Innovation, Imitation and Parallel Trade in the Pharmaceutical Industry

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Comments welcome†

August 2008

Abstract

There has been growing concern in recent years that the pharmaceutical industry is directing an increasing share of innovation resources toward small modifications of existing drugs instead of developing new break-through products. This paper argues that price controls may have contributed to this development and that parallel trade may help to reverse the trend. In a model with Cournot competition, parallel trade can increase incentives for the development of highly innovative products by reducing the attractiveness of drugs that imitate existing drugs.

JEL classification: F12; L13; I11

Keywords: Parallel trade, Product innovation, Pharmaceuticals

1 Introduction

The pharmaceutical industry has been criticized lately for concentrating research efforts on so called me-too products, i.e. drugs that imitate existing products and consist only of minor modifications1. These drugs differ enough to get a new patent, but do not provide any significant new benefit to the consumers. Me-too products are less risky and costly to develop than truly innovative drugs. In this paper, we show how price controls in

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†I am grateful to Rolf Weder and my colleagues from the International Trade Group, University of Basel, for helpful comments. I also thank Jean-Charles Rochet, Stefan Csordas and Michael Wohlfender.
1For a recent example see Morgan et al. (2005) and United States Government Accountability Office (2006).
the pharmaceutical market may have encouraged the production of me-too drugs and how parallel trade (PT), somewhat contrary to common opinion, might help to redirect resources towards the development of more innovative products.

Drug expenditures constitute a growing share of total health costs in most developed countries. Authorities in several such countries (e.g. in Canada, France, Spain and Italy) have reacted with increasingly tight price controls for pharmaceutical products. The resulting price differences between countries has induced high-price countries (such as the US and Switzerland) to consider allowing parallel traders to import patent protected drugs. While parallel trading is legal inside the borders of the European Union, such practice is until now prohibited in most other developed countries. Policy makers in high-price countries hope that PT will lower national drug prices. Critics emphasize that PT will lower profits in the industry, thus reducing incentives to undertake costly innovation. They argue that finally all consumers will lose, as fewer new drugs will come to the market.

Recent work by Grossman and Lai (2006) and Pecorino (2002) has challenged this view, arguing that PT might strengthen the bargaining position of pharmaceutical firms vis-à-vis the authorities and hence increase profits and innovation incentives. Nevertheless, the strong opposition of pharmaceutical firms against PT indicates that they expect resulting losses. This paper differs from the existing literature on PT as it does not analyze effects on total expenditures for product innovation, but focuses on whether these expenditures are spent for developing innovative products or merely on imitating existing drugs. We find that PT can reduce the attractiveness of imitation while making innovation relatively more profitable. This effect comes from two sources. First, similar as in Grossman and Lai (2006) and Pecorino (2002), firms that offer similar products struggle more to demand higher prices from authorities, which increases incentives to develop more differentiated products. Second, if firms have means other than the price to prevent PT of their products, they may tolerate PT when they are in close competition with a second firm. Since PT also reduces profits of the respective competitor, firms may respond in differentiating their products.

We analyze the effects of price controls and PT on innovation in a model where firms and parallel traders compete in a Cournot oligopoly. Most of the existing literature analyzes the effects of PT on innovation incentives considering a monopolist producer and perfect competition among parallel traders. The oligopoly setting in this paper can be rationalized by the fact that pharmaceutical firms holding a patent for a medication often face competition of other firms offering similar treatment. Furthermore, the number of parallel traders importing a particular drug is in general very small. A

2These means may include variation in package sizes, brand names and in dosage form and strength. For an overview of non-price responses see Kyle (2007).
recent paper that studies PT and innovation incentives in Cournot competition is Li (2006). We consider a model with an incumbent firm, which holds a patent for a drug. A second firm is undertaking investment to develop a new product for the same treatment. If investment is low, the firm develops a me-too product. By investing more resources in innovation, a more differentiated new drug is developed. This paper claims that PT may increase the incentive for developing an innovative product, as producers of unique drugs may better handle the competition of parallel traders.

