed to calculate welfare levels, we have considered a functional form for net utility which is separable in quality and price. This, like other specific functional forms, has its own limitations. We also linearize the correlation between income level and marginal willingness-to-pay. Our results should hold qualitatively for any other specific form of the utility function, as long as net utility is additively separable in quality and price, which has been widely used in the vertical differentiation literature. In addition we assume that production costs are zero, this is also a commonly used assumption in the literature and it fits our model objectives as we want to focus in the firms different ability to innovate rather than production costs.

The way in which we model innovation aims to capture the pharmaceutical sector. We assume that entry in the imitation sector is restricted, this follows from our observations of the Indian pharmaceutical sector. Imitation can happen at any level below the innovated drug's quality but, there is an exogenous fixed cost involved in designing an imitation and leapfrogging is not possible as it involves a technology not available to the imitator. The robustness of our results needs to be examined with respect to endogeneity of imitation cost, which constitutes our future research agenda. Free entry into imitation sector

could be another area of our future research. However, as long as the quality choice is endogenous for both quality followers as well as innovators, we do not expect entry to be significant [see Shaked and Sutton (1982)]. An alternative could be to assume that the imitative sector acts as a competitive fringe and that the fixed cost of imitation is zero, however this would seem to be a better fit for modelling the competition between branded drugs and generic competitor, which is not what we are aiming to capture in the present paper.

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Appendix

Proof of Lemma 3

Since, the limit quality is monotonically increasing in F , it is sufficient to show that $\tilde{s}_{Dl}^*(\bar{F}_D) = \tilde{s}_D^*$. Using (17) and (18),

$$\tilde{s}_{Dl}^*(\bar{F}_D) = \frac{1}{48} [12\bar{y}_H^2 + 7\bar{y}_L^2] = \tilde{s}_D^*. \quad (\text{A.1})$$

On the other hand, denoting the indifferent income under entry deterrence by \hat{y}_{LD}^* , we get,

$$\hat{y}_{LD}^* = \frac{\tilde{P}_{LD}^l}{\tilde{s}_{Dl}^*} = \frac{1}{2}\bar{y}_L = y_{LD}^*. \quad (\text{A.2})$$

Hence the claim.

Proof of Lemma 4

The profit that is realized for the MNC from the entry-detering strategy equals

$$\tilde{\pi}_{Dl}^* = \frac{48}{\bar{y}_L^2} \left[\frac{1}{4} (\bar{y}_L^2 + \bar{y}_H^2) F - \frac{24}{\bar{y}_L^2} F^2 \right]. \quad (\text{A.3})$$

Note that $\tilde{\pi}_{Dl}^* = 0$ for $F = \tilde{F}_D$:

$$\tilde{F}_D = \frac{1}{96} \bar{y}_L^2 (\bar{y}_L^2 + \bar{y}_H^2). \quad (\text{A.4})$$

Also note that $\tilde{\pi}_{Dl}^*$ reaches a maximum for $F = \hat{F}_D = \frac{1}{192} (\bar{y}_L^2 + \bar{y}_H^2) \bar{y}_L^2 = \frac{1}{2} \tilde{F}_D$. Also note that $\hat{F}_D > \bar{F}_D = \frac{\bar{y}_L^2}{192} [\bar{y}_H^2 + \frac{7}{12} \bar{y}_L^2]$. It follows that $\tilde{F}_D > \hat{F}_D >$

\bar{F}_D . Therefore, $\tilde{\pi}_{Dl}^*$ is monotonically increasing in F in the relevant range, i.e., for all $F < \bar{F}_D$. On the other hand, the maximum profit of the MNC under entry-detering strategy equals,

$$\tilde{\pi}_{Dl}^*(\hat{F}_D) = \frac{1}{32} (\bar{y}_L^2 + \bar{y}_H^2). \quad (\text{A.5})$$

