Weak IPR and imitation in the south and international exhaustion of patent rights in the north for innovated drugs: a policy game*

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April 16, 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, Parallel Imports) 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), 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: Patent Protection; TRIPS; Innovation; Imitation; 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 the Departments of Economics at the University of Birmingham, UK, and University of Kent, and Centre for Studies in Social Sciences, Kolkata for their comments and suggestions on an earlier version of the paper. The usual disclaimer applies, however.

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1 Introduction

The trade-related aspects of intellectual property rights (TRIPS) agreement is binding on all the member countries of the World Trade Organization (WTO). However, over the last two decades, implementation of TRIPS by developing countries, particularly for the pharmaceutical products, has been fiercely debated and politically contested. Such debate has often been linked to the desirability of allowing pharmaceutical companies to implement price discrimination across countries by prohibiting parallel imports of drugs. *This paper considers 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 equilibrium government policies and their welfare properties, along with their implications for the level of innovation of the drug, are analyzed.* **(I HAVE MOVED THIS)**

The main argument in favour of TRIPS is that it will accelerate innovations of drugs and therefore improve the quality of health care which will benefit developing and developed countries alike. However, whatever little evidence can be gathered does not seem to suggest that TRIPS will have any significant positive impact on innovation in the developing world [Primo Braga (1990)]. *This is because not only investments in basic R&D and costs of full development of a commercial drug are very high, but also most of the developing countries,* ***with notable exceptions like India (*****TAKE THIS OUT THE FOOTNOTE SEEMS TO SUGGEST OTHERWISE AND IT DOES NOT SUPPORT OUR CASE ANYWAY*****)***, *lack the technological capability and skill to undertake basic R&D [Lall (2003)].*[1]**(IN THE FOOTNOTE I WOULD JUST PUT THE REFERENCES)** Developing countries argue that TRIPS implementation will lead to closing down of business for a significantly large number of firms operating in the developing countries and loss of market access for the poor patients as a consequence of monopoly pricing of drugs by the patent-holder multinational corporations (MNCs). *There are two primary stakeholders in this argument. First are the small and medium pharmaceutical firms in India, China and Brazil, in particular, which under their weak IPR regimes have specialized in imitation and development of new processes of producing drugs innovated in the developed world. The second are the poor patients not only in these countries but also in Asia, Latin America and sub-Saharan Africa who benefited from cheap imports of such drugs from India, China and Brazil.***(I WOULD EITHER FOOTNOTE THIS OR TAKE OUT)**

Interestingly, the possibility of cross-country price discrimination by patent-holder MNCs under TRIPS has raised similar concerns of accessibility to new

[1] Chadha (2008) observes that the nature of R&D even in India is mostly adaptive rather than basic. The other notable feature is that although a few large Indian pharmaceutical firms have developed new molecules, they have then licensed them out at the initial stages of clinical development to the MNCs in the West. Thus, the benefits from such R&D remain far below the potential. On the other hand, based on a case study of 40 bio-pharmaceutical firms in India, Ramani and Maria (2005) observes that TRIPS is unlikely to have any incentive for local firms to become first innovators.

drugs for the poor in the rich world as well. To address these concerns, the WTO now allows countries to implement their own rules of exhaustion of patent rights once an on-patent drug is marketed. *Under Article Six of TRIPS, countries can allow parallel imports (henceforth, PI) of an on-patent drug from the low-priced low-income countries without the permission of the patent-holder MNC.***(I WOULD PUT IN FOOTNOTE)** *Understandably, however, a wide variation in the national rules for exhaustion among the rich countries is observed.*[2] *Whereas Japan allows international exhaustion and the EU allows regional exhaustion of patented goods, USA allows only national exhaustion of patents and copyrights to protect the interests of their MNC-exporters.***(I WOULD TAKE OUT, IT DOESN'T RELATE TO OUR MODEL I THINK.)**

This has given an interesting twist to the IPR regime for pharmaceutical *and other* products.[3]**(AGAIN, I WOULD FOOTNOTE OR TAKE OUT, IT DOESN'T RELATE TO OUR MODEL)** Whereas product patent *under a strict IPR***(WE HAVE NOT DEFINED WHAT THIS IS YET, I WOULD TAKE OUT)** regime may deny market access for the poor in the developing countries, the situation is apprehended to be worsened further by parallel imports allowed by the rich countries to ensure market access for the poor in their own countries. *The reason is simple. Parallel imports of on-patent drugs from low-income countries will lead to convergence of country-specific prices of drugs and thus the poor (as well as the rich) in the low-income countries will be worse-off .* [4] *At the extreme, the MNC may not cater to the poor countries at all [Malueg and Schwartz (1994)].***(I WOULD SHORTEN AND FOOTNOTE, THE IMPLICATION SEEMS CLEAR ENOUGH)** *There have been, therefore, oppositions to rich countries implementing international exhaustion of patent rights. Thus, national interests have not only differed among the rich countries, but also across the rich and poor countries.***(I WOULD TAKE THIS OUT SINCE AS THERE IS ONLY ONE TYPE OF RICH COUNTRY IN OUR MODEL)**

What appears is that benefits of TRIPS – *both product patent and flexible clauses and exceptions like PI*– **(TAKE OUT)** are neither unequivocal nor uniform across nations, and ensuring market access for poor patients is the common element in both not implementing a strict IPR (i.e., not allowing product patent) and allowing PI.

Since PI adversely affects innovation as shown by Valletti (2006) of late, there has been an equally interesting conflict between a strict IPR and allowing PI in terms of generating incentives for innovation. The relevant issue that crops up in these perspectives is that can these conflict of interests in co-

[2] See Maskus (2001).

[3] International exhaustion of patent rights has been applied in a wide range of products apart from the pharmaceutical products.

[4] The general theoretical consensus is that price convergence makes the richer countries unambiguously better off but the poorer countries unambiguously worse-off (Danzon (1998), Maskus (2001), Richardson (2002)).

implementing these two policies be resolved in terms of national welfare levels that incorporate effects of these policies on both the market access for poorer buyers and the innovation of drugs and health care? Alternatively, if strict and weak IPR regimes in developing world and the alternative rules of exhaustion in the rich countries are evaluated in terms of national welfare levels. **(I WOULD TAKE OUT, WE MENTION VALETTI LATER AND THE IMPLICATION ON INNOVATION HAS ALREADY BEEN MENTIONED)**. We consider 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. We analyze the equilibrium government policies and the welfare properties of those policies, depending on the optimal prices and qualities set by the firms under each policy framework.

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". *Of course, commitment of countries like India to implement TRIPS and a strict IPR regime as a member of the WTO has left them with no option to exercise such a choice any longer. However, there are certain flexibilities and exceptions within the scope of TRIPS that allow country-specific variations in the implementation of a stronger IPR regime. Article 27(1) of TRIPS specifies that patents will have to be provided for inventions which are "new, involve an inventive step and are capable of industrial application", but does not elaborately define these terms. This provides some flexibility to the developing countries to restrict the number of patents [Abbott (2001), Correa (2000a)]. On the other hand, the exception that is particularly relevant for the developing countries and provides us another motivation for considering a policy choice regarding the IPR regime is compulsory licensing (hereafter, 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 governments.*[5] *In essence, a CL is similar in effect to the threat of imitation as it lowers the price of drugs in the developing countries through price competition. We, however, do not confine ourselves to the case of CL, but put our concern in a more broader policy perspective of weak IPR protection.* **(I WOULD TAKE THIS OUR OR SHORTEN AND PUT IN A FOOTNOTE)** An evaluation of alternative IPR regimes in tandem with policy choices of rich countries in favour of PI will help us understand the welfare basis of the reservations in the developing world against implementing a strict IPR regime. It will also help us *explain historically observed weak IPR regimes in the developing world and the recent trend of PI being implemented by the rich world as optimal choices in a non-cooperative policy choice framework. This is*

[5] In the amendment of the Indian Patent Act of 1970 in 1999, in keeping with India's commitments for implementation of TRIPS with effect from the year 2005, a "mailbox facility" was created by which all applications claiming pharmaceutical inventions would be accepted and put away in a mailbox to be examined in 2005. By this "mailbox facility", applications would be judged for novelty on the basis of filing date and not with reference to 2005. The act provides that in regard to the "mailbox applications" that result in the grant of patents, an automatic CLs would be issued to those generic companies that made significant investment and were producing and marketing a drug covered by the mailbox application prior to 2005.

*the important policy issue that we are primarily concerned with in this paper.***(I HAVE MOVED THIS)**

The theoretical literature on patent policy, imitation and innovation, on the one hand, and on PI, innovation and welfare, on the other hand, have been quite exhaustive but disjoint except for the study by Ichino (2004). In the literature on imitation and innovation, two recent papers have some relevance for our analysis. First is the analysis of Kovac and Zigic (2007) that examines optimal trade policy choice when in a vertically differentiated developing country market a quality-leader developed-country firm faces the threat of imitation and learning from a follower developing-country firm. 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, how does the choice of rich countries over allowing and not allowing PI depend on the threat of imitation of innovated drug has not been addressed. The adverse long run effect of parallel imports under the assumption of partial coverage of markets demonstrated of late by Valetti (2006), however, has some relevance for the issues that we address here. 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.[6]

The only paper, to best of our knowledge, that links these two literature and provides a benchmark for the issue raised here is that of Ichino (2004). He considers a policy game between a low-income country choosing over allowing and not allowing piracy and a high-income country choosing over allowing and 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, 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 of the countries. Though Ichino draws his motivation from

[6] This analysis has been extended to all equilibrium market-coverage combinations (including full coverage of all country-markets) by Acharyya (2008). 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.

PI of Japanese pop music compact disks sold by the Japanese firms in China, Hong Kong and Taiwan, his analysis is equally relevant in the context of pharmaceutical pricing and patent protection policies.