In section 2, we develop the benchmark model with free pricing and nation exhaustion and then assume price controls in one country. Section 3 introduces parallel trade. In section 4, we extend the model by modifying the price setting behavior of the government and introducing non-price responses to PT for firms. Finally, section 5 concludes.

2 Setup of the Model

We consider a world with two countries, A and B, and two firms which are located in country A. For simplicity, both countries are of equal size and demand structure, though this assumption is not crucial. Firm 1 holds a patent for product 1, which it is ready to sell in both markets. Firm 2 is undertaking innovation to develop a new product 2. The firms know that the inverse demand function will be of the form $p_{ij} = 1 - x_{ij} - bx_{ik}$ where $i$ denotes the country and $j, k$ the two goods. Hence, the products are perfect substitutes if $b=1$, while demand is uncorrelated for $b=0$. We exclude the possibility of complementary products, so $0 \leq b \leq 1$.

Firm 2 decides how much costly research effort it invests to develop a new drug. It has two options. First, firm 2 may create at low costs a me-too product, which is different enough from product 1 to get a new patent, but does not provide any additional utility to the consumers. Hence, $b=1$ in the inverse demand function for a me-too product. Second, by investing more in research, firm 2 can differentiate its new drug from the existing product, which leads to $\hat{b} < 1$ in the inverse demand function. $\hat{b}$ is exogenously given and known to the firm. The costs of the research activity is given by $C(\hat{b})$, with $C(\hat{b}) > C(1)$. We normalize $C(1) = 0$, which also guarantees that firm 2 will always make positive profits. After the innovation process, firm 2 receives patent rights for its product and competes with firm 1 in a Cournot duopoly in both markets. We assume zero production and transportation costs once the product is developed.

We will compare innovation incentives in different settings by calculating the difference of the profits of firm 2 generated from a innovative and a

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3Li analyzes effects of PT on cost-reducing innovation, while this paper studies product innovation in a world with price controls.

4Thus, $i \in \{A, B\}$ and $j, k \in \{1, 2\}, j \neq k$. 

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me-too product. An important restriction in the analysis is that we always assume that firms make positive profits and do not leave the market, even if PT reduces overall profits. Thus, this model does not address total expenditures for pharmaceutical innovation, but it enables us to analyze whether these expenditures are aimed at developing truly innovative drugs or me-too products.

**Free pricing**

We start the analysis with free pricing in a national exhaustion (NE) regime, i.e. where PT is prohibited. Firms have the possibility to price discriminate between the two countries, but since we assume equal demand structure in both countries, this will never be the case as long as firms can set their prices freely. Hence, international price discrepancies will only be caused by governmental price control, not by the profit maximization of the two firms. With free pricing in both markets, the outcome is the classical Cournot equilibrium. Both firms will supply \( x_{ij} = \frac{1}{2+b} \) at prices \( p_{ij} = \frac{1}{2+b} \) if firm 2 innovates and \( x_{ij} = \frac{1}{3} \) at price \( p_i = \frac{1}{3} \) if firm 2 brings a me-too product to the market. The resulting total profit for firm 2 is then given by

\[
\Pi_{fp}^{i} (b) = \frac{2}{(2+b)^2} - C(b)
\]

if firm 2 develops an innovative product and equal to

\[
\Pi_{fp}^{n} = \frac{2}{9}
\]

otherwise. Firm 2 will invest in R&D if it can expect higher profits than by developing a me-too product to the market, i.e. if

\[
\Pi_{fp}^{i} (b) \geq \Pi_{fp}^{n}
\]

which gives the condition for innovation in the free pricing case

\[
\frac{2}{(2+b)^2} - \frac{2}{9} \geq C(b)
\]

i.e. the additional revenue generated from an innovative product must be at least as large as the additional costs of developing such a product. Thus, we call the LHS of (4) the incentive for innovation.

