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Product Innovation with Parallel Imports

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Abstract: In this paper, we develop a theoretical model of product innovation in the context of parallel imports with endogenous investment. It is shown that, in contrast to the existing arguments, parallel imports have ambiguous effect on product innovation and may facilitate product innovation. We find that parallel imports discourage product innovation in the following cases: symmetric transportation costs, unrelated products or symmetric market sizes when these two products are not substitutes. In other cases, parallel imports may facilitate product innovation.

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Product Innovation with Parallel Imports

1. Introduction

Controversy has arisen as to whether parallel imports reduce the manufacturer's incentives to innovate. Parallel imports are such activities that products produced under a protection or trademark, sold into another market without the manufacturer's permission. The popularity of parallel trade has received a wide attention for two main reasons: the first one is that it reduces the manufacturer's short-run profit by introducing intra-brand competition; the second reason which is the more important one is that parallel imports may decrease the long-run profit by creating the possibility of lowering the manufacturer's incentives to engage in innovation.

It is well known that there are two types of innovation: one is process innovation (cost-reducing innovation) and the other one is product innovation (develop a new product). Process innovation with parallel imports is the primary focus of another paper of mine. In that paper, it is found that cost-reducing innovation is helpful in lowering wholesale price. The main result is that parallel imports or the distortions associated with parallel imports discourage the manufacturer's incentives to make investment in process innovation. Those results are highly consistent with the existing intuitive analysis. Thus it is highly desirable to examine the product innovation in the presence of gray market activities. Accordingly of particular interest of this paper is trying to make a further step in bridging this gap.

The existing work on parallel trade argues that parallel imports discourage the manufacturer's incentive to make investment in innovation. [1] While such reasoning seems valid, after all parallel importers free ride on the manufacturer's investment and reduce the manufacturer's profit, it could be misleading not only because these arguments are typically based on intuitive analysis, but also because innovation could change the volume of parallel trade and result in the changes of sales together with the prices in related markets. Parallel imports reduce the profits no matter innovation is successful or not. It is the difference between these two levels of profitability that determines the manufacturer's incentive to innovate. Thus two important questions arise in this case: Do

[1] See Cavusgil and Sikora (1988); Cespedes, Corey and Rangan (1988); Duhan and Sheffet (1988); Michael and College (1998); Maskus (2000a, b) and Palia and Keown (1991).

parallel imports inhibit or facilitate product innovation? In which case will the parallel imports discourage product innovation? The answers to these questions are interesting not only because they shed light on the manufacturer's behavior in the presence of gray market activities, but also because they have policy implications about parallel imports for the policy makers. To answer these questions, it is necessary for us to develop a formal model.

We address these issues in a simple two countries model in which a manufacturer sells his product(s) into another market through an independent distributor. The distributor may find it profitable to sell the products back to the manufacturer's market. When the distributor sells the products back to country A, she competes with the manufacturer in Cournot fashion. There is an existing product X. Prior to the manufacturer's making a take-it or leave-it offer, he needs to decide whether to make investment in product innovation. The new invented product is Y.

A central finding of the present paper is that parallel imports could facilitate or inhibit the manufacturer's incentive to invest in product innovation, it depends on the transportation costs and the relative market sizes along with the natural relation between the existing product and the new product. Parallel trade of the new invented product is more harmful to product innovation than that of the existing product. It is shown that, if costs of parallel trade are small, then parallel imports reduce the manufacturer's incentives to innovate in the following cases: symmetric transportation costs, unrelated products or symmetric market sizes when these two products are not substitutes. Parallel imports could facilitate product innovation in the other cases.

In section 2, we develop the model incorporating parallel imports. We discuss two cases: In the first case, we simply do not allow parallel imports; In the second case, we allow parallel imports. In section 3, we determine the optimal wholesale price and profit. We provide our main results by comparing the two cases in section 2. We conclude in the final section with some further research directions. We provide the graphs and some proofs in appendix.

2. Model description

A manufacturer, M, has an existing product, X, and may make investment to innovate a new product, Y. M sells his products in two countries, A and B. M sells his products by himself in country A, and sells his products through an independent distributor, D, in country B. We assume that M cannot sell his product directly to country B. However the distributor can sell the products back to A through gray market. M cannot legally ban parallel trade activities. When D sells the products back to A, she competes with M in the fashion of Cournot competition in market A and incurs respective additional constant marginal costs $t_x \geq 0$, $t_y \geq 0$. In market A, the inverse demand for X is $f_A(x,y) = 1 - x + \beta y$ and the inverse demand for Y is $g_A(x,y) = 1 - y + \beta x$. In market B, the inverse demands for X and Y are respective $f_B(x,y) = a - x + \beta y$ and $g_B(x,y) = a - y + \beta x$.

Where $\beta \in (-1,1)$. Product X and Y are complements when $\beta > 0$. They are substitutes when $\beta < 0$ and they are unrelated (independent) goods when $\beta = 0$. To simplify our analysis, we assume that the marginal costs of both products are zero. That is, $c_x = 0$ and $c_y = 0$. The inverse demands are public information to both the manufacturer and the distributor.

The timing of the game is as follows: The manufacturer first decides that whether he should make investment in product innovation. Then he makes the distributor a take-it or leave-it offer in the form of (w_x, w_y, T_x, T_y), where w_x, w_y are the wholesale prices of good X and good Y, T_x and T_y are transfer payments from D to M for selling good X and good Y. Given the contracts, the distributor D will decide to accept or reject. If D rejects the offer, no goods will be sold in country B and M sets the optimal outputs in country A. Let x_{AM}, y_{AM} and x_{AD}, y_{AD} denote the quantities of X and Y sold in A by M and D, respectively, x_B and y_B are the quantities sold by D in market B. When the distributor accepts the offer, she chooses x_{AD}, y_{AD} and x_B, y_B simultaneously and M determines his outputs x_{AM}, y_{AM} in A. [2]

[2] If M does not innovate or he does not succeed in inventing product Y, then $w_y = T_y = y_{AM} = y_{AD} = y_B = 0$.

When M makes investment $k \in [0, k_0]$ to innovate a new product, Y, he succeeds with probability $\Pr ob(success) = \alpha(k) = -bk^2 + dk$ and fails with probability $\Pr ob(fail) = 1 - \alpha(k) = 1 + bk^2 - dk$, where $b > 0$ and $d > 0$. Suppose $d > 2bk_0$, so $\alpha(k)$ is a continuous and twice differentiable strictly increasing function with $\alpha(0) = 0$. We assume that $\alpha(k_0) = 1$. That is, M cannot get the new product, Y, when he does not invest in product innovation. Therefore whether M has the new product or not depends only on his investment. Although M could make sure that his innovation is successful by investing k_0, but it may not be optimal for him to do so.

2.1. The case in which parallel imports are prohibited

Our purpose of the present paper is to examine the policy question: should government legally prevent parallel imports if they wish to encourage product innovation? To answer this question, we first develop a model in which parallel trade does not occur because the government simply prevents gray market activities.

Let x_A and y_A denote the quantities of X and Y sold in country A by M., x_B and y_B are the quantities sold by D in market B. When the distributor accepts the offer, she chooses x_B, y_B in country B and simultaneously M determines his outputs x_A, y_A in country A. [3]

When M does not get success in his innovation, his total profit in both markets is

$$\pi_{MN} = \frac{1}{4}(1 + a^2) - k \tag{1}$$

When M invests in product innovation and succeeds, then M's profits in market A and D's gross profit in market B are $\pi_A = (1 - x_A + \beta y_A)x_A + (1 - y_A + \beta x_A)y_A$ (2)

$$\pi_B = (a - x_B + \beta y_B - w_x)x_B + (a - y_B + \beta x_B - w_y)y_B \tag{3}$$

It is pretty straight forward to get [4] $x_A = y_A = \dfrac{1}{2(1-\beta)}$, $x_B = \dfrac{(a - w_x) + \beta(a - w_y)}{2(1-\beta^2)}$

and $y_B = \dfrac{(a - w_y) + \beta(a - w_x)}{2(1-\beta^2)}$ (4)

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[3] If M does not invent product Y or the innovation is not successful, then $w_y = T_y = y_A = y_B = 0$.

[4] See appendix A.

Obviously x_A and y_A are increasing with β. That is, the sales of the two products in country A increase when the products are complements and decrease when they are substitutes. The numerators of x_B and y_B consist two components: the first part represents the effect of its own wholesale price on its sales; the second part reflects the impact of the other good's wholesale price on its sales.