Let F_D^* be such that $\tilde{\pi}_D^* = \tilde{\pi}_{Dl}^*(F_D^*)$. Recalling the profit levels under the entry accommodating and deterring strategies, we get

$$\frac{1152}{\bar{y}_L^4} F_D^{*2} - \frac{12(\bar{y}_L^2 + \bar{y}_H^2)}{\bar{y}_L^2} F_D^* - \frac{1}{8} \left[\bar{y}_H^2 + \frac{7}{12} \bar{y}_L^2 \right]^2 = 0, \quad (\text{A.6})$$

which solves for the two roots as:

$$F_{D,root}^* = \frac{\bar{y}_L^2}{192} \left[(\bar{y}_L^2 + \bar{y}_H^2) \pm \sqrt{(\bar{y}_L^2 + \bar{y}_H^2)^2 - \left[\bar{y}_H^2 + \frac{7}{12} \bar{y}_L^2 \right]^2} \right]. \quad (\text{A.7})$$

It can be checked that the smaller root is higher than \bar{F}_D . Hence, it is not worthwhile for the MNC to deter entry for all $F < \bar{F}_D$.

Proof of Lemma 5

It is readily verifiable that the MNC's profit under the entry-detering strategy

$$\tilde{\pi}_{pl}^* = 12F - \frac{(96)^2}{2(\bar{y}_H + \bar{y}_L)^4} F^2. \quad (\text{A.8})$$

is U shaped and monotonically increasing in the relevant range of fixed cost of imitation by the local firm, viz. for all $F \leq \bar{F}_p$.

$$\frac{\partial \tilde{\pi}_{pl}^*}{\partial F} > 0 \quad \forall F < \hat{F}_p = \frac{(\bar{y}_H + \bar{y}_L)^4}{16(48)}. \quad (\text{A.9})$$

But, $\hat{F}_p > \bar{F}_p$, which can be checked by recalling the value of \bar{F}_p from (27) in the text:

$$\hat{F}_p - \bar{F}_p = \frac{(\bar{y}_H + \bar{y}_L)^4}{16(48)} - \frac{7}{4(48)^2} (\bar{y}_H + \bar{y}_L)^4 > 0. \quad (\text{A.10})$$

Thus, $\frac{\partial \tilde{\pi}_{pl}^*}{\partial F} > 0 \quad \forall F < \bar{F}_p$. Moreover, $\tilde{\pi}_{pl}^*(\bar{F}_p) = \frac{144}{2(96)^2} (\bar{y}_H + \bar{y}_L)^4 > \tilde{\pi}_p^* > \tilde{\pi}_{pl}^*(0)$. Hence, as long as $\tilde{\pi}_{pl}^*(F)$ is continuous, there are two values of F such that $\tilde{\pi}_{pl}^*(F_{p,root}^*) = \tilde{\pi}_p^*$. But, only the smaller root is smaller than \bar{F}_p . From (A.8) and (26), we obtain the equation that defines such value:

$$F_{p,root}^* = \left[\frac{12 - \sqrt{95}}{4(48)^2} \right] (\bar{y}_H + \bar{y}_L)^4. \quad (\text{A.11})$$

Hence, for the relevant range of fixed costs, viz., $F \leq \bar{F}_p$, only the smaller root of $F_{p,root}^*$ is relevant such that given (A.9), $\tilde{\pi}_{pl}^*(F) > \tilde{\pi}_p^* \quad \forall F \in (F_{p,root}^*, \bar{F}_p]$. It can also be verified that $F_{p,root}^* < \bar{F}_p$ and $\bar{F}_D < \bar{F}_p$.