**Fixed prices in B**

In the next step, we assume that the government in B sets fixed prices after firm 2 has developed a new product. For now, we assume that the
government’s only objective is the short run consumer surplus in B. With no marginal production or transport costs, B will then set prices at \( p_B = 0 \), assuming that indifferent firms will choose to supply B with its products. Firms make zero profits in B, while prices and quantities remain unchanged in A. The resulting total profits for firm 2 are then given by

\[
\Pi^{pen}_n(\hat{b}) = \frac{1}{\left(2 + \hat{b}\right)^2} - C(\hat{b}) \quad \text{(5)}
\]

if it innovates and

\[
\Pi^{pen}_n = \frac{1}{9} \quad \text{(6)}
\]

otherwise. The resulting condition for innovation is then

\[
\frac{1}{\left(2 + \hat{b}\right)^2} - \frac{1}{9} \geq C(\hat{b}). \quad \text{(7)}
\]

**Proposition 1** If B minimizes consumption expenditures, price controls reduce the incentives for innovation.

This result is straightforward, as the LHS of (7) is strictly smaller than the LHS of (4) for any \( \hat{b} \in [0, 1) \), while the RHS are identical. Hence, innovation is more likely to take place with free pricing. Firm 2 cannot profit from an innovative product to the same extent when prices are fixed in B.

### 3 Introducing parallel trade

Assume now that A imposes an international exhaustion regime (IE), i.e. it allows parallel traders to reimport products from B. The parallel traders get active in the market only if there is a price difference between the two markets. We assume that for each product, there is only one potential parallel trader. This assumption can be justified by assuming entry costs for parallel traders, or the traders can be seen as an exclusive distributor of a particular product in market B. If a parallel trader is active in the market, she will buy the product in B at price \( p_B \) and resell it in A, where firms and parallel traders compete in quantities. Consumers in A are assumed to not differentiate between a reimported product and the same product sold by the original producer. Firms have two means to respond to price control and parallel trade. They can either restrict their sales to A and abandon the market in B, or they can continue to sell in B at the fixed price, facing the resulting competition of the parallel trader in A. If they do sell in B, we assume that the firms cannot distinguish between regular customers and parallel traders and that they must meet the whole demand at the given
price $p_B$.

We will consider the following game with perfect information. First, the government in A chooses its exhaustion regime, i.e. whether PT is legal or not. For the remainder of this paper, we will assume that A has legalized PT. Firm 2 then chooses its investment level. After $b$ is realized, the government in B announces a fixed price $p_B$. Firms then decide whether they want to sell their products in both countries or restrict sales to A. Finally, firms and up to two parallel traders (depending on whether the firms sell their product in B) will compete in a Cournot oligopoly in A.

**The supply decision and resulting payoffs**

We solve this game backwards, starting with the payoffs realized in the final stage, given all previous decisions. There are three possible outcomes for the final structure. Both firms may restrict their sales to A, one firm may restrict to A while the other firm serves both markets, or both firms may provide their product in A and B. What outcome will be achieved depends on the fixed price in B.

With both firms selling their product only in A, there will be no activity of parallel trading in the market. The two firms build up a duopoly and will receive revenues equal to

$$r_{Fboth}^1 = \frac{1}{(2 + b)^2}$$

which equals one half of the free pricing revenue.

If one firm (call it $F^{both}$) provides its product on both markets while the other ($F^{res}$) restricts sales to A, a parallel trader will enter the market and reimport the product of $F^{both}$ from B into A. In B, $F^{both}$ gets the whole consumer market plus the amount purchased by the parallel trader, denoted by $x^{PT}$, which yields payoffs in B of $[(1 - p_B) + x^{PT}]p_B$. With the given inverse demand functions in A, this yields revenue functions for $F^{both}$, $F^{res}$ and the parallel trader of

$$r_{F^{both}}^2 = [(1 - p_B) + x^{PT}]p_B + (1 - x^{F^{both}} - x^{PT} - bx^{F^{res}})x^{F^{both}}$$