Without parallel trade, the equilibrium prices in country A are $f_A^o = g_A^o = \frac{1}{2}$ (5)

By using two-part tariff, M's total profit when he succeeds in product innovation is

$$\pi_M(x, y) = \pi_A + \pi_B + w_x x_B + w_y y_B - k$$

$$= \frac{1}{4(1-\beta^2)}(2 + 2a^2 + 2\beta + 2a^2\beta - w_y^2 - w_x^2 - 2\beta w_x w_y) - k \qquad (6)$$

Because there are not parallel imports, thus the manufacturer would like to offer

$$w_x = w_y = 0 \text{ and } \pi_M = \frac{1+a^2}{2(1-\beta)} - k \qquad (7)$$

This result should not surprise us. In the case of no gray market activities, it is optimal for the manufacturer to offer wholesale prices equal to his marginal costs and achieve vertical pricing efficiency for both products. Let $R_M = \frac{1+a^2}{2(1-\beta)}$ and

$R_{MN} = \frac{1}{4}(1+a^2)$ denote M's total revenue when his product innovation is successful or not. Comparing R_M with R_{MN}, we notice that M's total revenue doubles if these products are unrelated goods $(\beta = 0)$ when M succeeds in product innovation. The logic is that when these two products are independent products, the revenue through sales of one good is exactly the same as the other, thus the total revenue doubles.

Accordingly M's expected profit when he makes investment in product innovation is

$$E_M = \alpha(k)R_M + [1-\alpha(k)]R_{MN} - k \qquad (8)$$

Where R_M and R_{MN} are M's revenues when M is successful in his product innovation or not. To ensure the manufacturer has incentives to invest in product innovation, we assume that $\alpha'(0) = d$ is large enough. Let

$\Delta R_M = R_M - R_{MN} = \pi_M - \pi_{MN} = \frac{(1+\beta)(1+a^2)}{4(1-\beta)}$. The first order condition of problem (8) yields $k = \frac{1}{2b}(d - \frac{1}{\Delta R_M})$ (9)

2.2 The case in which we allow parallel imports

2.2.1. The manufacturer is not successful in production innovation

In this subsection we discuss the case where the manufacturer does not succeed in product innovation. As usual, we should determine the manufacturer's optimal wholesale price and profit. This was done in my other papers. For the comparison purpose, we briefly repeat it here.

If M does not invest in product innovation, his profit is

$$\pi_{MN}^{p} = \frac{(1+w+t_x)^2}{9} + \frac{(1-2w-2t_x)^2}{9} + \frac{(a-w)^2}{4} + w[\frac{(1-2w-2t_x)}{3} + \frac{(a-w)}{2}] - k^p \quad (10)$$

We get the optimal wholesale price, w, by taking first order condition of (14).

(1). If $0 \le t_x < \frac{3}{14}$, then $w = \frac{2(1+4t_x)}{13}$. Parallel imports occur in this case. M's profit is given by $\pi_{MN}^{p} = \frac{1}{52}(12 + 13a^2 - 8t_x + 36t_x^2) - k^p$ (11)

(2). If $\frac{3}{14} \le t_x < \frac{1}{2}$, then M tends to offer wholesale price high enough to prevent gray market activities. Thus we have the optimal wholesale price, $w = \frac{1}{2} - t_x$, and profit

$$\pi_{MN}^{p} = \frac{1}{16}(3 + 4a^2 + 4t_x - 4t_x^2) - k^p \quad (12)$$

(3). If $t_x \ge \frac{1}{2}$, then the transportation cost is so high that it blocks parallel trade and enables the manufacturer to offer $w = 0$ and get monopoly profits in both countries.

$$\pi_{MN}^{p} = \frac{1}{4}(1 + a^2) - k^p \quad (13)$$

2.2.2. The manufacturer succeeds in product innovation

The above subsection is about the case in which the manufacturer does not succeed in product innovation. It follows that we need to examine the case where the manufacturer is successful in product innovation.

When M's product innovation is successful, then M's profit and D's gross profit through sales in country A are

$$\pi_{AM} = x_{AM}[1-(x_{AM}+x_{AD})+\beta(y_{AM}+y_{AD})]+y_{AM}[1-(y_{AM}+y_{AD})+\beta(x_{AM}+x_{AD})] \quad (14)$$

$$\pi_{AD} = x_{AD}[1-(x_{AM}+x_{AD})+\beta(y_{AM}+y_{AD})-w_x-t_x]$$
$$+y_{AD}[1-(y_{AM}+y_{AD})+\beta(x_{AM}+x_{AD})-w_y-t_y] \quad (15)$$

D's profit in market B is

$$\pi_B^p = x_B(a-x_B+\beta y_B-w_x)+y_B(a-y_B+\beta x_B-w_y) \quad (16)$$

M can get all the profit of D by using the transfer payments when he offers the contract, thus his total profit is

$$\pi_M^p = \pi_{AM}+\pi_{AD}+\pi_B^p+w_x(x_{AD}+x_B)+w_y(y_{AD}+y_B)-k^p \quad (17)$$

Let $R_M^p = \pi_M^p + k^p$ and $R_{MN}^p = \pi_{MN}^p + k^p$ denote M's total revenue when his product innovation is successful or not. Thus M's expected total profit when he invests in product innovation is

$$E_M^p = \alpha(k^p)R_M^p + [1-\alpha(k^p)]R_{MN}^p - k^p \quad (18)$$

To ensure that it is not optimal to set $k^p = 0$, we assume that $\alpha'(0)$ is large enough. Let $\Delta R_M^p = R_M^p - R_{MN}^p = \pi_M^p - \pi_{MN}^p$, the first order condition of (18) yields

$$k^p = \frac{1}{2b}\left(d - \frac{1}{\Delta R_M^p}\right) \quad (19)$$

We can compare k with k^p by comparing ΔR_M with ΔR_M^p in (9) and (19) to show whether parallel imports reduce the manufacturer's incentives to innovate. If $k > k^p$, then parallel imports inhibit product innovation; if $k < k^p$, parallel imports encourage product innovation and if $k = k^p$, then parallel trade has no impact on the manufacturer's product innovation.

3. Analysis

In this section, we continue to solve the model in the previous section and determine the manufacturer's optimal wholesale prices and total profit. We then show that whether parallel imports discourage the manufacturer's incentives to make investment in product innovation.

4. 1. The optimal wholesale prices

In this subsection, it is necessary for us to solve the optimal wholesale prices of the existing product and the new invented product. When M makes investment and succeeds in product innovation. By solving (14), (15) and (16), we get [5]

$$x_{AM}=\frac{(1+t_x+w_x)+\beta(1+t_y+w_y)}{3(1-\beta^2)},\quad x_{AD}=\frac{(1-2t_x-2w_x)+\beta(1-2t_y-2w_y)}{3(1-\beta^2)},$$

$$y_{AM}=\frac{(1+t_y+w_y)+\beta(1+t_x+w_x)}{3(1-\beta^2)},\quad y_{AD}=\frac{(1-2t_y-2w_y)+\beta(1-2t_x-2w_x)}{3(1-\beta^2)},$$

$$x_B=\frac{(a-w_x)+\beta(a-w_y)}{2(1-\beta^2)}\quad\text{and}\quad y_B=\frac{(a-w_y)+\beta(a-w_x)}{2(1-\beta^2)}\tag{20}$$

The sales of these products in both markets along with the volume of parallel imports, x_{AM}, x_{AD}, y_{AM}, y_{AD}, x_B and y_B, have two components. The first part in the numerators is related to wholesale price and transportation cost of one good. The second part of the numerators involving β is about the effect of the wholesale price and transportation cost of the other good. These results reveal that, when the manufacturer innovates a new product that is related to the existing product, the sales of the existing product in both markets together with the volumes of parallel trade depend on not only the existing product wholesale price and transportation cost but also the new product wholesale price and transportation cost. Likewise, the sales of the new product in both markets together with the volumes of parallel trade depend on the overall impact of the new product wholesale price, transportation cost and the existing product wholesale price as well as transportation cost. If $\beta>0$, then these two products are complements. All of x_{AM}, x_{AD}, y_{AM}, y_{AD}, x_B and y_B are increasing with β. That is, the innovation of product Y encourages both the sales of these products in the two countries and the volumes of parallel trade. While if $\beta<0$, these two products are substitutes, the innovation of

[5] See appendix B.

product Y has ambiguous impacts on either the sales of these products or the volumes of parallel imports. When $\beta = 0$, however, the sales of these two products in both countries are independent because they are unrelated goods. In this case, the result is the same as two monopolists choose their optimal outputs in separated markets.

With these results in hand, we are ready to get the manufacturer's profit. By plugging all the above solutions into M's profit function in (17), we get the manufacturer's total profit. [6]

The next step is to get the optimal wholesale prices given transportation costs. It requires that the wholesale prices together with the transfer payments maximize M's total profit.

Notice that transportation costs play important roles in determining optimal wholesale prices and volu ›f parallel imports of these two products. Specifically, we have nine possibilities of wholesale prices and parallel imports for different transportation costs. The manufacturer tends to offer different wholesale prices according to the values of t_x and t_y. In the following figure we summarize all the nine possibilities. We only list out the product(s) that has (have) parallel imports.