Policy regime	innovated quality	price in country L
strictIPR, MBD	$s_D^* = \frac{1}{4} [\bar{y}_L^2 + \bar{y}_H^2]$	$P_{jD}^* = \frac{1}{2} s_D^* \bar{y}_j$
weakIPR, MBD	$\tilde{s}_D^* = \frac{1}{48} [12\bar{y}_H^2 + 7\bar{y}_L^2]$	$\tilde{P}_{LD}^* = \frac{1}{4} \tilde{s}_D^* \bar{y}_L$
strictIPR, PI	$s_p^* = \frac{1}{8} [\bar{y}_H + \bar{y}_L]^2$	$P_p^* = \frac{1}{4} [\bar{y}_H + \bar{y}_L] s_p^*$
weakIPR, PI (I) DETERRENCE	$\tilde{s}_{pl}^* = \frac{96F}{(\bar{y}_H + \bar{y}_L)^2}$	$\tilde{P}_p^*(\tilde{s}_{pl}^*) = \frac{24F}{(\bar{y}_H + \bar{y}_L)}$
weakIPR, PI (II) ACCOMMODATION	$\tilde{s}_p^* = \frac{7}{96} (\bar{y}_H + \bar{y}_L)^2$	$\tilde{P}_p^*(\tilde{s}_p^*) = \frac{7}{768} (\bar{y}_H + \bar{y}_L)^3$

Table 1: Price and quality outcomes.

Policy regime	Country H's welfare	Country L's welfare
strictIPR, MBD	$W_{HD} = \frac{2\bar{y}_H + \bar{y}_L^2 (\bar{y}_L^2 + \bar{y}_H^2)}{32}$	$W_{LD} = \frac{\bar{y}_L^2 [\bar{y}_L^2 + \bar{y}_H^2]}{32}$
weakIPR, MBD	$\tilde{W}_{HD} = \frac{24\bar{y}_H^2 + 7\bar{y}_L^2 (12\bar{y}_H^2 + 7\bar{y}_L^2)}{(48)(96)}$	$\tilde{W}_{LD} - F = \frac{73 [12\bar{y}_H^2 + 7\bar{y}_L^2] \bar{y}_L^2}{144} - F$
strictIPR, PI	$W_{Hp} = \frac{11\bar{y}_H^2 + 3\bar{y}_L^2 - 2\bar{y}_H \bar{y}_L (\bar{y}_H + \bar{y}_L)^2}{256}$	$W_{Lp} = \frac{3\bar{y}_L - \bar{y}_H)^2 (\bar{y}_H + \bar{y}_L)^2}{256}$
weakIPR, PI (I)	$\tilde{W}_{Hp}(\tilde{s}_{pl}) = \frac{96F \left[\frac{13\bar{y}_H^2 + 2\bar{y}_H \bar{y}_L + 5\bar{y}_L^2}{32} - \frac{108}{(\bar{y}_H + \bar{y}_L)^2} F \right]}{(\bar{y}_H + \bar{y}_L)^2}$	$\tilde{W}_{Lp}(\tilde{s}_{pl}) = \frac{3(3\bar{y}_L - \bar{y}_H)^2}{(\bar{y}_H + \bar{y}_L)^2} F$
weakIPR, PI (II)	$\tilde{W}_{Hp} = \frac{7[161\bar{y}_H^2 - 14\bar{y}_H \bar{y}_L + 17\bar{y}_L^2] (\bar{y}_H + \bar{y}_L)^2}{8(48)(96)}$	$\tilde{W}_{Lp} - F = \frac{7[9\bar{y}_H^2 - 30\bar{y}_H \bar{y}_L + 153\bar{y}_L^2] (\bar{y}_H + \bar{y}_L)^2}{8(48)(96)} - F$

Table 2: Welfare levels.