$$r_{F^{res}}^2 = (1 - x^{F^{res}} - bx^{F^{both}} - bx^{PT})x^{F^{res}}$$

$$r_{PT}^2 = (1 - x^{F^{both}} - x^{PT} - bx^{F^{res}} - p_B)x^{PT}$$

All agents maximizing with respect to quantities gives equilibrium total revenues for $F^{both}$ and $F^{res}$ of

$$r_{F^{both}}^2 = \left[ (1 - p_B) + \frac{2 - b - (4 - b^2) p_B}{6 - 2b^2} \right] p_B + \frac{(2 - b + (2 - b^2) p_B)^2}{(6 - 2b^2)^2}$$

$$r_{F^{res}}^2 = \frac{(3 - (2 - p_B) b)^2}{(6 - 2b^2)^2}$$
respectively.

Finally, if both firms choose to supply A and B, two parallel traders each import a product from B and resell it in A. In this case, the firms share the consumer market in B at given price $p_B$. The revenue functions for firms and parallel traders then become

$$r_{3i}^F = \left( \frac{1 - p_B}{1 + b} + x_{PTi} \right) p_B + (1 - x_{Fi} - x_{PTi} - bx_{Fj} - bx_{PTj}) x_{Fi}$$ \hspace{1cm} (14)

$$r_{3i}^{PT} = (1 - x_{Fi} - x_{PTi} - bx_{Fj} - bx_{PTj} - p_B) x_{PTi}$$ \hspace{1cm} (15)

With firms and parallel traders optimizing with respect to quantities in A, total revenues for firms then equal

$$r_3^F = \left[ \frac{1 - p_B}{1 + b} + \frac{1 - (2 + b) p_B}{3 + 2b} \right] p_B + \frac{(1 + (1 + b) p_B)^2}{(3 + 2b)^2}$$ \hspace{1cm} (16)

The firms decide simultaneously whether they sell in both markets or restrict their sales to A, i.e. they play a simultaneous game with strategies \{serve A and B\} and \{serve A only\}.

**The price setting decision of B**

We assume that B wants to ensure the availability of both products, but at the lowest price possible. B then sets prices, such that \{A and B, A and B\} is the dominant strategy. The price $p_B$ must then be chosen such that the resulting payoffs of the firms satisfy

$$r_2^{Fboth} \geq r_1^F$$ \hspace{1cm} (17)

$$r_3^F \geq r_2^{Fres}$$ \hspace{1cm} (18)

Note that for both inequalities, the LHS increases faster in $p_B$ than the RHS for all feasible $b$ and $p_B$.\(^5\) Let's denote the smallest price which satisfies both these inequalities, and hence the price which the government in B will choose, with $p_B^{PT}(b)$. By plugging $p_B^{PT}(b)$ into $r_3^F(b)$, we then get the expected revenue for the firms $r^{PT}(b)$ dependent on innovation level $b$. Thus, expected total profit of firm 2 in case of innovation is given by

$$\Pi_2^{PT}(\hat{b}) = r^{PT}(\hat{b}) - C(\hat{b})$$ \hspace{1cm} (19)

If firm 2 produces a me-too product, the resulting total profit is

$$\Pi_n^{PT} = r^{PT}(1)$$ \hspace{1cm} (20)

Comparing these profits with those from the NE analysis leads to following results:\(^6\)

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\(^5\)This comes from the fact that a firm gains more from an increase in $p_B$ if it is actually selling in B.

\(^6\)Please refer to the Appendix for proof of Proposition 2.
Figure 1: Innovation incentives with national (dotted line) and international exhaustion (solid line)

**Proposition 2** If $B$ minimizes prices, total profits of both firms are lower when PT is allowed for any given $b > 0$ and they are equal for $b = 0$.

$B$ must compensate the firms for the losses due to PT of their own product. Otherwise, they would abandon the market in $B$. But they do not receive compensation to their losses due to PT of their competitor’s product, as these do not influence the decision of supplying $B$. Hence, firms will only get fully compensated if $b = 0$, i.e. when products are independent.