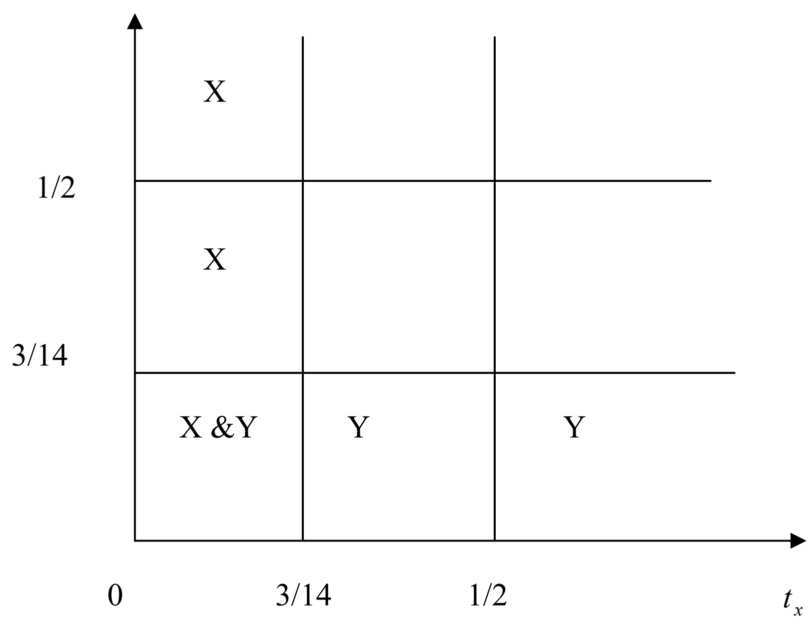

Figure 1

[6] See (B7) in appendix B.

To simplify our analysis, we make the following assumptions:

A1: $(3-14t_x)+\beta(3-14t_y)\geq 0$**;**

A2: $(3-14t_y)+\beta(3-14t_x)\geq 0$**.**

(1). If $0\leq t_x,t_y<\frac{3}{14}$, then $w_x=\frac{2}{13}(1+4t_x)$ and $w_y=\frac{2}{13}(1+4t_y)$. There are parallel imports for both product X and Y. It is important to see that the wholesale price of one product, w_i, is increasing with its own transportation cost t_i, $i=x,y$, this is the same as in the case of one product. The wholesale price of one good, however, is independent on the other good's transportation cost. [7]

Corollary 1: *If* $0\leq t_x,t_y<\frac{3}{14}$*,* then v*olume of parallel trade of product* i *is linear in transportation cost* t_i *and* t_j*,* $i,j=X,Y$.

Proof: We substitute w_x and w_y into x_{AD} and y_{AD}, then get $x_{AD}=\frac{1}{13}[\frac{3}{1-\beta}-\frac{14(t_x+\beta t_y)}{1-\beta^2}]$ and $y_{AD}=\frac{1}{13}[\frac{3}{1-\beta}-\frac{14(t_y+\beta t_x)}{1-\beta^2}]$. Obviously x_{AD} and y_{AD} are linear in transportation cost t_i and t_j, $i,j=X,Y$. [8] ♠

These results are interesting. First, volumes of parallel trade, x_{AD} and y_{AD}, decrease with t_x and t_y respectively. This is because higher transportation cost, t_i, results in the higher wholesale price of w_i. This, in turn, discourages gray market activities of good i and reduces the sales of this good in market B. Second, higher transportation cost, t_i, has ambiguous effect on volume of parallel imports of the other product. It depends on the relation between these products. Interestingly, when $\beta>0$, X and Y are complements, then volume of parallel trade of one product decreases in transportation cost of the other good, and when $\beta<0$, X and Y are substitutes, then volume of parallel trade of one product increases in transportation cost of the other good. This seems counter intuitive. This puzzle can be explained by M 's direct sales. By plugging w_x and

[7] See (B10) in appendix B(1) for the total profit.

[8] We can see that x_{AD} and y_{AD} are nonnegative under assumption 1 and 2.

w_y into x_{AM} and y_{AM}, then we have $x_{AM} = \frac{1}{13}[\frac{5}{1-\beta} + \frac{7(t_x + \beta t_y)}{1-\beta^2}]$ and $y_{AM} = \frac{1}{13}[\frac{5}{1-\beta} + \frac{7(t_y + \beta t_x)}{1-\beta^2}]$. Obviously x_{AM} and y_{AM} are increasing with t_y and t_x respectively when $\beta > 0$, x_{AM} and y_{AM} are decreasing with t_y and t_x respectively when $\beta < 0$. That is, when $\beta > 0$, these two products are complements, the increases of M's direct sales x_{AM} and y_{AM} force volumes of parallel trade x_{AD} and y_{AD} to go down. When $\beta < 0$, these two products are substitutes, it reduces M's direct sales x_{AM} as well as y_{AM} and encourages volumes of parallel trade x_{AD} and y_{AD}. Third, high transportation cost, t_i, may increase or decrease the manufacturer's total profit. [9]

(2). If $0 \le t_x < \frac{3}{14}$ and $\frac{3}{14} \le t_y < \frac{1}{2}$, then there are parallel imports for good X but there are not for good Y.

$$w_x = \frac{1}{26(1-\beta^2)}[4(1+4t_x) - \beta(9+13\beta - 42t_y - 26\beta t_x)] \tag{21}$$

and $w_y = \frac{1}{26(1-\beta^2)}[(13-26t_y) + \beta(9-4\beta - 16\beta t_y - 42t_x)]$. [10] (22)

There are two components in w_x. The first part represents M's willingness to offer without considering the new product. That is, if the two goods are independent or unrelated goods $(\beta = 0)$, then M offers $w_x = \frac{2(1+4t_x)}{13}$. The second part of w_x involving β reflects the effect of the new product on the existing product. Similarly w_y has two components as well. The manufacturer will offer the wholesale price for the new product equals to $\frac{1}{2}(1-2t_y)$ in the case that these two products are unrelated goods. That is the first part of w_y. This is the same as in the case with only one product. The second part of w_y involving β reflects the impact of the existing product on the new product.

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[9] This is because $\frac{\partial \pi_M^p}{\partial t_i} = \frac{2}{13(1-\beta^2)}[(9t_i - 1) + \beta(9t_j - 1)] \ge or \le 0$.

[10] See appendix B(2) for the details.

Once the manufacturer notices the relation between these two products, he would like to adjust his decisions when he offers wholesale prices. [11]

Corollary 2: *If* $0 \le t_x < \frac{3}{14}$ *and* $\frac{3}{14} \le t_y < \frac{1}{2}$*, then volume of parallel trade of product* X *is,* $x_{AD} = \frac{1}{13}[\frac{3}{1-\beta} - \frac{14(t_x + \beta t_y)}{1-\beta^2}]$. [12] [13]

Although x_{AD} takes the same form as in corollary 1, it is different from that one because the transportation cost of good Y are different. See figure 2.

(3). If $0 \le t_x < \frac{3}{14}$ and $t_y \ge \frac{1}{2}$, then t_y is high enough to block parallel imports of product Y. However there are parallel imports for good X. Thus we should rewrite M's profit function and determine optimal wholesale prices by taking first order condition. [14] If $\beta > 0$, then X and Y are complementary goods. M will offer $w_x = \frac{2}{13-4\beta^2}(1-\beta^2)(1+4t_x)$. w_x is exactly the same as case one when $\beta = 0$. Those terms in w_x involving β represent the effects of the new product on the exiting product. The innovation of product Y may raise or lower the wholesale price of product X. M will offer $w_y = 0$ to get vertical pricing efficiency for the new product. However X and Y are substitutes when $\beta < 0$. M will offer $w_x = \frac{2}{13}(1+4t_x)$ and $w_y = -\frac{2}{13}\beta(1+4t_x)$. It is worth mentioning that regardless X and Y are substitutes or complements, parallel trade of product Y does not occur. [15] However parallel trade of good X does occur. These results are interesting for two reasons: First when X and Y are substitutes, M is willing to offer positive wholesale price for the new product. Intuitively positive w_y increases the distortion of product Y, but it increases the sales of product X in country B.

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[11] See (B11) in appendix B(2) for the profit.
[12] See (B12) in appendix B(2).
[13] Assumption 1 ensures that x_{AD} is nonnegative.
[14] See appendix B(3).
[15] If $\beta > 0$, then $w_y + t_y = t_y \ge \frac{1}{2}$, there is not parallel trade of Y. If $\beta < 0$, then $w_y + t_y > \frac{1}{2}$, and there is not parallel trade of Y as well.