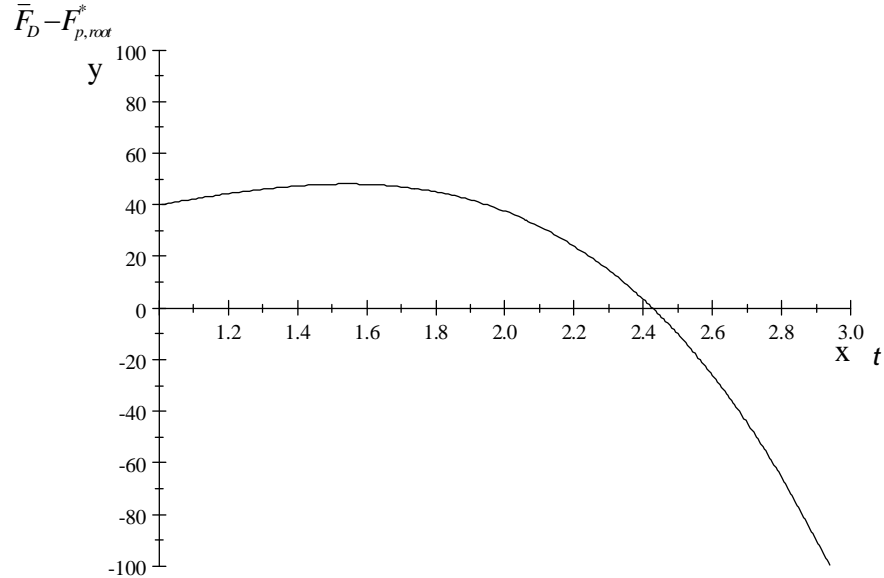


Figure 1: Comparison of critical fixed costs ($t = \frac{\bar{y}_H}{\bar{y}_L}, \bar{y}_L = 1$).

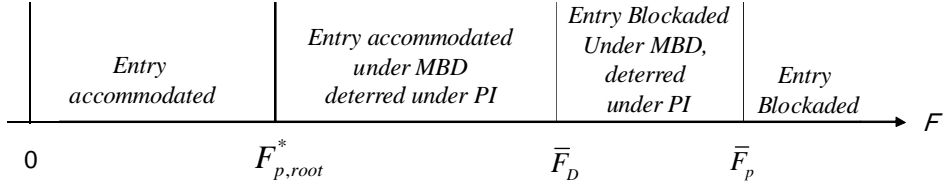


Figure 2: Entry conditions for different entry costs.

Cases	Range of Fixed Costs	Payoff Matrix Strategy Sets: L: Strict IPR, Weak IPR; H: MBD, PI				
Case I	$F_{p,root}^* < F < \bar{F}_D$	<table border="1"> <tr> <td>W_{LD}, W_{HD}</td> <td>W_{Lp}, W_{Hp}</td> </tr> <tr> <td>$\tilde{W}_{LD} - F, \tilde{W}_{HD}$</td> <td>$\tilde{W}_{Lp}(\tilde{s}_{pl}), \tilde{W}_{Hp}(\tilde{s}_{pl})$</td> </tr> </table>	W_{LD}, W_{HD}	W_{Lp}, W_{Hp}	$\tilde{W}_{LD} - F, \tilde{W}_{HD}$	$\tilde{W}_{Lp}(\tilde{s}_{pl}), \tilde{W}_{Hp}(\tilde{s}_{pl})$
W_{LD}, W_{HD}	W_{Lp}, W_{Hp}					
$\tilde{W}_{LD} - F, \tilde{W}_{HD}$	$\tilde{W}_{Lp}(\tilde{s}_{pl}), \tilde{W}_{Hp}(\tilde{s}_{pl})$					
Case II	$F < F_{p,root}^*$	<table border="1"> <tr> <td>W_{LD}, W_{HD}</td> <td>W_{Lp}, W_{Hp}</td> </tr> <tr> <td>$\tilde{W}_{LD} - F, \tilde{W}_{HD}$</td> <td>$\tilde{W}_{Lp} - F, \tilde{W}_{Hp}$</td> </tr> </table>	W_{LD}, W_{HD}	W_{Lp}, W_{Hp}	$\tilde{W}_{LD} - F, \tilde{W}_{HD}$	$\tilde{W}_{Lp} - F, \tilde{W}_{Hp}$
W_{LD}, W_{HD}	W_{Lp}, W_{Hp}					
$\tilde{W}_{LD} - F, \tilde{W}_{HD}$	$\tilde{W}_{Lp} - F, \tilde{W}_{Hp}$					

Figure 3: The policy game (assuming $F < \bar{F}_D$ and $F_{p,root}^* < \bar{F}_D$).