**Proposition 3** If $B$ minimizes prices, innovation incentives are greater when PT is allowed for any given value of $b$.

**Proof** The innovation incentives are given by the difference in profits from an innovative and a me-too product, i.e. by $\Pi_i^{PT}(\hat{b}) - \Pi_i^{PT}$ when PT is allowed and by $\Pi_i^{Pcn}(\hat{b}) - \Pi_i^{Pcn}$ in the national exhaustion case. As Figure 1 shows, this difference is larger with international exhaustion for all potential values of $\hat{b}$.

The loss due to PT of the competitor’s product increases with $b$, i.e. when competition between the two firms gets tighter. It is largest when firm 2 develops a me-too product with $b = 1$. Consequently, when we calculate the difference in payoffs of an innovative product and a me-too product in the PT setting, we get that this difference and hence the incentive for innovation is strictly greater for all values of $\hat{b} < 1$ compared to the non-PT setting with $p_B = 0$.

Thus, allowing PT in this setting unambiguously lowers profits but increases incentive of firm 2 to develop an innovative product.
4 Effects without price adjustment

Critics may argue that it is unclear whether we can observe adjustment of fixed prices in response to PT. In this section, we show that even if prices in B remain at a fixed level, the effect of international exhaustion on innovation incentives is ambiguous. To show this, we introduce the opportunity for firms to prevent parallel trading with non-price strategies. The results are similar to the one achieved in section 3. The international exhaustion regime can induce more incentives for firm 2 to invest in research, in order to develop an innovative product and hence to avoid close competition with firm 1. While a firm in a monopoly-like position will be able to handle parallel traders easily, they can bring more intense competition in market with products that are not differentiated.

We drop the assumption that B’s only objective is to minimize product prices. Instead, it sets a price higher than the marginal costs. This seems reasonable, as we do not observe price ceilings at marginal cost level in the real world. This change proves to be important, particularly if prices are high enough under national exhaustion so that no price adjustment is necessary after PT is legalized. In the model developed so far, a constant price $p_B$ leads to unambiguously smaller innovation incentives under IE. For the remaining, we assume that the government in B sets a fixed price for all products, which is communicated prior to innovation and which is high enough, so that no adjustment will be necessary.

By imposing a minor modification to the model, we show that the increased competition due to PT may again lead to higher innovation incentives, even without price adjustment in B. To see this, we introduce the possibility that firms prevent parallel traders from entering the market, using non-price strategies. The firms will decide whether they use this option after the price in B has been communicated and firm 2 has developed the new product. As we will see, monopolists are able to use this tool more efficiently than firms that are locked in a tight competition, which makes moving away from this competition more rewarding for firms and hence increases innovation incentives.

To make this point as clear as possible, we make two simplifying assumptions. First, we assume that if a firm chooses to use such non-price strategies, it can completely deter entry and no parallel trader will reimport its product into A. If a firm does not deter entry, we again assume that one parallel trader will enter the market, buy the product in B at price $p_B$ and sell it in A, where firms and parallel traders compete in quantities. Second, we assume that firms can exercise this deterring strategies at zero costs. It shows that even with zero costs, firms will not always prevent parallel traders from entering the market. Firms that are in tight competition can actually be willing to accept a parallel trader that reimports their product into A, as they do make profits from the parallel trader buying their product in B and
do not take into account the negative effects that PT has on the other firm’s profits.

**Strategic decision of firms**

Similar as in section 3, firms play a simultaneous game after A has announced its exhaustion regime and B has announced its price $p_B$. The firms’ strategies now consist of using or not using a measure to prevent PT. If both firms decide to prevent PT, the resulting revenue for both firms is equal to the NE outcome, given by

$$r_{pp} = \frac{1 - p_B}{1 + b} p_B + \frac{1}{(2 + b)^2}$$

(21)

while both firms allowing PT of their products results in

$$r_{aa} = \left[ \frac{1 - p_B}{1 + b} + \frac{1 - (2 + b) p_B}{3 + 2 b} \right] p_B + \frac{(1 + (1 + b) p_B)^2}{(3 + 2 b)^2}$$

(22)

which equals $r_F^3$ from the previous section.