Here the first effect is dominated by the second effect. Thus M is likely to offer positive w_y to increase his total profit. Second, we can see that w_x is lower in the case of X and Y are complements than that in the case of X and Y are substitutes. The logic is that if X and Y are complements, then M's direct sales of good X in country A is higher, [16] it forces D to sell fewer good X back to country A. This enables M to offer lower w_x to reduce the distortion in market B. [17]

Corollary 3: *If* $0 \le t_x < \dfrac{3}{14}$ *and* $t_y \ge \dfrac{1}{2}$*, then when* $\beta \ge 0$*,* we have

$x_{AD} = \dfrac{1}{3}[\dfrac{1-2t_x}{1-\beta^2} - \dfrac{4(1+4t_x)}{13-4\beta^2}]$ *and when* $\beta < 0$*, we have* $x_{AD} = \dfrac{3-14t_x}{13(1-\beta^2)}$. [18] [19]

(4). If $\dfrac{3}{14} \le t_x < \dfrac{1}{2}$ and $0 \le t_y < \dfrac{3}{14}$, then

$$w_x = \frac{1}{26(1-\beta^2)}[(13-26t_x)+\beta(9-4\beta-16\beta t_x-42t_y)]$$ and

$$w_y = \frac{1}{26(1-\beta^2)}[4(1+4t_y)-\beta(9+13\beta-42t_x-26\beta t_y)].$$ This case is symmetric with case (2). Again there are two components in w_x. When the innovation is not successful or X and Y are unrelated goods, the wholesale price of X is $\frac{1}{2}(1-2t_x)$, that is the first part of w_x. The terms in w_x involving β reflects the impact of innovation on the wholesale price of the existing product. When X and Y are independent goods, the optimal wholesale price of product Y is $\frac{2}{13}(1+4t_y)$, that is the first part of w_y. It is exactly the same as in the case in which there is just one good Y. The terms in w_y involving β reflects the effect of the existing product X on the wholesale price of the new product. In this case, parallel trade occurs for the new product Y and parallel imports for the existing product X are deterred by the high wholesale price. [20]

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[16] See appendix B(3).
[17] See (B25) and (B27) in appendix B(3) for the profits.
[18] See (B26) and (B28) in appendix B(3).
[19] It is easy to verify that x_{AD} is nonnegative.
[20] See (B29) in appendix B(4) for the profit.

Corollary 4: *If* $\frac{3}{14} \le t_x < \frac{1}{2}$ *and* $0 \le t_y < \frac{3}{14}$*, then volume of parallel trade of product* Y *is,* $y_{AD} = \frac{1}{13}[\frac{3}{1-\beta} - \frac{14(t_y + \beta t_x)}{1-\beta^2}]$. [21]

(5). If $\frac{3}{14} \le t_x, t_y < \frac{1}{2}$, then the first order conditions of the profit function with respect to w_x and w_y are positive. [22] Thus the manufacturer's incentives to prevent parallel trade are so high that he would like to offer wholesale prices are high enough to deter gray market activities for both products. That is, $w_x = \frac{1}{2}(1-2t_x)$ and $w_y = \frac{1}{2}(1-2t_y)$. It is not surprising to see that they are symmetric in terms of their own transportation cost. But w_x and w_y take the same forms as there is only one product. It is interesting that these wholesale prices only depend on their own transportation cost rather than on the other good's transportation cost. Obviously parallel imports for both goods are deterred in this case. The manufacturer's total profit is (B30) in appendix B(5).

(6). If $\frac{3}{14} \le t_x < \frac{1}{2}$ and $t_y \ge \frac{1}{2}$, then the high transportation cost of product Y blocks the parallel trade of the new good. The first order condition of M's profit function with respect to w_x is positive. [23] It is beneficial for M to offer high wholesale price for product X to deter parallel imports. Thus the optimal wholesale prices are $w_x = \frac{1}{2}(1-2t_x)$ and $w_y = 0$ when X and Y are complements ($\beta > 0$), and are $w_x = \frac{1}{2}(1-2t_x)$ and $w_y = -\beta\frac{1}{2}(1-2t_x)$ when X and Y are substitutes ($\beta < 0$). It is interesting that when X and Y are substitutes, M is willing to offer positive wholesale price for the new product Y. This will increase to distortion of product Y in country B. This distortion attributes to the impact of the existing product X on the new invented product Y.

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[21] Assumption 2 guarantees that y_{AD} is nonnegative.

[22] See appendix B(5).

[23] See appendix B(6).

If $\beta > 0$, then $\pi_M^p = \dfrac{1}{16(1-\beta)}[8(1+a^2) - \dfrac{(1-2t_x)^2}{1+\beta}] - k^p$ (23)

If $\beta < 0$, then $\pi_M^p = \dfrac{1}{16(1-\beta)}[8(1+a^2) - (1-\beta)(1-2t_x)^2] - k^p$ (24)

It is easy to see that the profit function is continuous because (23) and (24) are equal when $\beta = 0$. What surprising is that the manufacturer's profit is higher when $\beta < 0$ than that when $\beta > 0$.[24] In other words, when X and Y are substitutes the total profit is higher than that when X and Y are complements. Because there not parallel trade for both goods, when $\beta < 0$, w_y does not impact on the profit in market A. But higher w_y has two effects in market B: one is that higher wholesale price of product Y increases the distortion of this product, it has negative effect on M's profit; the other one is that higher wholesale price of Y raises the sales of product X. This has positive effect on M's profit. The manufacturer should balance these two effects and exercise wholesale prices. For this case the second effect outweighs the first one, and the total profit is higher when $\beta < 0$.

(7). If $t_x \geq \frac{1}{2}$ and $0 \leq t_y < \frac{3}{14}$, then t_x is high enough to block the parallel imports of product X. But parallel trade for good Y occurs. This case is symmetric with case (3) if we switch the roles of product X and Y. As in case (3), we should rewrite M's profit function and determine the optimal wholesale price for product Y by taking first order condition. If $\beta > 0$, then X and Y are complementary goods. M will offer $w_y = \dfrac{2}{13-4\beta^2}(1-\beta^2)(1+4t_y)$. w_y is exactly the same as case one when $\beta = 0$. Those terms in w_y involving β represent the effects of the existing product on the new invented product. M will offer $w_x = 0$ to get vertical pricing efficiency for the existing product. However when X and Y are substitutes. M will offer $w_x = -\frac{2}{13}\beta(1+4t_y)$ and

[24] Because $(1-\beta) < \dfrac{1}{1+\beta}$, thus the profit in (24) is higher than that in (23).

$w_y = \frac{2}{13}(1+4t_y)$. Here parallel trade of product X does not occur, but parallel trade of good Y does occur. Again w_x is positive when X and Y are substitutes and w_y is lower in the case of X and Y are complements than that in the case of X and Y are substitutes. We share the same intuition as in case (3). We shall not repeat them. [25]

Corollary 5: *If* $t_x \geq \frac{1}{2}$ *and* $0 \leq t_y < \frac{3}{14}$, *then when* $\beta \geq 0$, we have

$y_{AD} = \frac{1}{3}[\frac{1-2t_y}{1-\beta^2} - \frac{4(1+4t_y)}{13-4\beta^2}]$ *and when* $\beta < 0$, *we have* $y_{AD} = \frac{3-14t_y}{13(1-\beta^2)}$. [26]

(8). If $t_x \geq \frac{1}{2}$ and $\frac{3}{14} \leq t_y < \frac{1}{2}$, then the high transportation cost t_x blocks parallel trade of X. Similar to case (6), the first order condition of M's profit function with respect to w_y is positive. Thus M is willing to offer w_y high enough to prevent parallel trade of good Y. If X and Y are complements ($\beta > 0$), then the optimal wholesale prices are $w_x = 0$ and $w_y = \frac{1}{2}(1-2t_y)$. If X and Y are substitutes ($\beta < 0$), then the optimal wholesale prices are $w_x = -\frac{1}{2}\beta(1-2t_y)$ and $w_y = \frac{1}{2}(1-2t_y)$. Symmetric with case (6), M is willing to offer positive w_x when X and Y are substitutes. This will increase the sales of product Y at the cost of losing the sales of X by introducing the distortion to product X in country B. [27]

The manufacturer's profit is higher when $\beta < 0$ than that when $\beta > 0$. That is to say, when X and Y are substitutes, M's total profit is higher than that when X and Y are complements. We share the same intuition with case (6). Because there not parallel trade for both goods, when $\beta < 0$, higher w_x does not impact on the profit in market A. But it affects the profit in market B. On one hand, higher w_x increases the distortion of product X and reduces the sales of X; on the other hand, it encourages the sales of Y. For this case the second effect dominates the first one, and the total profit is higher when $\beta < 0$.

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[25] See (B35) and (B36) in appendix B(7) for the profits.

[26] It is very straightforward to verify that y_{AD} is nonnegative.

[27] The profits are (B37) and (B38) in appendix B(8).

Consequentially it is beneficial for M to offer positive wholesale price for the existing product X when $\beta < 0$.