However, Ichino's analysis is deficient in one important respect. By assuming exogenously given quality level of the on-patent intellectual property right product, he neglects the adverse effect of both PI and piracy (or imitation) on the level of innovation and consequently the quality of the product. But given the adverse innovation effect of PI as mentioned above the incentive for poorer countries for allowing imitation when the rich country allows PI may be smaller as well since those who buy the innovated drug instead of the imitated drug are strictly worse off. Policy choices, therefore, should be re-examined taking into account the adverse innovation effects of PI and imitation (or weak IPR regime). This is one of the major analytical departure of the present paper from that of Ichino (2004).

There are several other important 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 and medicines, we assume a single potential imitator instead of perfectly competitive imitators. Even under the Patent Act 1970 that allowed imitation, reverse engineering and patents for new processes in India till it was being replaced by the Patent Act 1999, the entry of firms had never been to the extent of eroding all profit margins for the incumbents and new entrants. One reason why imitating firms could still enjoy positive supernormal profits even under a weak patent protection may be the fixed costs involved in imitation and reverse engineering which essentially restricted entry. Second, we consider a leader-follower structure in the innovation-imitation subgame similar to Kovac and Zigic (2007) except for that we do not allow for any quality reversal through imitation, for there is no such evidence even for Indian pharmaceutical firms who have the technical and manpower skills as mentioned above. That is, we assume pharmaceutical industries in different countries differ in their ability to produce innovative drugs. (FROM THIS POINT ONWARD NEXT FEW PARAGRAPHS ARE RE-ORIENTED TO ACCOMMODATE REFEREE#1'S MINOR COMMENTS (IV)). *Third, we assume that the imitator must incur in a fixed cost so as to be able to imitate. Once this has been paid, the imitator can produce a quality level anywhere below that of the innovation. 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), having both intra and cross country income disparity. There is a non-empty interval of consumers in each country, the location of each consumer in an interval being determined by his income level. 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 H has the technology to innovate a new drug while the firm in L only has the technology to produce an imitation. Whether or not

the L-firm is allowed to produce an imitation is determined by whether the L-government enforces a weak-IPR regime (imitation allowed) or strict-IPR regime (imitation not allowed). The sequence of events in the policy game played by the governments is as follows. First, national governments simultaneously (and without communicating) choose their policy regimes. For H, where the innovator firm is based (the higher income country), the policy choice consists of allowing parallel imports (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 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 frameowrk, we derive 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 deters entry. Third, the welfare properties of the two SPNE reveals that though 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 MNC based countries to TRIPS implementation would be to allow parallel imports.

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 forces 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

[7] In the literature on strategic competition between firms in a vertically differentiated market, firms are usually assumed to commit on their quality levels first and then compete in prices. See Shaked and Sutton (1982) for example. Donnenfeld and Weber (1995) and Lutz (1997), on the other hand, considered limit qualities set by incumbent firms to deter entry.

from PI can be fully realized and this is more desirable than MBD for the rich country.

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 reexamine the policy choices considering compulsory licensing allowed by the low-income country. Finally, concluding remarks are made in section 6.

2 The analytical framework

Let us consider a two-country world, we refer to these 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, although we assume that personal income is uniformly distributed in each country j ($j = H, L$) between $\underline{y}_j$ and $\overline{y}_j$ $\left(\overline{y}_j > \underline{y}_j\right)$, we also assume that both the richest and poorest consumer in country H have a higher level of income than those in country L, i.e., $\overline{y}_H > \overline{y}_L$ and $\underline{y}_H > \underline{y}_L$. This reflects the existence of income inequality both within and across countries. **A consumer in country-j with income y 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.**To take care of Referee #1's main comments #2, I would like to drop the reference of the numeraire good and rewrite the above two sentences in bold as the following. *A consumer in country-j with income y buys, if at all, only one unit of the drug.* The potential buyers in country-j are distributed uniformly over the relevant income range $[\underline{y}_j, \overline{y}_j]$ with unit density for each income level. Thus, $\left[\overline{y}_j - \underline{y}_j\right]$ is the extent of (intra-country) demand dispersion.[8] As we will see, as long as $\underline{y}_j$ is sufficiently small relative to $\overline{y}_j$ 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., $\overline{y}_H > \overline{y}_L$), but at the same time they are not too rich in the sense $\overline{y}_H < 3\overline{y}_L$. Of course, the extent of market coverage should be endogenously determined as we elaborate below and can indeed influence the policy choices, but we will confine ourselves in this paper with 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.

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

[8] Note that the total population size may still be larger and income disparity wider in the low-income country relative to the high-income country.

quality indexed by $s^* > 0$. Innovation requires investment of a sum of money C in R&D that increases at an increasing rate with the target level of innovation:

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

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.

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, in the L-country the local 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 parallel imports of the drug innovated by its own firm and sold in the L-country. If parallel imports are not allowed, the innovator firm will be able to price discriminate across countries.

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 innovator 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 vary 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. *This means that the marginal willingness-to-pay for a quality varies across different income levels in each country*[9]. (THIS FOOTNOTE IS ADDED TO TAKE CARE OF REFEREE#1'S COMMENTS (1)) Assume that such a preference relationship is linear in income and quality so that if a consumer purchases a drug of quality s^*,

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

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

$$v_j(y, s^*, P_j) = ys^* - P_j^*, \tag{3}$$

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

[9] Here we follow the specification used in Ichino (2004) and in our earlier analyses [Acharyya and Garcia-Alonso (2005, 2007)]. See Gabszweicz and Thisse (1979) and Shaked and Sutton (1982) for relating the marginal willingness-to-pay for a quality to income levels of consumers in the context of endogeneous quality choice. An alternative basis of differences in the marginal willingness-to-pay for a quality can be taste diversities, rather than income disparities, as in Mussa and Rosen (1978). Of course, one might argue, and this may be particularly relevant for health care, that rich and poor alike have the same marginal willingness-to-pay for a particular quality but different *ability* to pay [see Acharyya (2005), for example]. We, however, abstract here from such distinction between willingness and ability to pay.

With these specifications, we consider the following timing in 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 parallel imports 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 set their prices. Finally, the consumers in each 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 regimes: strict-IPR regime in both countries with and without parallel imports allowed by the H-country, and a weak-IPR regime in L-country with and without parallel imports allowed by the H-country. Finally, we will discuss Subgame Perfect Nash Equilibrium strategy choices for the governments – choice over strict and weak IPR for the L-country government, and choice over allowing and not allowing PI for the H-country government.

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 parallel imports 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) above. 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 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:

$$v_L(y, s, P) = ys - P \geq 0, \tag{4}$$

$$v_L(y, s^*, P_L^*) \geq v_L(y, s, P) \Longrightarrow ys^* - P_L^* \geq ys - P, \tag{5}$$

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.

3 Firm strategies under alternative policy regimes

3.1 Strict IPR and MBD

Let P^*_{jD} and s^*_D denote respectively the price in country-j market and the innovated quality under MBD. Let y^*_{jD} be the marginal consumer in country-j market who derives zero net benefit from the price, quality menu $(P^*_{jD},\ s^*_D)$ offered by the MNC to the potential buyers there. Thus by the IR constraints,

$$y^*_{jD} = \frac{P^*_{jD}}{s^*_D}. \tag{6}$$

By the tie-breaking rule, the marginal (and indifferent) consumers buy the drug. Since consumers with higher income derive greater benefits, so all these buyers buy the drug as for them the individual-rational constraint is satisfied. Thus, if $\underline{y}_j < y^*_{jD}$, 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 $\underline{y}_j > y^*_{jD}$, 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 market is $\left[\overline{y}_j - y^*_{jD}\right]$. Hence, the profit of the MNC equals,

$$\pi^*_D = \sum_{j=L,H} \left[P^*_{jD}\overline{y}_j - \frac{P^{*2}_{jD}}{s^*_D} \right] - \frac{1}{2}s^{*2}_D. \tag{7}$$

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

$$P^*_{jD} = \frac{1}{2}s^*_D\overline{y}_j, \qquad j = L, H. \tag{8}$$

Substitution of (8) in (6) yields,

$$y^*_{jD} = \frac{1}{2}\overline{y}_j. \tag{9}$$

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 $\underline{y}_j < \frac{1}{2}\overline{y}_j$, $j = H, L$

ii) country-i market fully but the country-j market partially for all $\underline{y}_i > \frac{1}{2}\overline{y}_i$ and $\underline{y}_j < \frac{1}{2}\overline{y}_j$, $i \neq j = H, L$, $\underline{y}_H \in \left[\frac{1}{2}\overline{y}_L, \frac{1}{2}\overline{y}_H\right]$

iii) both the markets fully for all $\underline{y}_j > \frac{1}{2}\overline{y}_j$.

All these claims follow from the profit-maximizing choice of the extent of market coverage as specified in (9). In rest of the analyses we will assume that the intra-country income disparity is sufficiently large in the sense that $\underline{y}_j < \frac{1}{2}\overline{y}_j$, $j = H, L$. 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 and price levels:

$$s_D^* = \frac{1}{4}\left[\overline{y}_L^2 + \overline{y}_H^2\right], \tag{10}$$

$$P_{jD}^* = \frac{1}{8}\overline{y}_j\left[\overline{y}_L^2 + \overline{y}_H^2\right]. \tag{11}$$

3.2 Weak IPR and MBD

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, $\widetilde{s}_D \in [0, \widetilde{s}_D^*)$, where $\widetilde{s}_D^*$ denote the quality of the drug innovated by the MNC under the threat of imitation. The lower price of this imitated drug, $\widetilde{P}$, compared to that charged by the MNC, $\widetilde{P}_{LD}^*$ 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, which we define later, provided of course it is relatively profitable to do so. As we will see later, such a decision to deter entry depends on the level of fixed cost.