Finally, with one firm preventing and one firm allowing PT, the respective payoffs are equal to

$$r_{pa} = \frac{1 - p_B}{1 + b} p_B + \frac{(3 - (2 - p_B) b)^2}{(6 - 2 b)^2}$$

(23)

$$r_{ap} = \frac{1 - p_B}{1 + b} p_B + \frac{(2 - b + (2 - b^2) p_B)^2}{(6 - 2 b)^2}$$

(24)

Since $r_{ap} \geq r_{pp}$ implies $r_{aa} \geq r_{pa}$ for all feasible values for $p_B$ and $b$, there always exists at least one symmetric Nash equilibrium in pure strategies. To simplify the analysis, we assume that both firms choose to prevent PT if there are two symmetric Nash equilibria. Hence, firms allow PT of their product if this is the dominant strategy, i.e. if $r_{ap} \geq r_{pp}$. For this inequality to hold for a given $b$, we need

$$p_B \geq p_B^{crit}(b) = \frac{3 b^4 - 16 b^2 + 20}{b^5 + 2 b^4 - 10 b^3 - 20 b^2 + 20 b + 40}$$

(25)

which is a decreasing function of $b$ for $b \in [0, 1]$. This yields the following results for the innovation decision of firm 2, given a potential value $\hat{b}$:

**Proposition 4** If $p_B < \frac{7}{33}$, PT-entry will be deterred for all values of $b$, and all profits and innovation incentives are identical in the NE and IE setting.

If the price in B is too low, firms have no interest to allow PT. Hence, PT is always deterred. Payoffs are then given by (21) and thus equal to the NE setting. Accordingly, innovation incentives are identical as well.
Proposition 5 If \( \frac{7}{33} \leq p_B < p_{B}^{\text{crit}}(\hat{b}) \), PT-entry will be deterred if firm 2 develops an innovative product, but not if it brings a me-too product to market. Innovation incentives are strictly greater when PT is allowed.

Payoffs under NE and after innovation under IE are still given by (21), but a me-too products now yields a payoff given by (22) evaluated at \( b = 1 \). Since \( r^{\text{aa}}(1) \) is strictly smaller than \( r^{\text{pp}}(1) \) for any feasible \( p_B \), innovation incentives are higher in the IE setting.

The key argument is that with prices in this range, firms will allow PT if they are in close competition and prevent it if their products are differentiated. Firms both gain and loose from PT of their product. They loose market share in A, but they also get a return from the parallel trader buying their product in B. If the products are similar, a larger share of the losses accrue to the competitor’s market share. Hence, if firms are in close competition, they will not prevent PT, but suffer losses due to PT of their competitor’s product.

Proposition 6 If \( p_B \geq p_{B}^{\text{crit}}(\hat{b}) \), PT-entry will never be deterred. Innovation incentives are strictly greater when PT is prohibited.

When prices in B are relatively high and the potential outcome of innovation \( \hat{b} \) is relatively close the one, it is a dominant strategy for firms not to prevent PT independent of the innovation decision of firm 2. Hence, we are back in the setting with constant prices in B and PT, where the incentive for innovation is always decreased through the legalization of PT.

5 Conclusion

We study a model with product innovation, price controls and parallel trade in an oligopoly setting. This setup yields new insights and adds to the classical analysis with a monopoly or monopolistic competition with three main findings. First, the introduction of price controls through a fixed price level reduces the innovation incentives for firm 2. Second, when the controlled prices are set at the lowest possible level, legalizing parallel trade unambiguously increases the incentives to develop an innovative product. And finally, if prices are fixed at a higher level and firms have cost-free means to prevent parallel trade, the effect of parallel trade on innovation incentives may be positive or negative, depending on the fixed price level and the potential outcome of innovation activity.