(9). If $t_x \geq \frac{1}{2}$ and $t_y \geq \frac{1}{2}$, then the transportation costs t_x, t_y are so high that they block the gray market activities for both goods. This allows the manufacturer to offer zero wholesale prices and get maximum profits for both products in both countries. That is, $w_x = w_y = 0$. M's total profit is exactly the same as in the model in which there are no parallel imports at all.

3.2. Parallel trade of the existing product versus that of the new product

Given what we have observed in the previous discussions, one may wonder what happens if we prevent parallel trade of one good and allow parallel trade of the other? In this subsection, we formally investigate this possibility. For convenience, let the existing parallel imports represents the parallel imports of product X and the anticipated parallel trade denotes the parallel trade of product Y.

Proposition 1: *Consider these two cases:*

(1). Assume $t_x = t_1$ is high enough such that parallel trade of X is blocked. However, $t_y = t_2$ is small enough such that it allows parallel trade of Y.

(2). We switch the role of X and Y in the above case by assuming that $t_y = t_1$ is high enough such that parallel trade of Y is blocked and $t_x = t_2$ is small enough such that it allows parallel trade of X.

Given the above two cases, the manufacturer is more likely to make investment in product innovation in the second case than that in the first case.

We put the proof of this proposition in appendix C. This proposition implies that parallel imports of the new product are more harmful in reducing the manufacturer's incentives to invest in product innovation than those of the existing product. That is, the anticipated parallel trade discourages product innovation more than that of the existing parallel trade. Intuitively when the product innovation is successful, M's total profit increases more in the second case than that in the first case. Or we say in the other way, given the innovation cost and the probability of success in product innovation, when the innovation is not successful, M can get higher profit in the first case than that in the second case. Thus M is less likely to make investment in product innovation in the first case. It is somehow that the uncertainty of success in innovation makes the manufacturer distinguish the existing parallel trade from the anticipated parallel trade. Accordingly the manufacturer has different willingness to make investment in product innovation.

3.3. Do parallel imports lower the manufacturer's incentive to innovate?

How do we understand the role of parallel imports in a world in which the manufacturer may invest in product innovation? Some scholars assert that parallel trade inhibits the manufacturer's incentive to innovate. The basic logic behind these arguments is that the manufacturer's product innovation has the property of public goods so that parallel traders could free ride on it, the manufacturer does not internalize this effect and hence parallel imports may reduce the manufacturer's incentives to innovate. While these analysis sounds reasonable, M's incentives to innovate could be so high that it outweighs the consideration of gray market activities. That is, parallel imports may facilitate the product innovation. With the previous discussions in hand, we are ready to confirm our conclusion.

It follows that we should analyze the impacts of parallel imports on M's incentive to innovate. We can compare k with k^p by comparing ΔR_M with ΔR_M^p in (9) and (19) to show that whether parallel imports reduce the manufacturer's incentives to innovate. From figure 1, we know that there are nine possibilities. It is really messy to consider all these cases. To highlight our idea, in the rest of the paper we will focus on the first case of section 3.1 in which there are parallel imports for both products to show the impact of parallel imports on the manufacturer's incentives to innovate.

Proposition 2: *Parallel imports may or may not reduce the manufacturer's incentives to make investment in product innovation if* $0 \le t_x, t_y < \frac{3}{14}$.

The proof of this proposition is in appendix D. This proposition is surprising for two reasons: First it is interesting to know that β does not matter in comparing k^p with k in the proof of the first part. This is to say, no matter the existing product and the new product are substitutes or complements, we always have $k^p < k$ as long as $t_x = t_y = 0$ and $a = 1$. Alternatively, we can say that parallel trade does reduce the manufacturer's incentives in product innovation provided that $t_x = t_y = 0$ and $a = 1$. This result is highly consistent with previous arguments about parallel imports. We have confirmed their intuitive analysis by making use a simple numerical model.

Second, our proof in the second part indicates parallel imports may facilitate the manufacturer's incentive to innovate. This finding makes a big contrast with the existing arguments. Heavily based on intuitively analysis, the previous literature argues that parallel imports reduce M's incentive to invest in innovation. But here we show that the manufacturer could be willing to invest more in product innovation under the condition of parallel trade. The reason to the unusual result is that in the case of parallel imports product innovation may yield higher returns than that in the case of no parallel trade.

This proposition tells us parallel imports have ambiguous effect on product innovation. Parallel trade may encourage or discourage product innovation. The key to the surprising result is that whether parallel trade makes the manufacturer less likely to innovate or not depends on the transportation costs and the relation between these two products as well as the market sizes. Without specifying these parameters values, it is hard to say whether parallel imports reduce the manufacturer's incentive to make investment in product innovation.

Next we are going to focus on some special cases. As a benchmark, we start with the case in which there are zero transportation costs for both the existing product and the new product.

Corollary 6: *Parallel imports discourage the manufacturer's incentives to make investment in product innovation if the transportations costs are both equal to zero,* $t_x = t_y = 0$.

We put the proof in appendix E. It is worth mentioning that this is a sufficient but not necessary condition that parallel imports could reduce the manufacturer's incentive to engage in product innovation. In this corollary, we specify a more general case in which M is less likely to innovate in the presence of parallel imports. In this case, there are no transportation costs at all for both the existing good and the new good, parallel importers can benefit from involving in gray market activities. The increase in total is lower from successful innovation with parallel trade than that without parallel trade. This makes M less likely to invest in the product innovation.

Motivated by the case of zero transportation costs for both products, we now turn to look at the case in which both the transportation costs approach to $\frac{3}{14}$ from the left side. Our results are represented in corollary 7.

Corollary 7: *The manufacturer is less likely to invest in product innovation with parallel trade than that without parallel trade if the transportations costs are both equal and close to* $\frac{3}{14}$*, i.e.* $t_x = t_y \to \frac{3}{14}$.

The proof of this corollary is in appendix F. Corollary 6 and 7 give us a suggestion that whether we can get the same properties in the case of symmetric transportation costs. In the following proposition, we formally investigate this possibility and prove that our guess is correct.

Proposition 3: *Parallel imports inhibit product innovation if the transportations costs are equal,* $0 \le t_x = t_y = t < \frac{3}{14}$. [28]

Encouraged by the findings in the case of symmetric transportation cost, it is natural to examine what happens in the case of symmetric market sizes in these two countries. We are pleased that we have the same properties under the condition of symmetric market sizes and these two products are not substitutes. This result is generated in the following proposition.

Proposition 4: *When* $0 \le t_x, t_y < \frac{3}{14}$ *and* $\beta \ge 0$*, parallel imports reduce the manufacturer's incentives to invest in product innovation if market size of country B is the same as country A (*$a = 1$*).* [29]

Contrary to the case of process innovation that the manufacturer's incentive is independent with the distributor's market size, this proposition says that, if product X and Y are not substitutes, then the manufacturer is less likely to make investment in product innovation in the case of symmetric market sizes with parallel imports than that without parallel imports. As in the corollary 6, 7 together with proposition 3, this

[28] See appendix G for the proof.
[29] See appendix H for the proof.

proposition is sufficient but not necessary for M is less likely to innovate in the presence of gray market activities.

It is worth commentary for the case in which $a = 1$ and $\beta < 0$. If product X and Y are substitutes, we are not sure whether parallel imports discourage product innovation or not. Parallel trade could either facilitate [30] or inhibit [31] product innovation.

Proposition 3 concerns with the behavior of the manufacturer in a situation where the transportation costs are symmetric for the existing product and the new product. Proposition 4 focus the manufacturer's responses in a world where the two market sizes are the same when $\beta \geq 0$. Given what we have observed in this subsection, one may be encouraged to say whether there are some regular patterns concerning with M's decision for some values of β. The result is generated in the next proposition.

Proposition 5: *If* $0 \leq t_x, t_y < \frac{3}{14}$*, then parallel imports discourage product innovation when these two products are unrelated goods, i.e.* $\beta = 0$. [32]

Proposition 5 shows that when these two products are independent goods, parallel trade inhibits product innovation regardless the market sizes and the transportation costs. Unfortunately, for the other values of β, it is impossible to see some general rules after our investigation. Although we have revealed some difficulties associated with the impact of parameter β on M's incentives to innovate, it is useful to reiterate that β plays an important role in determining M's investment in product innovation.

Proposition 3 and 4 imply that in the case of symmetric market sizes when $\beta \geq 0$ and (or) the symmetric transportation costs, parallel imports discourage the manufacturer's incentives to invest in product innovation. Proposition 5 focuses on the case where $\beta = 0$. In the other cases than those in proposition 3, 4 and 5, parallel imports may encourage M's incentives to innovate.

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[30] For example, if $t_x = \frac{3}{70}$, $t_y = 0$ and $\beta = -\frac{4}{5}$, then $\Delta = \frac{1751}{573300} > 0$ and $k^p > k$.