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

$$[\widetilde{y}_{LD}^* - \widetilde{y}_D] = \frac{\widetilde{P}_{LD}^* - \widetilde{P}_D}{\widetilde{s}_D^* - \widetilde{s}_D} - \frac{\widetilde{P}_D}{\widetilde{s}_D} \tag{12}$$

and

$$[\overline{y}_L - \widetilde{y}_{LD}^*] = \overline{y}_L - \frac{\widetilde{P}_{LD}^* - \widetilde{P}_D}{\widetilde{s}_D^* - \widetilde{s}_D} \tag{13}$$

respectively. Hence, profit maximization yields the following prices and the quality level for the innovator and imitator:

$$\widetilde{P}^*_{LD} = \frac{1}{4}\widetilde{s}^*_D\overline{y}_L, \tag{14}$$

$$\widetilde{P}^*_{HD} = \frac{1}{2}\widetilde{s}^*_D\overline{y}_H, \tag{15}$$

$$\widetilde{P}_D = \frac{1}{14}\widetilde{s}^*_D\overline{y}_L. \tag{16}$$

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

$$\widetilde{s}^*_D = \frac{1}{48}\left[12\overline{y}^2_H + 7\overline{y}^2_L\right], \tag{17}$$

$$\widetilde{s}_D = \frac{4}{7}\widetilde{s}^*_D. \tag{18}$$

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 a local 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, the lower price compensates the effect of the lowered quality resulting in greater coverage of the L-country market by the MNC

$$y^*_{LD} - \widetilde{y}^*_{LD} = \frac{1}{2}\overline{y}_L - \frac{5}{12}\overline{y}_L > 0. \tag{19}$$

That is, the MNC now caters to an additional $(y^*_{LD} - \widetilde{y}^*_{LD})$ 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 $y \in [\widetilde{y}_D, \widetilde{y}^*_{LD})$ 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:

$$\widetilde{\pi}^*_D = \frac{1}{2}\left(\widetilde{s}^*_D\right)^2 = \frac{1}{2(48)^2}\left[12\overline{y}^2_H + 7\overline{y}^2_L\right]^2, \tag{20}$$

$$\widetilde{\pi}_D = \frac{1}{48}\overline{y}_L^2 \widetilde{s}_D^* = \frac{1}{(48)^2}\left[12\overline{y}_H^2 + 7\overline{y}_L^2\right]\overline{y}_{L.}^2 \tag{21}$$

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

$$F < \overline{F}_D = \widetilde{\pi}_D\left(\widetilde{s}_D\right). \tag{22}$$

Otherwise, for higher fixed costs of imitation, entry is blockaded and a weak IPR regime does not pose any threat to the innovator.[10] 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 (21)) varies directly with the innovated quality $\widetilde{s}_D^*$,the MNC can innovate a lower *limit* quality $\widetilde{s}_{Dl}^*$ which, for any given F, deters entry by pushing the net potential profit for the local imitator to zero. From (22), using (21), such a limit quality equals,

$$\widetilde{s}_{Dl}^* = \frac{48}{\overline{y}_L^2}F. \tag{23}$$

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-deterring 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. Thus, the prices set by the MNC under the entry-deterring limit quality would be similar to what has been specified in (8):

$$\widetilde{P}_{jD}^l = \frac{1}{2}\widetilde{s}_{Dl}^*\overline{y}_j,\ j = H, L. \tag{24}$$

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 produces a lower quality and lowers the 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. *Since, the limit quality is monotonically increasing in F, it is sufficient to show that $\widetilde{s}_{Dl}^*\left(\overline{F}_D\right) = \widetilde{s}_D^*$. Using (21) and (22),*

$$\begin{aligned}\widetilde{s}_{Dl}^*\left(\overline{F}_D\right) &= \frac{1}{48}\left[12\overline{y}_H^2 + 7\overline{y}_L^2\right] \\ &= \widetilde{s}_D^*.\end{aligned}$$

[10] Note that $\overline{F}_D = \widetilde{\pi}_D\left(\widetilde{s}_D\right) = 0$ when $\widetilde{y}_D = \dfrac{\widetilde{P}_D}{\widetilde{s}_D} = \dfrac{1}{8}\overline{y}_L < \underline{y}_L$, hence, our earlier assumption implies that $\overline{F}_D > 0$.

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

$$\widehat{y}^*_{LD} = \frac{\widetilde{P}^l_{LD}}{\widehat{s}^*_{Dl}} = \frac{1}{2}\overline{y}_L = y^*_{LD}.$$

Hence the claim. ■

Note that, given Lemmas 2 and 3, under a [weak IPR,MBD] policy regime, there is less 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-deterring 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 it actually covers a greater fraction of the L-country market. On the other hand, under the entry-deterring 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 however, 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* $F > \overline{F}_D$.

Proof. *See Appendix.* ■

That is, if it is worthwhile for the local imitator to enter, the MNC *always* accommodates him. Essentially entry deterrence is worthwhile only 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 parallel imports of the drug from the L-country. Arbitrage then forces the MNC is forced to charge a uniform price P^*_p across the 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 the potential buyers:

$$y^*_p = \frac{P^*_p}{s^*_p}.$$

For the same reason as already spelled out above, if $y < y^*_p$, both the markets are partially covered. In that case, the profit of the MNC equals,

$$\pi_p^* = P_p^* \left[\overline{y}_H + \overline{y}_L\right] - \frac{2\left(P_p^*\right)^2}{s_p^*} - \frac{1}{2}s_p^{*2}. \tag{25}$$

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

$$P_p^* = \frac{1}{4}\left[\overline{y}_H + \overline{y}_L\right] s_p^*. \tag{26}$$

Resulting in indifferent consumer at

$$y_p^* = \frac{1}{4}\left[\overline{y}_H + \overline{y}_L\right]. \tag{27}$$

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

Under these assumptions, the innovation and price levels can be calculated as:

$$s_p^* = \frac{1}{8}\left[\overline{y}_H + \overline{y}_L\right]^2, \tag{28}$$

$$P_p^* = \frac{1}{32}\left[\overline{y}_H + \overline{y}_L\right]^3. \tag{29}$$

Note that $s_p^* < s_D^*$, which is the under-investment result of Valletti (2006): parallel imports lowers 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 parallel import of the original drug from the L-country. Let $\widetilde{P}_p^*$ and $\widetilde{P}_p$ be the prices of the original and imitated drug, and $\widetilde{s}_p^*$ be the level of quality of the innovated drug when entry is accommodated. Proceeding as before,[12] it is straightforward to check that, when entry is accommodated, consumers in the H and L-country having at least income levels $\widetilde{y}_{Hp}^*$ and $\widetilde{y}_{Lp}^*$ respectively purchase the innovation, where:

[11] This 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.

[12] Firms in countries H and L maximize profit functions

$$\widetilde{\pi}_p^* = \widetilde{P}_p^*\left(\overline{y}_H + \overline{y}_L - \widetilde{y}_{Hp}^* - \widetilde{y}_{Lp}^*\right) - \frac{1}{2}\widetilde{s}_p^{*2}$$

and

$$\widetilde{y}_{Hp}^{*}=\frac{\widetilde{P}_{p}^{*}}{\widetilde{s}_{p}^{*}}=\frac{2\left(\widetilde{s}_{p}^{*}-\widetilde{s}_{p}\right)}{8\widetilde{s}_{p}^{*}-5\widetilde{s}_{p}}\left(\overline{y}_{H}+\overline{y}_{L}\right), \tag{30}$$

$$\widetilde{y}_{Lp}^{*}=\frac{\widetilde{P}_{p}^{*}-\widetilde{P}_{p}}{\widetilde{s}_{p}^{*}-\widetilde{s}_{p}}=\frac{2\widetilde{s}_{p}^{*}-\widetilde{s}_{p}}{8\widetilde{s}_{p}^{*}-5\widetilde{s}_{p}}\left(\overline{y}_{H}+\overline{y}_{L}\right). \tag{31}$$

On the other hand, in the L-country, the consumers having at least the income level $\widetilde{y}_{p}$ (less than $\widetilde{y}_{Lp}^{*}$) buy the imitated drug, where $\widetilde{y}_{p}$ is such that,

$$\widetilde{y}_{p}=\frac{\widetilde{P}_{p}}{\widetilde{s}_{p}}=\frac{\widetilde{s}_{p}^{*}-\widetilde{s}_{p}}{8\widetilde{s}_{p}^{*}-5\widetilde{s}_{p}}\left(\overline{y}_{H}+\overline{y}_{L}\right). \tag{32}$$

Given the above segmentation of the L-country market, the entry accommodating profit-maximizing innovation level equal

$$\widetilde{s}_{p}^{*}=\frac{7}{96}\left(\overline{y}_{H}+\overline{y}_{L}\right)^{2}, \tag{33}$$

$$\widetilde{s}_{p}=\frac{8}{11}\widetilde{s}_{p}^{*}=\frac{56}{(11)(96)}\left(\overline{y}_{H}+\overline{y}_{L}\right)^{2} \tag{34}$$

and profits are

$$\widetilde{\pi}_{p}^{*}=\frac{1}{2}\left(\widetilde{s}_{p}^{*}\right)^{2}=\frac{49}{2(96)^{2}}\left(\overline{y}_{H}+\overline{y}_{L}\right)^{4}. \tag{35}$$

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

$$\overline{F}_{p}=\widetilde{\pi}_{p}=\frac{7}{4(48)^{2}}\left(\overline{y}_{H}+\overline{y}_{L}\right)^{4} \tag{36}$$