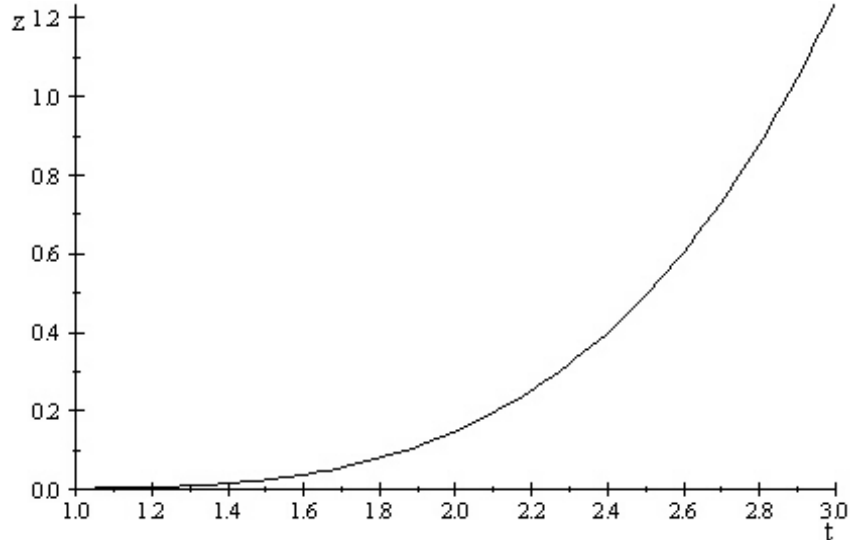


Figure 4: $z = \tilde{W}_{HD} - \tilde{W}_{Hp}$.

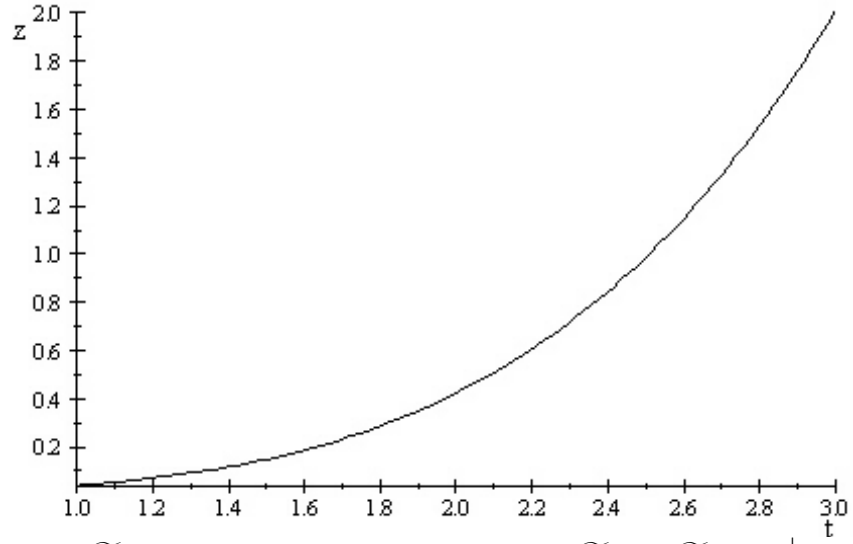


Figure 5: $\widetilde{W}_{Hp}(\widetilde{s}_{pl})$ reaches a maximum at F'' , $z = \widetilde{W}_{HD} - \widetilde{W}_{Hp}(\widetilde{s}_{pl}) \Big|_{F=F''}$. .