[31] For example, if $t_x = \frac{1}{7}$, $t_y = \frac{3+\beta}{14}$ and for any $\beta \in (-1,0)$, then $\Delta = -\frac{(1+\beta)}{49(1-\beta)} < 0$ and $k^p < k$.

[32] See appendix I for the proof.

4. Conclusions

Our contribution of the present paper is examining the debate concerning product innovation in the presence of parallel imports with endogenous investment choices. In contrast to the existing less formal argument on product innovation under gray market activities, we have developed a formal model to show whether parallel imports discourage the manufacturer's incentives to innovate and provided many valuable insights. In constructing the model, great emphasis has been placed on the tractability and analysis. Our purpose is to have a model that can capture some important aspects of the markets with product innovation in the context of parallel trade and is yet simple enough to permit explicit solutions.

The first finding which is the most important one of this paper is that parallel trade may encourage or discourage the manufacturer's incentive to innovate, depending on the parameter values of the transportation costs, the market sizes together with the relation between these two products. This result is in sharp contrast to the existing arguments about parallel imports. The previous work in this literature argues that parallel imports inhibit innovation activities. We conclude that this standard result may or may not hold for the product innovation in the presence of parallel imports. It is not surprising to see that parallel trade discourages the manufacturer's incentive to make investment in product innovation because, after all, parallel importers free ride on the manufacturer's investment and reduces the total profit by introducing intra-brand competition. What is surprising, however, is that parallel imports could encourage the manufacturer's product innovation. The intriguing issue here is that the product innovation changes not only the sales and prices in both markets but also the volume of parallel trade of the existing product as well as the total profit. The increase in profit through successful innovation could be higher with parallel trade than that without parallel trade. Thus the manufacturer's incentives to innovate vary according to the dominant effect.

Another result implies that parallel imports of the new product are more harmful to product innovation than that of the existing product. That is to say, the manufacturer is more likely to make investment in the case of parallel trade of the existing product than that of the new product. Therefore the existing parallel trade differs from the anticipated parallel trade in determining the manufacturer's investment in product innovation. It seems that the uncertainty of innovation matters here: the manufacturer is more willing to invest in product innovation when he has higher expected returns from this innovation.

The final result indicates that the manufacturer is less likely to make investment in product innovation in the presence of gray market activities in the following cases: symmetric transportation costs, unrelated products or symmetric market sizes when these two products are not substitutes. That is, parallel imports do discourage product innovation in these three cases: symmetric transportation costs, independent products or symmetric market sizes when these two products are not substitutes. We should mention here these conditions are sufficient but not necessary for parallel trade to discourage the manufacturer's investment in product innovation.

Although it is very important of the relation between the existing product and the new product in determining the manufacturer's investment in product innovation, we have not seen the regular pattern when they are related products. It could be possible that parallel trade makes the manufacturer more likely to invest in product innovation regardless these two products are substitutes or complements.

While we believe this paper is offering some valuable insights on how parallel imports affect the manufacturer's incentive to engage in product innovation, it is not enough in understanding the impacts of parallel trade on product innovation in more general cases. It would be interesting for the future research to extend the model is this paper to incorporate multiple markets and multiple distributors. Another interesting direction for further research is to include the possibility of incomplete information on the distributor's market. In addition, it would be desirable to find some data and test our conclusions of this paper.

Appendix:

A. M's profit in A and D's gross profit in B are

$$\pi_A = (1 - x_A + \beta y_A)x_A + (1 - y_A + \beta x_A)y_A \tag{A1}$$

$$\pi_B = (a - x_B + \beta y_B - w_x)x_B + (a - y_B + \beta x_B - w_y)y_B \tag{A2}$$

The first order conditions of (A1) and (A2) yield

$$x_A:\ 1 - 2x_A + 2\beta y_A = 0 \tag{A3}$$

$$y_A:\ 1 - 2y_A + 2\beta x_A = 0 \tag{A4}$$

$$x_B:\ a - 2x_B + 2\beta y_B - w_x = 0 \tag{A5}$$

$$y_B:\ a - 2y_B + 2\beta x_B - w_y = 0 \tag{A6}$$

We solve (A3), (A4), (A5) and (A6) to get the solutions.

$$x_A = y_A = \frac{1}{2(1-\beta)},\ x_B = \frac{(a - w_x) + \beta(a - w_y)}{2(1-\beta^2)} \text{ and } y_B = \frac{(a - w_y) + \beta(a - w_x)}{2(1-\beta^2)} \tag{A7}$$

By using two-part tariff, M's total profit when he succeeds in product innovation is

$$\pi_M(x, y) = \pi_A + \pi_B + w_x x_B + w_y y_B - k$$

$$= \frac{1}{4(1-\beta^2)}(2 + 2a^2 + 2\beta + 2a^2\beta - w_y^2 - w_x^2 - 2\beta w_x w_y) - k \tag{A8}$$

$\dfrac{\partial \pi_M}{\partial w_x} = -\dfrac{w_x + \beta w_y}{2(1-\beta^2)} = 0$ and $\dfrac{\partial \pi_M}{\partial w_y} = -\dfrac{w_y + \beta w_x}{2(1-\beta^2)} = 0$. Thus we have

$$w_x = w_y = 0 \text{ and } \pi_M = \frac{1 + a^2}{2(1-\beta)} - k \tag{A9}$$

B. The first order conditions of (14), (15) and (16) are given by

$$x_{AM}:\ 1 - (2x_{AM} + x_{AD}) + \beta(2y_{AM} + y_{AD}) = 0 \tag{B1}$$

$$y_{AM}:\ 1 - (2y_{AM} + y_{AD}) + \beta(2x_{AM} + x_{AD}) = 0 \tag{B2}$$

$$x_{AD}:\ 1 - (x_{AM} + 2x_{AD}) + \beta(y_{AM} + 2y_{AD}) - w_x - t_x = 0 \tag{B3}$$

$$y_{AD}:\ 1 - (y_{AM} + 2y_{AD}) + \beta(x_{AM} + 2x_{AD}) - w_y - t_y = 0 \tag{B4}$$

$$x_B:\ a - 2x_B + 2\beta y_B - w_x = 0 \tag{B5}$$

$$y_B:\ a - 2y_B + 2\beta x_B - w_y = 0 \tag{B6}$$

It follows that we need to solve equations (B1) to (B6). The solutions are

$$x_{AM} = \frac{(1+t_x+w_x)+\beta(1+t_y+w_y)}{3(1-\beta^2)}, \quad x_{AD} = \frac{(1-2t_x-2w_x)+\beta(1-2t_y-2w_y)}{3(1-\beta^2)},$$

$$y_{AM} = \frac{(1+t_y+w_y)+\beta(1+t_x+w_x)}{3(1-\beta^2)}, \quad y_{AD} = \frac{(1-2t_y-2w_y)+\beta(1-2t_x-2w_x)}{3(1-\beta^2)},$$

$$x_B = \frac{(a-w_x)+\beta(a-w_y)}{2(1-\beta^2)} \quad \text{and} \quad y_B = \frac{(a-w_y)+\beta(a-w_x)}{2(1-\beta^2)}$$

With these results in hand, we are ready to get the manufacturer's profit. By plugging all the above solutions into M's profit function in (17), we have

$$\pi_M = \frac{1}{72}\Big(\frac{32}{1-\beta}+\frac{36a^2}{1-\beta}-\frac{16t_x}{1-\beta}+\frac{20t_x^2}{1-\beta}+\frac{20t_x^2}{1+\beta}-\frac{16t_y}{1-\beta}+\frac{40t_xt_y}{1-\beta}-\frac{40t_xt_y}{1+\beta}+\frac{20t_y^2}{1-\beta}+\frac{20t_y^2}{1+\beta}$$
$$+\frac{8w_x}{1-\beta}+\frac{16t_xw_x}{1-\beta}+\frac{16t_xw_x}{1+\beta}+\frac{16t_yw_x}{1-\beta}-\frac{16t_yw_x}{1+\beta}-\frac{13w_x^2}{1-\beta}-\frac{13w_x^2}{1+\beta}+\frac{8w_y}{1-\beta}+\frac{16t_xw_y}{1-\beta}-\frac{16t_xw_y}{1+\beta}$$
$$+\frac{16t_yw_y}{1-\beta}+\frac{16t_yw_y}{1+\beta}-\frac{26w_xw_y}{1-\beta}+\frac{26w_xw_y}{1+\beta}-\frac{13w_y^2}{1-\beta}-\frac{13w_y^2}{1+\beta}\Big)-k^p \tag{B7}$$

The next step is to get the optimal wholesale prices given transportation costs. It requires that the wholesale prices together with the transfer payments maximize M's total profit.