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

$$\widetilde{s}_{pl}^{*}=\frac{96}{\left(\overline{y}_{H}+\overline{y}_{L}\right)^{2}}F. \tag{37}$$

$$\widetilde{\pi}_{p}-F=\widetilde{P}_{p}\left(\frac{\widetilde{P}_{p}^{*}-\widetilde{P}_{p}}{\widetilde{s}_{p}^{*}-\widetilde{s}_{p}}-\frac{\widetilde{P}_{p}}{\widetilde{s}_{p}}\right)-F,$$

with resulting prices

$$\widetilde{P}_{p}^{*}=\frac{2\left(\widetilde{s}_{p}^{*}-\widetilde{s}_{p}\right)\widetilde{s}_{p}^{*}\left(\overline{y}_{H}+\overline{y}_{L}\right)}{8\widetilde{s}_{p}^{*}-5\widetilde{s}_{p}}$$

and

$$\widetilde{P}_{p}=\frac{\widetilde{s}_{p}\widetilde{P}_{p}^{*}}{2\widetilde{s}_{p}^{*}}.$$

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

$$\widetilde{\pi}_{pl}^{*} = 12F - \frac{(96)^2}{2\left(\overline{y}_H + \overline{y}_L\right)^4} F^2. \tag{38}$$

Lemma 5 *Under a [weak IPR,PI] policy regime, the MNC deters entry by setting a limit quality* $\widetilde{s}_{pl}^{*}$ *specified in (37) for all* $F \in \left(F_{p,root}^{*},\ \overline{F}_p\right]$. *On the other hand, entry is blockaded if* $F > \overline{F}_p$, *and accommodated if* $F < F_{p,root}^{*}$, *where*

$$F_{p,root}^{*} = \left[\frac{12 - \sqrt{95}}{4\,(48)^2}\right]\left(\overline{y}_H + \overline{y}_L\right)^4. \tag{39}$$

Proof. *See Appendix.* ■

Once again, imitation by a local firm lowers the profit of the MNC. however, there is one essential difference. Under MBD, though the MNC was forced to compete with the local imitator in the L-country, it could still charge monopoly price in its own country. But now under PI, it must charge a uniform price in both the markets and thus prospect of imitation lowers the MNC's profit in *both* the markets. The limit quality enables the MNC to charge the (non-discriminatory, uniform) monopoly price. At the same time, there are profit losses from the lower limit quality. This is due to smaller market coverage compared to that under 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

Let us now consider the policy choices by the two national governments. *Each government maximizes national welfare levels which is simply the sum of the 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 innovating H-firm. Otherwise, the national welfare in the L-country is simply the consumers surplus, for any given price-quality menu chosen by the innovator. For example, The national welfare levels when a weak IPR is implemented in the L-country and entry is accommodated by the innovating H-firm have the following components:*

$$\widetilde{W}_{LD} = \left[\int_{\widetilde{y}_{LD}^{*}}^{\widetilde{y}_D} \left(\widetilde{s}_D y - \widetilde{P}_D\right) dy\right] + \left[\int_{\widetilde{y}_D}^{\overline{y}_L} \left(\widetilde{s}_D^{*} y - \widetilde{P}_D^{*}\right) dy\right] + \widetilde{\pi}_D - F \tag{40}$$

$$\widetilde{W}_{HD} = \left[\int_{\widetilde{y}^*_{HD}}^{\overline{y}_H} \left(\widetilde{s}^*_D y - \widetilde{P}^*_{HD} \right) dy \right] + \widetilde{\pi}^*_D \tag{41}$$

where, the profit levels are as defined above. (REFEREE#1'S MAIN COMMENT #2 IS THAT WE HAVE NOT DEFINED NATIONAL WELFARE ANYWHERE. THAT IS WHY I HAVE ADDED THE ABOVE SENTENCES AND THE ALGEBRAIC EXPRESSIONS.)

As evident from the above discussions, the level of fixed cost of imitation influence the firm strategies. This will in turn affect welfare levels. The SPNE policy choices thus vary accordingly. However, we will confine ourselves with only the range of fixed costs for which entry is not blockaded, i.e., it is worthwhile for the potential local 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,

$$F < \overline{F}_D. \tag{42}$$

On the other hand, though $F^*_{p,root} < \overline{F}_p$, $F^*_{p,root}$ may be greater than $\overline{F}_D$ for some high cross-country income differences as shown in Figure 1.[13] In that case, given the assumption in (42), 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, we have only two distinctly different cases (as specified in the Lemma below) when the levels of highest incomes in the two countries are such that,

$$F^*_{p,root} < \overline{F}_D. \tag{43}$$

Otherwise, we have only one of these cases, or to be more precise, the case which we label below as Case II.

Lemma 6 *When the L-government implements a weak IPR regime, under the assumptions (42)-(43), 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.

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

[13] The diagram is drawn letting $\overline{y}_H = t\overline{y}_L$ and then normalizing $\overline{y}_L$ to unity; the relevant range of cross-country difference is thus given by the interval $[1, 3]$ for the parameter t.

limit for which both the markets are served by the MNC. Note that $F < F^*_{p,root} < \overline{F}_D$ would corresponds to Ichino's (2004) policy game, extended to endogenous innovation decision. Figure 2 represents the payoff matrix for countries to summarize the notation for all the possible welfare levels. Figure 4 in the Appendix provides the expressions for each of those welfare levels. By simply comparing the different welfare levels we immediately obtain following results:

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

As formally shown in the appendix, $\widetilde{W}_{LD} - \overline{F}_D > W_{LD}$. 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,

$$\widetilde{W}_{LD} - F > W_{LD} \; \forall \; F \in \left[0, \overline{F}_D\right]. \tag{44}$$

It is also straightforward to prove that

$$\widetilde{W}_{HD} < W_{HD} \; . \tag{45}$$

The gain from a weak IPR regime when entry is accommodated comes from two sources. First is the greater market coverage: the MNC caters to some poorer consumers whom it would not cater to under a stronger IPR, and the even poorer buyers who cannot still buy the original drug, can now buy the low-priced imitated drug. Second 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 intra-marginal buyers. This is an interesting result which provides a theoretical justification for 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.

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

Proof. *See Appendix.* ■

Note that the quality of the innovated drug now is lower whereas the (uniform) price is higher compared to the lower 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 (27), $y_H^* - y_p^* = \frac{1}{4}[\overline{y}_H - \overline{y}_L] > 0$. As shown in the appendix, this gain appears to be 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 parallel imports benefit only the richer countries.

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 9 *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: $\overline{F}_D > F > F^*_{p,root}$) 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) emerges as the unique SPNE policy choices.*

Proof: *See Appendix for details.*

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, PI is the best strategy for the H-country. On the other hand, note that $\widetilde{W}_{Lp}(\widetilde{s}_{Pl})$ is monotonically *increasing* in the fixed cost of imitation (see Table 4) and is strictly less than W_{Lp} for F close to $\overline{F}_p$. For $F = \overline{F}_p$, entry is blockaded so that essentially the weak IPR regime with entry deterrence boils down to the strict IPR regime. But, as F falls below $\overline{F}_p$, 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 intra-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, smaller is the level of fixed cost of imitation. Hence,

$$\widetilde{W}_{Lp}(\widetilde{s}_{pl}) < W_{Lp} \ \forall \ F < \overline{F}_D. \tag{46}$$

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, in the appendix we prove that $\widetilde{W}_{HD} > \widetilde{W}_{Hp}(\widetilde{s}_{pl})$. 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 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 for parallel imports through regional or international exhaustion of patent rights.

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 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 $\widetilde{y}_p^*$ 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. What we show in the appendix is that in the relevant range of fixed costs, viz. $F \in \left[0, F_{p,root}^*\right]$, and for all relevant range of cross-country income differences, the L-country unambiguously gains from the weak IPR when the H-country allows parallel imports. That is, the welfare loss from lower innovation is outweighed by the gains spelled out above.

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. As detailed out in the appendix, 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.

5.1 Properties of SPNE policy choices

What appears from Proposition 9 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 (Figures 3 and 4 summarize equilibrium quality, price and welfare levels).

First, it is readily verifiable (using (9), (19) and (27)) 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.[14] Moreover, the buyers in the L-country even poorer than $\widetilde{y}^*_{LD}$ 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. For cross-country income differences sufficiently large in the sense that $\overline{y}_H > 1.8\overline{y}_L$, innovation level is higher at the (Weak IPR, MBD)-SPNE than under (Strict IPR, PI).[15]

Turning to the national welfare levels, recall that we have already established that the L-country unambiguously looses at the (strict IPR, PI)-SPNE compared

[14] Simply note that $y_P = \frac{1}{4}(\overline{y}_L + \overline{y}_H) > \frac{5}{12}\overline{y}_L = \widetilde{y}^*_{LD}$ and $y_P = \frac{1}{4}(\overline{y}_L + \overline{y}_H) < \frac{1}{2}\overline{y}_H = \widetilde{y}^*_{HD} = y^*_{HD}$.

[15] Simply by comparing $\widetilde{s}^*_D$ and s^*_p.

to the other SPNE (see equation (46)). For the H-country, on the other hand, welfare increases at the WTO-compliant SPNE, i.e., $\widetilde{W}_{HD} < W_{Hp}$ (see appendix). 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 10 *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.*

Proof. *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. See appendix for details.* ■

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

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

5.2 Compulsory licensing versus parallel imports

As we have mentioned earlier, 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)]. Canada has been a country that had successfully implemented CL during from the 1920s. More recently, India has allowed automatic CLs for mailbox applications. Even the WTO (2002) recognizes its importance though instead of CL, the Article 31 refers to "use without authorization of the right holder". It also does not place any restrictions on the grounds under which a CL can be provided to a local

non-patentee[16]. In the 1923 Patent Act of Canada, a CL allowed the licensee the right to manufacture, use or sell a patented innovation before the patent expires without the consent of the patent holder and in exchange the licensee was required to pay a royalty. This royalty was then paid to the patent holder.

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 that we now have is regarding the profit of the local firm 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 $\widetilde{\pi}_D^* + R$ or $\widetilde{\pi}_p^* + R$ whereas the local firm's profit equals $\widetilde{\pi}_D - R$ or $\widetilde{\pi}_p - R$ 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 $\overline{R}_i$, $i = D, p$, where $\overline{R}_i$ is such that $\widetilde{\pi}_i = \overline{R}_i$. 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.