We propose two reasonings for why PT may have positive effects on innovation. First, firms with more differentiated products can demand higher
prices from authorities when PT is legalized, as the threat to abandon a market is increasingly credible when the firm’s market position becomes closer to a monopoly. Second, firms in a monopoly-like position are more willing to apply non-price strategies as a measure to prevent PT, while firms in close competition are more reluctant to use such a measure. Allowing PT of the own product reduces the profits of the competitor, making firms willing to invest in innovation in order to move away from too tight competition. Interestingly, firms will not always prevent PT of their product, even if they can do so at zero costs.

We simplified the analysis by assuming that firms will always make positive profits, so they will not leave the market. Taking this into account, we cannot make any statements about effects on total expenditures for innovation. This study proposes a setting where PT may increase incentives to direct these expenditures towards the development of more innovative products. We believe that this finding constitutes a new and important contribution to both the existing scientific literature and the political discussion on innovation and legalizing PT in the pharmaceutical sector. This paper offers an explanation how price controls may have caused the recent slowdown in the development of breakthrough drugs, and proposes that PT can help to reverse this trend.

The price setting behavior of authorities in low-price counties plays an important role in this model. Further research is needed to clarify the exact goals and means of these authorities. Particularly, it is unclear so far whether we can observe a reaction in government’s price setting behavior in response to parallel trade, as proposed by Pecorino (2002) and Grossman and Lai (2006), and as analyzed in section 3 of this paper. This paper argues that further clarification in this matter is needed, in order to better understand the effects of parallel trade on innovation.

References


Appendix

Proof of Proposition 2

In the non-PT setting with \( p_B = 0 \), firm 2 gets a payoff of \( \frac{1}{2+b} \). Consider first the case where after innovation \( \hat{b} = 0 \), and thus \( r^{pcn}(0) = \frac{1}{4} \). In the PT setting, B will need to increase prices in order to ensure that its market will be served. Note that \( r^{Fres}_2(0) = r^F_1(0) = \frac{1}{4} \) and that \( r^{Fboth}_2(0) = r^F_3(0) \).

Hence, the constraints for B to ensure product availability after innovation reduce to \( r^{Fboth}_2 \geq \frac{1}{4} \) which will be satisfied with equality in the government’s optimum. Profits for firms with PT will therefore equal the profits it PT is not allowed if \( \hat{b} = 0 \).

To see that \( r^F_3(b) < r^{pcn}(b) \) for all \( b > 0 \), first note that in the governments optimum, (17) or (18) must be binding. Consider the case where (18) is binding, i.e. \( r^F_3(b) = r^{Fres}_2(b) \). Assume now that \( r^F_3(b) \geq r^{pcn}(b) \). We then must have \( r^{Fres}_2(b) \geq r^{pcn}(b) \). Solving this for \( p_B \) yields \( p_B \geq \frac{1}{2+b} \). Note that \( p_B > \frac{1}{2+b} \) is not feasible as prices in B would then be higher than under free pricing. But at \( p_B = \frac{1}{2+b} \), we have \( r^F_3(b) = \frac{2}{(2+b)^2} > \frac{1}{(2+b)^2} = r^{Fres}_2(b) \) and (18) cannot be binding. Thus, we must have \( r^F_3(b) < r^{pcn}(b) \) if (18) is binding.

When (17) is binding, we have \( r^{Fboth}_2 = r^F_1 \). Note that \( r^{Fboth}_2 \geq r^F_3 \) for all feasible \( b \) and \( p_B \), with equality only if \( b = 0 \) or \( p_B \geq \frac{1}{2+b} \). But with \( p_B \geq \frac{1}{2+b} \), (17) is not binding. Hence, if (17) is binding, we must have \( r^F_3 < r^{Fboth}_2 = r^{pcn}(b) \).