(1). If $0 \le t_x, t_y < \frac{3}{14}$, then the first order conditions of (B7) with respect to w_x and w_y are respectively given by

$$\frac{1}{18(1-\beta^2)}[(2+8t_x-13w_x)+\beta(2+8t_y-13w_y)=0 \tag{B8}$$

$$\frac{1}{18(1-\beta^2)}[(2+8t_y-13w_y)+\beta(2+8t_x-13w_x)=0 \tag{B9}$$

Thus we have then $w_x = \frac{2}{13}(1+4t_x)$ and $w_y = \frac{2}{13}(1+4t_y)$.

$$\pi_M^p = \frac{1}{26}\Big[\frac{12+13a^2}{1-\beta}-\frac{4(t_x+t_y)}{1-\beta}+\frac{18(t_x^2+2\beta t_xt_y+t_y^2)}{1-\beta^2}\Big]-k^p \tag{B10}$$

(2). If $0 \le t_x < \dfrac{3}{14}$ and $\dfrac{3}{14} \le t_y < \dfrac{1}{2}$, then we have

$$2 + 8t_y - 13w_y = 2 + 21t_y - 13(w_y + t_y) \ge 2 + 21 \times \frac{3}{14} - 13 \times \frac{1}{2} = 0.$$

Let $F = 2 + 8t_x - 13w_x$ and $G = 2 + 8t_y - 13w_y \ge 0$, then (B8) is simplified to be

$\dfrac{\partial \pi_M^p}{\partial w_x} = \dfrac{1}{18(1-\beta^2)}(F + \beta G) = 0$. So we get $F = -\beta G$ and (B9) becomes

$\dfrac{\partial \pi_M^p}{\partial w_y} = \dfrac{1}{18(1-\beta^2)}(G + \beta F) = \dfrac{1}{18(1-\beta^2)}(G - \beta^2 G) = \dfrac{G}{18} \ge 0$. Thus M will offer w_y high enough to prevent the parallel imports of good Y. That is, w_x and w_y solve

$\dfrac{\partial \pi_M^p}{\partial w_x} = \dfrac{1}{18(1-\beta^2)}(F + \beta G) = 0$ and $y_{AD} = \dfrac{(1 - 2t_y - 2w_y) + \beta(1 - 2t_x - 2w_x)}{3(1-\beta^2)} = 0$. This

yields $w_x = \dfrac{1}{26(1-\beta^2)}[4(1+4t_x) - \beta(9 + 13\beta - 42t_y - 26\beta t_x)]$ and

$w_y = \dfrac{1}{26(1-\beta^2)}[(13 - 26t_y) + \beta(9 - 4\beta - 16\beta t_y - 42t_x)]$. By plugging w_x and w_y into

(B7), we get M's profit

$$\pi_M^p = \frac{1}{208(1-\beta)}(96 + 104a^2 - \frac{9}{1-\beta} - 32t_y + \frac{84(t_y + \beta t_x)}{1-\beta^2} - \frac{49t_y^2}{1-\beta} - \frac{98t_y^2}{(1+\beta)^2} + \frac{95t_y^2}{1+\beta} - 32t_x$$
$$+ 288t_x t_y - \frac{98t_x t_y}{1-\beta} + \frac{196t_x t_y}{(1+\beta)^2} - \frac{386t_x t_y}{1+\beta} - \frac{49t_x^2}{1-\beta} - \frac{98t_x^2}{(1+\beta)^2} + \frac{291t_x^2}{1+\beta}) - k^p \tag{B11}$$

Plugging w_x and w_y into (20), we have $x_{AD} = \dfrac{1}{13}[\dfrac{3}{1-\beta} - \dfrac{14(t_x + \beta t_y)}{1-\beta^2}]$ (B12)

(3) If $0 \le t_x < \dfrac{3}{14}$ and $t_y \ge \dfrac{1}{2}$, then we get the profits of M and D through sales in country.

$$\pi_{AM} = x_{AM}[1 - (x_{AM} + x_{AD}) + \beta y_{AM}] + y_{AM}[1 - y_{AM} + \beta(x_{AM} + x_{AD})] \tag{B13}$$

$$\pi_{AD} = x_{AD}[1 - (x_{AM} + x_{AD}) + \beta y_{AM} - w_x - t_x] \tag{B14}$$

D's profit in market B is $\pi_B^p = x_B(a - x_B + \beta y_B - w_x) + y_B(a - y_B + \beta x_B - w_y)$ (B15)

M's total profit is $\pi_M^p = \pi_{AM} + \pi_{AD} + \pi_B^p + w_x(x_{AD} + x_B) + w_y y_B - k^p$ (B16)

The first order conditions of (B16) are given by

$$x_{AM}:\ 1-(2x_{AM}+x_{AD})+2\beta y_{AM}=0 \tag{B17}$$

$$y_{AM}:\ 1-2y_{AM}+\beta(2x_{AM}+x_{AD})=0 \tag{B18}$$

$$x_{AD}:\ 1-(x_{AM}+2x_{AD})+\beta y_{AM}-w_x-t_x=0 \tag{B19}$$

$$x_B:\ \ a-2x_B+2\beta y_B-w_x=0 \tag{B20}$$

$$y_B:\ \ a-2y_B+2\beta x_B-w_y=0 \tag{B21}$$

We solve all the equations from (B17) to (B21) and get

$$x_{AM}=\frac{1}{2(1-\beta)}-\frac{1}{6}(1-2t_x-2w_x),\ \ x_{AD}=\frac{(1-2t_x-2w_x)}{3},$$

$$y_{AM}=\frac{1}{2(1-\beta)},\ x_B=\frac{(a-w_x)+\beta(a-w_y)}{2(1-\beta^2)}\ \text{and}\ y_B=\frac{(a-w_y)+\beta(a-w_x)}{2(1-\beta^2)}$$

Plug all the solutions to (B16), we have

$$\pi_M^p=\frac{1}{36(1-\beta^2)}(17+18a^2+18\beta+18a^2\beta+\beta^2-8t_x+8\beta^2t_x+20t_x^2-20\beta^2t_x^2+4w_x$$

$$-4\beta^2w_x+16t_xw_x-16\beta^2t_xw_x-13w_x^2+4\beta^2w_x^2-18\beta w_xw_y-9w_y^2)-k^p \tag{B22}$$

The first order conditions are given by

$$\frac{\partial\pi_M^p}{\partial w_x}=\frac{1}{36(1-\beta^2)}(4-4\beta^2+16t_x-16\beta^2t_x-26w_x+8\beta^2w_x-18\beta w_y)=0 \tag{B23}$$

$$\frac{\partial\pi_M^p}{\partial w_y}=\frac{-1}{2(1-\beta^2)}(\beta w_x+w_y)\le 0 \tag{B24}$$

By solving (B23) and (B24), we have that if $\beta>0$ then

$w_x=\frac{2}{13-4\beta^2}(1-\beta^2)(1+4t_x)$ and $w_y=0$, and if $\beta<0$ then $w_x=\frac{2}{13}(1+4t_x)$ and

$w_y=-\frac{2}{13}\beta(1+4t_x)$. We plug the wholesale prices into (B22) and x_{AD}, we get M's profit and the volume of parallel trade.

If $\beta>0$, then $\pi_M^p=\frac{1}{4(1-\beta)}[2(1+a^2)+4(1-\beta)t_x^2-\frac{(1-\beta)(1+4t_x)^2}{13-4\beta^2}]-k^p$ (B25)

$$x_{AD}=\frac{1}{3}[\frac{1-2t_x}{1-\beta^2}-\frac{4(1+4t_x)}{13-4\beta^2}] \tag{B26}$$

If $\beta < 0$, then $\pi_M^p = \frac{1}{52(1-\beta)}[25 + 26a^2 + \beta - 4(1-\beta)t_x(2-9t_x)] - k^p$ [33] (B27)

$$x_{AD} = \frac{3-14t_x}{13(1-\beta^2)} \quad (B28)$$

[34]

(4). If $\frac{3}{14} \le t_x < \frac{1}{2}$ and $0 \le t_y < \frac{3}{14}$, then

$$\pi_M^p = \frac{1}{208(1-\beta)}(96 + 104a^2 - \frac{9}{1-\beta} - 32t_x + \frac{84(t_x + \beta t_y)}{1-\beta^2} - \frac{49t_x^2}{1-\beta} - \frac{98t_x^2}{(1+\beta)^2} + \frac{95t_x^2}{1+\beta} - 32t_y$$

$$+ 288t_x t_y - \frac{98t_x t_y}{1-\beta} + \frac{196t_x t_y}{(1+\beta)^2} - \frac{386t_x t_y}{1+\beta} - \frac{49t_y^2}{1-\beta} - \frac{98t_y^2}{(1+\beta)^2} + \frac{291t_y^2}{1+\beta}) - k^p \quad (B29)$$

(5). If $\frac{3}{14} \le t_x, t_y < \frac{1}{2}$, we are going to show that the first order conditions of (B7) are positive. Based on the notations in appendix B (2). If $\frac{3}{14} \le t_x, t_y < \frac{1}{2}$, then $F = 2 + 8t_x - 13w_x \ge 0$ and $G = 2 + 8t_y - 13w_y \ge 0$. Thus we should prove

$\frac{\partial \pi_M^p}{\partial w_x} = \frac{1}{18(1-\beta^2)}(F + \beta G) \ge 0$ and $\frac{\partial \pi_M^p}{\partial w_y} = \frac{1}{18(1-\beta^2)}(G + \beta F) \ge 0$.