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.

[16]It though specifies certain conditions which include that the non-patentee must have made efforts to get a voluntary license on reasonable commercial terms, and the CL can be terminated if and when the circumstances which led it cease to exist and are unlikely to occur.

The robustness of the above results needs to be examined with respect to endogeneity of imitation cost, which constitutes our future research agenda.

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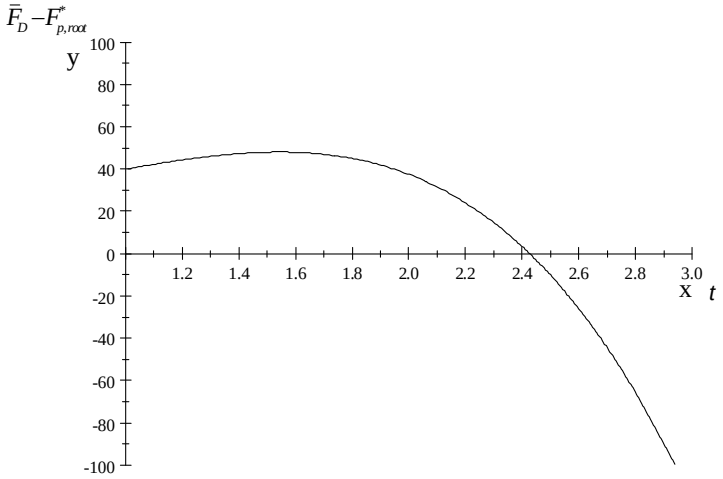


Figure 1. Comparison of critical fixed costs ($\overline{y}_H = t\overline{y}_L$, $\overline{y}_L = 1$, $t \in [1,3]$).

Cases	Range of Fixed Costs	Payoff Matrix Strategy Sets: L: Strict IPR, Weak IPR; H: MBD, PI	
Case I	$F^*_{p,root} < F < \overline{F}_D$	W_{LD}, W_{HD}	W_{Lp}, W_{Hp}
		$\widetilde{W}_{LD} - F, \widetilde{W}_{HD}$	$\widetilde{W}_{Lp}(\widetilde{s}_{pl}), \widetilde{W}_{Hp}(\widetilde{s}_{pl})$
Case II	$F < F^*_{p,root}$	W_{LD}, W_{HD}	W_{Lp}, W_{Hp}
		$\widetilde{W}_{LD} - F, \widetilde{W}_{HD}$	$\widetilde{W}_{Lp} - F, \widetilde{W}_{Hp}$

Figure 2. The policy game (assuming $F < \overline{F}_D$ and $F^*_{p,root} < \overline{F}_D$).

Policy regime	*innovated quality*	*price in country L*
$strictIPR,\ MBD$	$s^*_D = \frac{1}{4}\left[\overline{y}^2_L + \overline{y}^2_H\right]$	$P^*_{jD} = \frac{1}{8}\overline{y}_j\left[\overline{y}^2_L + \overline{y}^2_H\right]$
$weakIPR,\ MBD$	$\widetilde{s}^*_D = \frac{1}{48}\left[12\overline{y}^2_H + 7\overline{y}^2_L\right]$	$\widetilde{P}^*_{LD} = \frac{1}{8}\overline{y}_L\left(\frac{1}{32}\left(12\overline{y}^2_H + 7\overline{y}^2_L\right)\right)$
$strictIPR,\ PI$	$s^*_p = \frac{1}{8}\left[\overline{y}_H + \overline{y}_L\right]^2$	$P^*_p = \frac{7}{224}\left(\overline{y}_H + \overline{y}_L\right)^3$
$weakIPR,\ PI$ $(I)DETERRENCE$	$\widetilde{s}^*_{pl} = \frac{96F}{(\overline{y}_H + \overline{y}_L)^2}$	$\widetilde{P}^*_p(\widetilde{s}^*_{pl}) = \frac{24F}{(\overline{y}_H + \overline{y}_L)}$
$weakIPR,\ PI$ $(II)ACCOMMODATION$	$\widetilde{s}^*_p = \frac{7}{96}\left(\overline{y}_H + \overline{y}_L\right)^2$	$\widetilde{P}^*_p(\widetilde{s}^*_p) = \frac{7}{768}\left(\overline{y}_H + \overline{y}_L\right)^3$

Figure 3: Price and quality outcomes

Appendix

A.1. Proof of Lemma 4: entry deterring vs. accommodating strategy under MBD

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

$$\widetilde{\pi}^*_{Dl} = \frac{48}{\overline{y}_L^2}\left[\frac{1}{4}\left(\overline{y}_L^2 + \overline{y}_H^2\right)F - \frac{24}{\overline{y}_L^2}F^2\right]. \tag{A.1}$$

First, note that $\widetilde{\pi}^*_{Dl} = 0$ for $F = \widetilde{F}_D$:

$$\widetilde{F}_D = \frac{1}{96}\overline{y}_L^2\left(\overline{y}_L^2 + \overline{y}_H^2\right) \tag{A.2}$$

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

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

$$\widetilde{\pi}^*_{Dl}\left(\widehat{F}_D\right) = \frac{1}{32}\left(\overline{y}_L^2 + \overline{y}_H^2\right).$$

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

$$\frac{1152}{\overline{y}_L^4}F_D^{*^2} - \frac{12\left(\overline{y}_L^2 + \overline{y}_H^2\right)}{\overline{y}_L^2}F^*_D - \frac{1}{8}\left[\overline{y}_H^2 + \frac{7}{12}\overline{y}_L^2\right]^2 = 0$$

which solves for the two roots as:

$$F^*_{D,root} = \frac{\overline{y}_L^2}{192}\left[\left(\overline{y}_L^2 + \overline{y}_H^2\right) \pm \sqrt{\left(\overline{y}_L^2 + \overline{y}_H^2\right)^2 - \left[\overline{y}_H^2 + \frac{7}{12}\overline{y}_L^2\right]^2}\right] \tag{A.3}$$

Note that $F^*_{D,root}$ is the smaller root of the critical level of fixed cost F^*_D such that $\widetilde{\pi}^*_{Dl}\left(F^*_D\right) = \widetilde{\pi}^*_D$. But, it can be checked that $F^*_{D,root} > \overline{F}_D$. Hence, it is not worthwhile for the MNC to deter entry for all $F < \overline{F}_D$. The comparison of profit levels for the MNC under the entry accommodating and deterring strategies is shown in Figure 1.

A.2. Proof of Lemma 5: entry deterring vs. accommodating strategies under PI

It is readily verifiable that although the profit that realized for the MNC from the entry-deterring strategy, $\widetilde{\pi}^*_{pl}$ (stated in equation (38)) is inverted-U shaped, it is monotonically increasing in the relevant range of fixed cost of imitation by the local firm, viz. for all $F \leq \overline{F}_p$.

$$\frac{\partial \widetilde{\pi}^*_{pl}}{\partial F} > 0 \; \forall \; F < \widehat{F}_p = \frac{\left(\overline{y}_H + \overline{y}_L\right)^4}{16\,(48)}. \tag{A.4}$$

But, $\widehat{F}_p > \overline{F}_p$, which can be checked by recalling the value of $\overline{F}_p$ from (36) in the text:

$$\widehat{F}_p - \overline{F}_p = \frac{\left(\overline{y}_H + \overline{y}_L\right)^4}{16\,(48)} - \frac{7}{4\,(48)^2}\left(\overline{y}_H + \overline{y}_L\right)^4 > 0.$$

Thus, $\dfrac{\partial \widetilde{\pi}^*_{pl}}{\partial F} > 0 \; \forall \; F < \overline{F}_p$. Moreover, $\widetilde{\pi}^*_{pl}(\overline{F}_p) = \dfrac{144}{2\,(96)^2}\left(\overline{y}_H + \overline{y}_L\right)^4 > \widetilde{\pi}^*_p > \widetilde{\pi}^*_{pl}(0)$.

Hence, as long as $\widetilde{\pi}^*_{pl}(F)$ is continuous, there exists a value of $F < \overline{F}_p$, denoted by $F^*_{p,root}$ such that[17] $\widetilde{\pi}^*_{pl}(F^*_{p,root}) = \widetilde{\pi}^*_p$. From (38) and (35), we obtain the equation that defines the value of $F^*_{p,root}$ as:

$$F^*_{p,root} = \left[\frac{12 \pm \sqrt{95}}{4\,(48)^2}\right]\left(\overline{y}_H + \overline{y}_L\right)^4.$$

It is straighforward to prove that the smaller root of the above is smaller than $\overline{F}_p$. Similarly, it can be checked that $\overline{F}_p <$ larger $F^*_{P,root}$. Hence, for the relevant range of fixed costs, viz., $F \leq \overline{F}_p$, only the smaller root of F^*_P is relevant such that given (A.9), $\widetilde{\pi}^*_{pl}(F) > \widetilde{\pi}^*_p \; \forall \; F \in \left(F^*_{P,root}, \overline{F}_p\right]$ .It can be verified that $F^*_{p,root} < \overline{F}_p$ and $\overline{F}_D < \overline{F}_P$.

A.3. Welfare outcomes

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

[17] Actually there are two roots for critical value of F for which profits under entry deterrence and accommodation equal. The smaller root falls in the relevant range and is denoted by $F^*_{p,root}$.

Table 4a.

Policy regime	*Country L's welfare*
strictIPR, MBD	$W_{LD} = \frac{\overline{y}_L^2\left[\overline{y}_L^2+\overline{y}_H^2\right]}{32}$
weakIPR, MBD	$\widetilde{W}_{LD} - F = \frac{\frac{73}{48}\left[12\overline{y}_H^2+7\overline{y}_L^2\right]\overline{y}_L^2}{144} - F$
strictIPR, PI	$W_{Lp} = \frac{\left[3\overline{y}_L-\overline{y}_H\right]^2(\overline{y}_H+\overline{y}_L)^2}{256}$
weakIPR, PI(I)	$\widetilde{W}_{Lp}(\widetilde{s}_{pl}) = \frac{3(3\overline{y}_L-\overline{y}_H)^2}{(\overline{y}_H+\overline{y}_L)^2}F$
weakIPR, PI(II)	$\widetilde{W}_{Lp} - F = \frac{7\left[9\overline{y}_H^2-30\overline{y}_H\overline{y}_L+153\overline{y}_L^2\right](\overline{y}_H+\overline{y}_L)^2}{8(48)(96)} - F$

Table 4b.

Note that since under entry deterrence, the MNC charges the same (uniform) monopoly price as when there is no threat of imitation under a stronger IPR implemented in the L-country, so once again the L-country market will be served at all as long as $3\overline{y}_L > \overline{y}_H$. Thus, $\widetilde{W}_{Lp}(\widetilde{s}_{pl}) > 0$ only for the limited range of cross-country income disparity. Also note that $\widetilde{W}_{Hp}(\widetilde{s}_{pl})$ is strictly positive only for $F < F' \equiv \dfrac{\left(13\overline{y}_H^2 + 2\overline{y}_H\overline{y}_L + 5\overline{y}_L^2\right)\left(\overline{y}_H + \overline{y}_L\right)^2}{(32)\,(108)}$.

A.4. Proof of Lemma 7: welfare under MBD: weak vs strong IPR

It is enough to check that $\left(\widetilde{W}_{LD} - \overline{F}_D\right) > W_{LD}$. First note that

$$\widetilde{W}_{LD} - \overline{F}_D = \frac{35}{72}\left[\frac{1}{4}\overline{y}_H^2 + \frac{7}{48}\overline{y}_L^2\right]\overline{y}_L^2. \tag{A.5}$$

Thus,

$$\begin{aligned}\left(\widetilde{W}_{LD} - \overline{F}_D\right) - W_{LD} \quad &= \quad \frac{35}{72}\left[\frac{1}{4}\overline{y}_H^2 + \frac{7}{48}\overline{y}_L^2\right]\overline{y}_L^2 - \frac{1}{32}\left[\overline{y}_H^2 + \overline{y}_L^2\right]\overline{y}_L^2 > 0 \\ &\iff \quad \frac{557}{3456}\overline{y}_H^2 - \frac{1}{32}\overline{y}_L^2 > 0.\end{aligned}$$

Hence the result.

A.5. Proof of Lemma 8: welfare gain and loss from PI under strict IPR regime

First, note that:

$$W_{HD} - W_{Hp} = \frac{1}{32}\left[\overline{y}_H^2 + \overline{y}_L^2\right]\left[2\overline{y}_H^2 + \overline{y}_L^2\right] - \frac{1}{256}\left[11\overline{y}_H^2 + 3\overline{y}_L^2 - 2\overline{y}_H\overline{y}_L\right]\left[\overline{y}_H + \overline{y}_L\right]^2 \quad \text{(A.6)}$$

$$= \frac{1}{256}\left[\left(\overline{y}_L - \overline{y}_H\right)\left(14\overline{y}_H^2\overline{y}_L - 5\overline{y}_H^3 + 4\overline{y}_L^3\right) + \overline{y}_L\left(\overline{y}_L^3 - \overline{y}_H^3\right)\right].$$

Now consider the terms within the curly bracket on the RHS (denoting it as K):

$$K = 14\overline{y}_H^2\overline{y}_L - 5\overline{y}_H^3 + 4\overline{y}_L^3$$
$$= \overline{y}_H^2(15\overline{y}_L - \overline{y}_H) + \overline{y}_L(4\overline{y}_L^2 - \overline{y}_H^2) = 5\overline{y}_H^2(3\overline{y}_L - \overline{y}_H) + \overline{y}_L(2\overline{y}_L + \overline{y}_H)(2\overline{y}_L - \overline{y}_H).$$

Thus, for all $\overline{y}_H \leq 2\overline{y}_L$, the term K is strictly positive so that given $\overline{y}_L < \overline{y}_H$, $W_{HD} < W_{Hp}$.

For $\overline{y}_H \in [2\overline{y}_L, 3\overline{y}_L]$, note the following:

$$W_{HD}(\overline{y}_H = 2\overline{y}_L) = \frac{29}{32}\overline{y}_L^4 < \frac{387}{256}\overline{y}_L^4 = W_{Hp}(\overline{y}_H = 2\overline{y}_L) \quad \text{(A.7)}$$

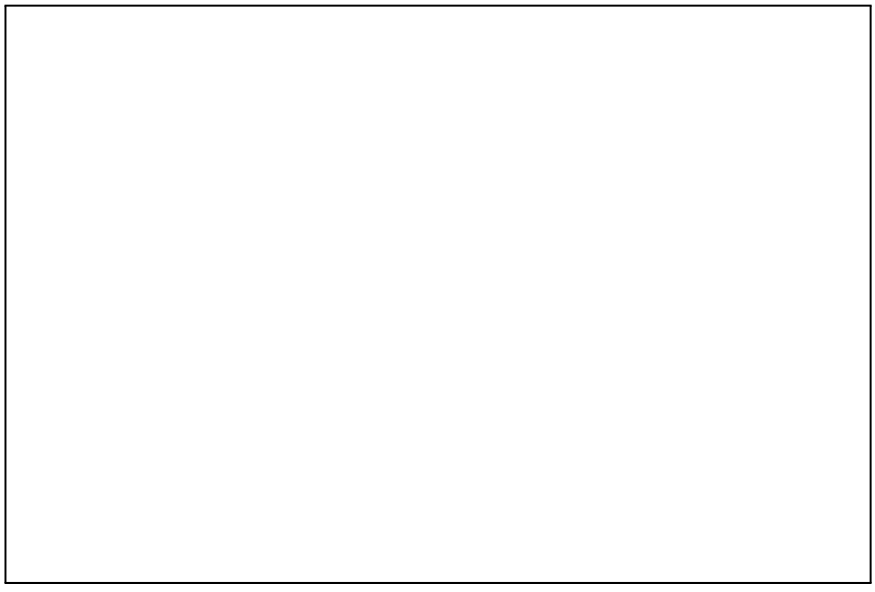
and

$$W_{HD}(\overline{y}_H = 3\overline{y}_L) = 7.6\overline{y}_L^4 < 28.17\overline{y}_L^4 = W_{Hp}(\overline{y}_H = 3\overline{y}_L). \quad \text{(A.8)}$$

Since both W_{HD} and W_{Hp} are monotonically increasing in $\overline{y}_H$, so (A.6) and (A.8) imply that $W_{HD} < W_{Hp}$ for all $\overline{y}_H \in [2\overline{y}_L, 3\overline{y}_L]$.

Alternatively, starting from the first expression, we can simply plot

$$z = \frac{1}{32}\left(t^2 + 1\right)\left(2t^2 + 1\right) - \frac{1}{256}\left(11t^2 + 3 - 2t\right)(t+1)^2.$$



Hence, $W_{HD} < W_{Hp}$.

A.6. Proof of Proposition 9$\left(\widetilde{W}_{HD} > \widetilde{W}_{Hp}(\widetilde{s}_{pl}) \forall F \in \left[0, \overline{F}_D\right]\right)$

First, note that $\widetilde{W}_{Hp}(\widetilde{s}_{pl})$ is maximum at

$$F'' \equiv \frac{\left(13\overline{y}_H^2 + 5\overline{y}_L^2 + 2\overline{y}_H\overline{y}_L\right)\left(\overline{y}_H + \overline{y}_L\right)^2}{32(216)}.$$

Evaluating $\widetilde{W}_{Hp}(\widetilde{s}_{pl})$ at this level of fixed cost we get the maximum welfare level for the L-country under weak IPR when the MNC deters entry:

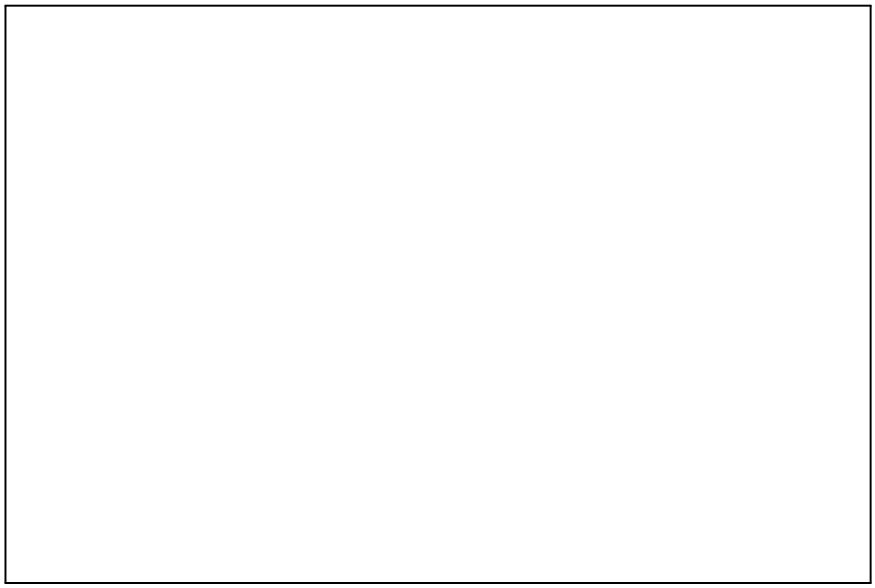
$$\widetilde{W}_{Hp}(\widetilde{s}_{pl}, F'') = \frac{(96)(108)}{(32)^2(216)^2}\left(13\overline{y}_H^2 + 5\overline{y}_L^2 + 2\overline{y}_H\overline{y}_L\right).$$

Hence,

$$\widetilde{W}_{HD} - \widetilde{W}_{Hp}(\widetilde{s}_{pl}, F'') = \frac{1}{(48)(96)}\left[119\overline{y}_H^4 + 24\overline{y}_L^4 + 118\overline{y}_H^2\overline{y}_L^2 - 52\overline{y}_H^3\overline{y}_L - 20\overline{y}_H\overline{y}_L^3\right].$$

which is strictly positive for all relevant cross-country income differences as evident from the following diagram (which is drawn letting $\overline{y}_H = t\overline{y}_L$ and then normalizing $\overline{y}_L$ to unity; the relevant range of cross-country difference is thus given by the interval $[1, 3]$ for the parameter t):

$$z = \frac{1}{(48)(96)}\left(119t^4 + 24 + 118t^2 - 52t^3 - 20t\right).$$



Therefore, since $\widetilde{W}_{Hp}(\widetilde{s}_{pl})$ is monotonically increasing in F up to F'', $\widetilde{W}_{HD} > \widetilde{W}_{Hp}(\widetilde{s}_{pl}) \ \forall \ F \in \left[0, \overline{F}_D\right]$.

A.7. Proof of $\widetilde{W}_{Lp} - F < W_{Lp}$ for all $F < F^*_{P,root}$

First, we define a critical fixed cost F_L such that, $\widetilde{W}_{Lp} - F_L = W_{Lp}$. If such an F_L exists, then by the monotonicity property of the welfare function we have $\widetilde{W}_{Lp} - F > W_{Lp} \ \forall \ F < F_L$. From the welfare expressions, we get,

$$F_L = \frac{1}{3\,(48)\,(256)}\left(654\overline{y}_H\overline{y}_L - 81\overline{y}_H^2 - 225\overline{y}_L^2\right)\left(\overline{y}_H + \overline{y}_L\right)^2.$$

Now we check whether this F_L falls in the relevant range. Note that

$$F^*_{P,root} - F_L = \left[\frac{12-\sqrt{95}}{9216}\right]\left(\overline{y}_H + \overline{y}_L\right)^4 - \frac{1}{3\,(48)\,(256)}\left(654\overline{y}_H\overline{y}_L - 81\overline{y}_H^2 - 225\overline{y}_L^2\right)\left(\overline{y}_H + \overline{y}_L\right)^2,$$

$$z = F^*_{p,root} - F_L = \left(\frac{1}{768} - \frac{(95)^{\frac{1}{2}}}{9216}\right)(t+1)^2 - \frac{1}{256(144)}\left(-81t^2 + 654t - 225\right).$$

Hence, $F^*_{P,root} < F_L$, and consequently, $\widetilde{W}_{Lp} - F < W_{Lp}$ for all $F < F^*_{P,root}$.

A.8. Proof of $\widetilde{W}_{HD} > \widetilde{W}_{Hp}$

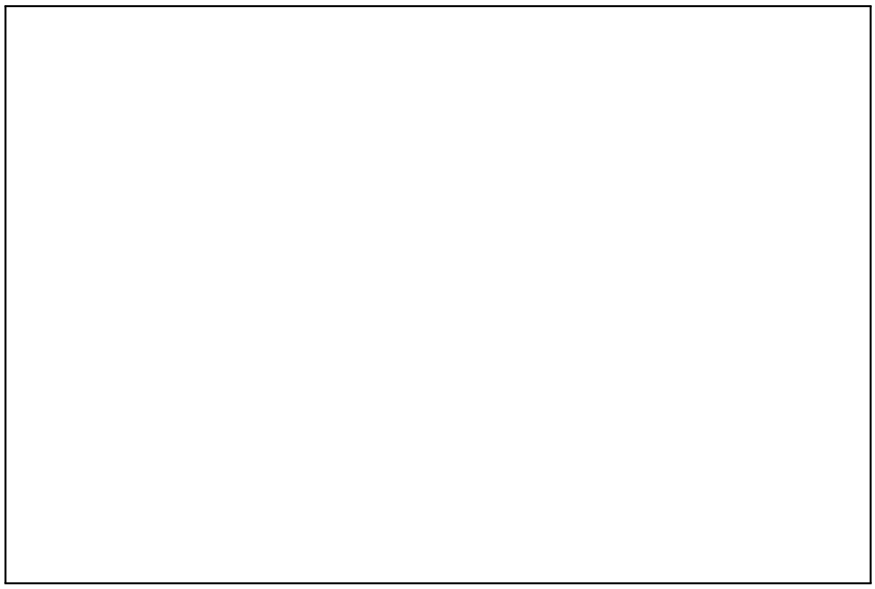
First note:

$$\widetilde{W}_{HD}-\widetilde{W}_{Hp}=\frac{\left[24\overline{y}_H^2+7\overline{y}_L^2\right]\left(12\overline{y}_H^2+7\overline{y}_L^2\right)}{(48)\,(96)}-\frac{7\left[161\overline{y}_H^2-14\overline{y}_H\overline{y}_L+17\overline{y}_L^2\right]\left(\overline{y}_H+\overline{y}_L\right)^2}{8(48)(96)}.$$

We make $\overline{y}_H=t\overline{y}_L$ and take $\overline{y}_L^4$ out to get:

$$z=\frac{\left(24\,(t)^2+7\right)\left(12\,(t)^2+7\right)}{(48)\,(96)}-\frac{7\left(161\,(t)^2-14t+17\right)(t+1)^2}{8(48)(96)},$$

which we plot bellow for $t\in[1,3]$.



The above demostrates that $\widetilde{W}_{HD}>\widetilde{W}_{Hp}$.

A.9. Proof of Proposition 10: welfare properties of SPNE policy choices

A.9.1 The high income country prefers (weak IPR, MBD) to (strict IPR,PI) $\left(\widetilde{W}_{HD}<W_{HP}\right)$

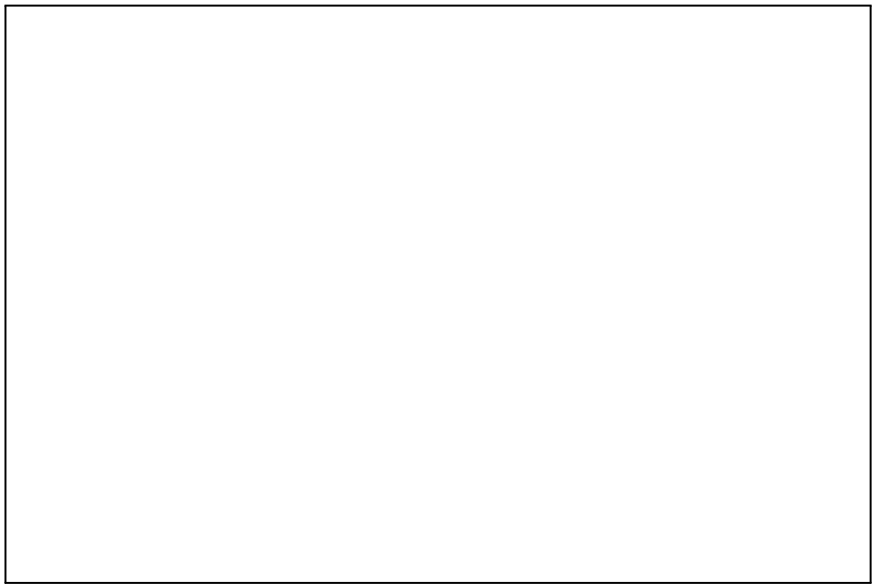
First note:

$$\widetilde{W}_{HD}-W_{Hp}=\frac{\left[24\overline{y}_H^2+7\overline{y}_L^2\right]\left(12\overline{y}_H^2+7\overline{y}_L^2\right)}{(48)\,(96)}-\frac{\left[11\overline{y}_H^2+3\overline{y}_L^2-2\overline{y}_H\overline{y}_L\right]\left(\overline{y}_H+\overline{y}_L\right)^2}{256}.$$

We make $\overline{y}_H=t\overline{y}_L$ and take $\overline{y}_L^4$ out to get:

$$z=\frac{\left(24t^2+7\right)\left(12t^2+7\right)}{(48)\,(96)}-\frac{\left(11t^2+3-2t\right)(t+1)^2}{256},$$

which we plot bellow for $t\in[1,3]$.



This shows that $\widetilde{W}_{HD}<W_{HP}$ for all cross-country income differences. Hence, the H-country gains from implementation from the (Strict IPR, PI) SPNE policy choices.

A.9.2. Global welfare under (weak IPR, MBD) vs (strict IPR, PI) $\left(\widetilde{W}_{LD}-F+\widetilde{W}_{HD}>W_{Lp}+W_{Hp}\right)$

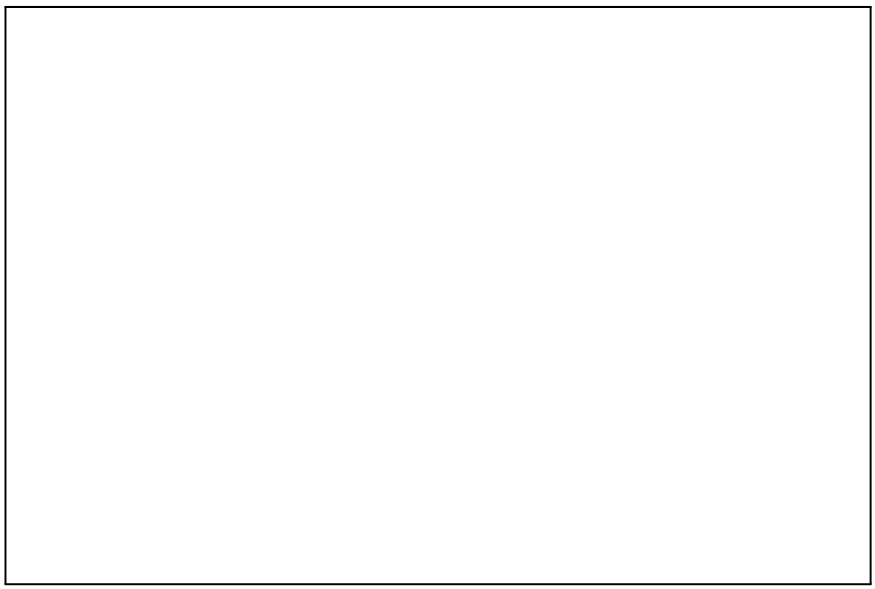
Note that $\widetilde{W}_{LD}-F+\widetilde{W}_{HD}>W_{Lp}+W_{Hp}\Leftrightarrow$

$$\left(\frac{\frac{73}{48}\left[12\overline{y}_H^2+7\overline{y}_L^2\right]\overline{y}_L^2}{144}-F+\frac{\left[24\overline{y}_H^2+7\overline{y}_L^2\right]\left(12\overline{y}_H^2+7\overline{y}_L^2\right)}{(48)(96)}\right)-\left(\frac{[3\overline{y}_L-\overline{y}_H]^2(\overline{y}_H+\overline{y}_L)^2}{256}+\frac{\left[11\overline{y}_H^2+3\overline{y}_L^2-2\overline{y}_H\overline{y}_L\right](\overline{y}_H+\overline{y}_L)^2}{256}\right)>0.$$

We then introduce the highest possible $F=\overline{F}_D=\frac{1}{(48)^2}\left[12\overline{y}_H^2+7y_L^2\right]\overline{y}_L^2$ to

get a sufficient condition and we make $\overline{y}_H=t\overline{y}_L$ and take $\overline{y}_L^4$ out to get:

$$z=\frac{\frac{73}{48}\left(12t^2+7\right)}{144}-\frac{1}{(48)^2}\left(12t^2+7\right)+\frac{\left(24t^2+7\right)\left(12t^2+7\right)}{(48)(96)}-\left(\frac{(3-t)^2(t+1)^2}{256}+\frac{\left(11t^2+3-2t\right)(t+1)^2}{256}\right).$$



Hence we can conclude that global welfare is higher in the (weak IPR, MBD) case.

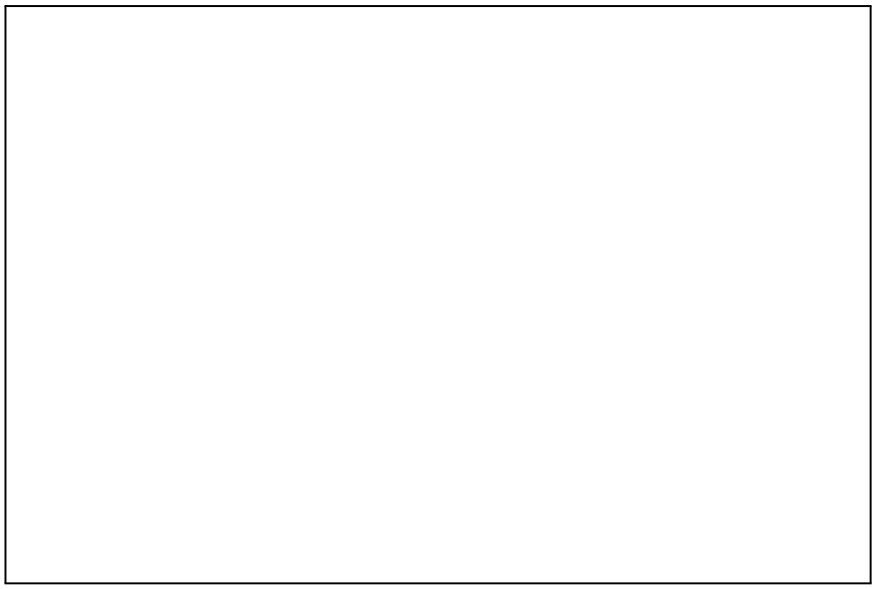
A.9.3. Global welfare under (strict IPR, MBD) vs (strict IPR PI) ($W_{LD}+W_{HD}>W_{Lp}+W_{Hp}$)

$$W_{LD}+W_{HD}>W_{Lp}+W_{Hp}\Leftrightarrow$$

$$\left(\frac{\overline{y}_L^2\left[\overline{y}_L^2+\overline{y}_H^2\right]}{32}+\frac{\left[2\overline{y}_H^2+\overline{y}_L^2\right]\left(\overline{y}_L^2+\overline{y}_H^2\right)}{32}\right)-\left(\frac{[3\overline{y}_L-\overline{y}_H]^2(\overline{y}_H+\overline{y}_L)^2}{256}-\frac{\left[11\overline{y}_H^2+3\overline{y}_L^2-2\overline{y}_H\overline{y}_L\right](\overline{y}_H+\overline{y}_L)^2}{256}\right)>0.$$

As usual, we make $\overline{y}_H=t\overline{y}_L$ and take $\overline{y}_L^4$ out to get:

$$\left(\frac{\left(1+t^2\right)}{32}+\frac{\left(2t^2+1\right)\left(1+t^2\right)}{32}\right)-\left(\frac{(3-t)^2(t+1)^2}{256}-\frac{\left(11t^2+3-2t\right)(t+1)^2}{256}\right).$$



Hence, under the strict IPR regime, global welfare is higher with MBD.

A.9.4. Global welfare under (weak IPR, MBD) vs (strict IPR, MBD) $\left(\widetilde{W}_{LD}-F+\widetilde{W}_{HD}>W_{LD}+W_{HD}\right)$

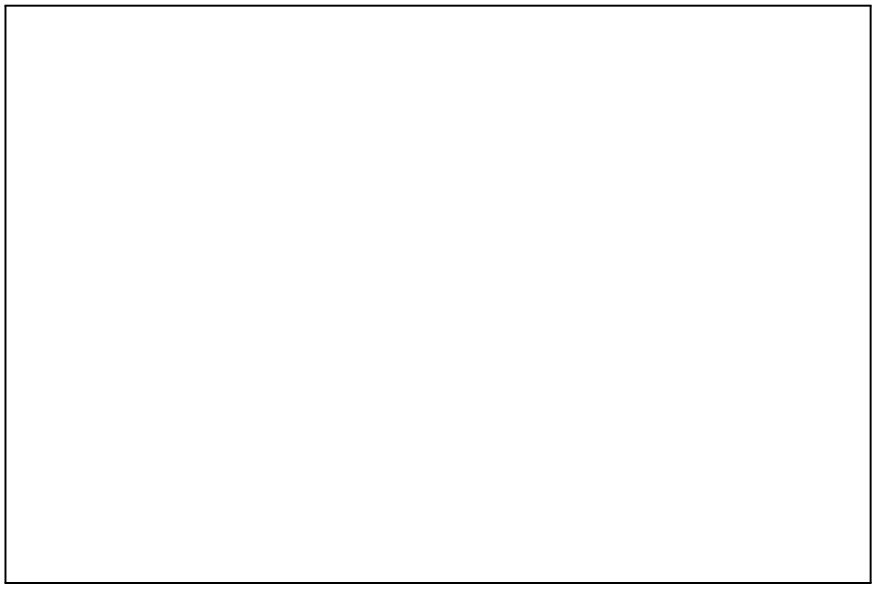
$$\widetilde{W}_{LD}-F+\widetilde{W}_{HD}>W_{LD}+W_{HD}\Leftrightarrow$$

$$\left(\frac{\frac{73}{48}\left[12\overline{y}_H^2+7\overline{y}_L^2\right]\overline{y}_L^2}{144}-F+\frac{\left[24\overline{y}_H^2+7\overline{y}_L^2\right]\left(12\overline{y}_H^2+7\overline{y}_L^2\right)}{(48)(96)}\right)-\left(\frac{\overline{y}_L^2\left[\overline{y}_L^2+\overline{y}_H^2\right]}{32}+\frac{\left[2\overline{y}_H^2+\overline{y}_L^2\right]\left(\overline{y}_L^2+\overline{y}_H^2\right)}{32}\right)>0$$

We then introduce the highest possible $F=\overline{F}_D=\dfrac{1}{(48)^2}\left[12\overline{y}_H^2+7y_L^2\right]\overline{y}_L^2$

to get a sufficient condition and we make $\overline{y}_H=t\overline{y}_L$ and take $\overline{y}_L^4$ out to get:

$$z=\left(\frac{\frac{73}{48}\left(12t^2+7\right)}{144}-\frac{1}{(48)^2}\left(12t^2+7\right)+\frac{\left(24t^2+7\right)\left(12t^2+7\right)}{(48)(96)}\right)-\left(\frac{\left(1+t^2\right)}{32}+\frac{\left(2t^2+1\right)\left(1+t^2\right)}{32}\right).$$



Hence, we can conclude that $\widetilde{W}_{LD} - F + \widetilde{W}_{HD} > W_{LD} + W_{HD}$.

A.10. Price increase due to implementation of strict IPR

The relevant expressions are

$$\frac{P_p^*}{\widetilde{P}_p^*} = \frac{24}{7},$$

$$\frac{P_{LD}^*}{\widetilde{P}_{LD}^*} = \frac{\frac{1}{8}\left(t^2+1\right)}{\frac{1}{8}\left(\frac{1}{32}\left(12t^2+7\right)\right)},$$

$$\frac{P_p^*}{\widetilde{P}_{LD}^*} = \frac{\frac{7}{224}\left(\overline{y}_H+\overline{y}_L\right)^3}{\frac{1}{8}\overline{y}_L\left(\frac{1}{32}\left(12\overline{y}_H^2+7\overline{y}_L^2\right)\right)} = \frac{\frac{7}{224}\left(t+1\right)^3}{\frac{1}{8}\left(\frac{1}{32}\left(12\left(t\right)^2+7\right)\right)}.$$

By plotting all the above expressions, we can conclude that the most likely higher price increases arise when going (Weak IPR, MBD) to (Strict IPR, PI) (represented as the thicker line).