Proof: Given the first order conditions, we only need to show both $F + \beta G \ge 0$ and $G + \beta F \ge 0$. Suppose it is not true, and then we have

(1). Assume one of $F + \beta G$ and $G + \beta F$ is zero and the other is negative. Without loss of generality, we suppose that of $F + \beta G = 0$ and $G + \beta F < 0$. Thus we have $G + \beta F = G - \beta^2 G = (1-\beta^2) > 0$, it is contradictory with our assumption $G + \beta F < 0$. Therefore it cannot be true that one of $F + \beta G$ and $G + \beta F$ is zero and the other is negative.

(2). Assume $F + \beta G < 0$ and $G + \beta F < 0$, this case possible only if $\beta < 0$. From $F + \beta G < 0$, we got $G > -\frac{F}{\beta}$. Thus $G + \beta F > -\frac{F}{\beta} + \beta F = F(\beta - \frac{1}{\beta}) > 0$. This is in

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[33] The profits in (B25) and (B26) are equal when $\beta = 0$. That is, M's profit function is continuous at $\beta = 0$.

[34] x_{AD} is continuous at $\beta = 0$.

contradiction with assumption $G+\beta F<0$. Accordingly it is impossible that both $F+\beta G$ and $G+\beta F$ are negative.

(3). Assume one of $F+\beta G$ and $G+\beta F$ is positive and the other is negative. Without loss of generality, we suppose that of $F+\beta G>0$ and $G+\beta F<0$. From $F+\beta G>0$, we get $F>-\beta G$, hence $G+\beta F>G-\beta^2 G=(1-\beta^2)G>0$. It contradicts assumption $G+\beta F<0$. Thus it is false that one of $F+\beta G$ and $G+\beta F$ is positive and the other is negative.

Based on the proofs of all the three cases above, we can see that both $F+\beta G\geq 0$ and $G+\beta F\geq 0$. The first order conditions of (B7) should be positive. ♠

M' profit is $$\pi_M^p=\frac{1}{8}\Big[\frac{3+4a^2}{1-\beta}+\frac{2(t_x+t_y)}{1-\beta}-\frac{4\beta t_x t_y+2(t_x^2+t_y^2)}{1-\beta^2}\Big] \qquad \text{(B30)}$$

(6). If $\frac{3}{14}\leq t_x<\frac{1}{2}$ and $t_y\geq\frac{1}{2}$, then the first order conditions of M's profit with respect to w_x and w_y are given by

$$\frac{\partial\pi_M^p}{\partial w_x}=\frac{1}{36(1-\beta^2)}(4-4\beta^2+16t_x-16\beta^2 t_x-26w_x+8\beta^2 w_x-18\beta w_y) \qquad \text{(B31)}$$

$$\frac{\partial\pi_M^p}{\partial w_y}=\frac{-1}{2(1-\beta^2)}(\beta w_x+w_y) \qquad \text{(B32)}$$

We will show that $\frac{\partial\pi_M^p}{\partial w_x}\geq 0$.

Proof: From (B32), we know that $\frac{\partial\pi_M^p}{\partial w_y}=\frac{-1}{2(1-\beta^2)}(\beta w_x+w_y)\leq 0$ and $w_y\leq-\beta w_x$.

Substitute $w_y\leq-\beta w_x$ into (B31), we have

$$\frac{\partial\pi_M^p}{\partial w_x}=\frac{1}{18(1-\beta^2)}(2-2\beta^2+8t_x-8\beta^2 t_x-13w_x+4\beta^2 w_x-9\beta w_y)$$

$$\geq\frac{1}{18(1-\beta^2)}(2-2\beta^2+8t_x-8\beta^2 t_x-13w_x+4\beta^2 w_x+9\beta^2 w_x)$$

$$=\frac{1}{18(1-\beta^2)}[(2+8t_x-13w_x)-\beta^2(2+8t_x-13w_x)]=\frac{1}{18}(2+8t_x-13w_x)$$

$$=\frac{1}{18}[2+21t_x-13(w_x+t_x)]\geq\frac{1}{18}(2+21\times\frac{3}{14}-13\times\frac{1}{2})=0$$ ♠

If $\beta>0$, then $\pi_M^p=\frac{1}{16(1-\beta)}[8(1+a^2)-\frac{(1-2t_x)^2}{1+\beta}]-k^p$ (B33)

If $\beta<0$, then $\pi_M^p=\frac{1}{16(1-\beta)}[8(1+a^2)-(1-\beta)(1-2t_x)^2]-k^p$ [35] (B34)

(7). If $t_x\geq\frac{1}{2}$ and $0\leq t_y<\frac{3}{14}$, then this case is symmetric with case (3).

If $\beta>0$, then $\pi_M^p=\frac{1}{4(1-\beta)}[2(1+a^2)+4(1-\beta)t_y^2-\frac{(1-\beta)(1+4t_y)^2}{13-4\beta^2}]-k^p$ (B35)

If $\beta<0$, then $\pi_M^p=\frac{1}{52(1-\beta)}[25+26a^2+\beta-4(1-\beta)t_y(2-9t_y)]-k^p$ [36] (B36)

(8). When $t_x\geq\frac{1}{2}$ and $\frac{3}{14}\leq t_y<\frac{1}{2}$, we have

If $\beta>0$, then $\pi_M^p=\frac{1}{16(1-\beta)}[8(1+a^2)-\frac{(1-2t_y)^2}{1+\beta}]-k^p$ (B37)

If $\beta<0$, then $\pi_M^p=\frac{1}{16(1-\beta)}[8(1+a^2)-(1-\beta)(1-2t_y)^2]-k^p$ [37] (B38)

C. Proof of proposition 1:

(1). The first case is equivalent to case 7 in section 3.1. M's profit, π_{M1}^p, is represented by (B35) or (B36) when M gets success in the innovation. However M's profit π_{M1} is the same as in (13) when M fails the innovation.

(2). The second case is equivalent to case 3 in section 3.1. M's profit, π_{M2}^p, is given by (B25) or (B27) when M succeeds in the innovation. However M's profit π_{M2} is the same as in (11) when M fails the innovation.

[35] It is easy to see that the profit function is continuous because (B33) and (B34) are equal when $\beta=0$.

[36] The profits in (B35) and (36) are equal when $\beta=0$.

[37] The profits in (B37) and (B38) are equal when $\beta=0$

Because $\pi_{M1} > \pi_{M2}$ and $\pi_{M1}^p = \pi_{M2}^p$ provided the condition 2. Hence we have $\Delta R_{M1}^p = \pi_{M1}^p - \pi_{M1} < \Delta R_{M2}^p = \pi_{M2}^p - \pi_{M2}$ and $k_1^p = \frac{1}{2}(d - \frac{1}{\Delta R_{M1}^p}) < \frac{1}{2}(d - \frac{1}{\Delta R_{M2}^p}) = k_2^p$. Therefore the manufacturer is more willing to make investment in product innovation in the second case than that in the first case. ♠

D. Proof of proposition 2: One problem we face is that the profit functions are too messy to compare without specifying some parameter values. However our focus is to get the basic idea about the impacts of parallel imports on M's incentive to innovate, we therefore look at some special cases here.

(1). In the first case of section 3.1 where M succeeds in product innovation, if we assume that $t_x = t_y = 0$ and $a = 1$, then we have $\Delta R_M^p = \pi_M^p - \pi_{MN}^p = \frac{25(1+\beta)}{52(1-\beta)}$. This is an extreme case with symmetric transportation costs and markets. If we consider the model in section 2.1 and assume that $a = 1$, then we get $\Delta R_M = \pi_M - \pi_{MN} = \frac{(1+\beta)}{2(1-\beta)}$. It is easy to see that $\Delta R_M^p < \Delta R_M$ and $k^p < k$. Accordingly, the manufacturer's incentive to make investment in product innovation is lower in the presence of parallel imports.

(2). But for the first case in section 3.1, if we assume that $t_x = \frac{3}{28}$, $t_y = 0$ and $\beta = -\frac{1}{2}$, then we get $\Delta R_M^p = \pi_M^p - \pi_{MN}^p = \frac{1}{30576}(2601 + 2548a^2)$. For the model in section 2.1, if we assume $\beta = -\frac{4}{5}$, then we get $\Delta R_M = \pi_M - \pi_{MN} = \frac{1}{12}(1+a^2)$. It is easy to check that $\Delta R_M^p > \Delta R_M$ [38] and $k^p > k$. That is, parallel imports encourage M's investment in product innovation. [39] ♠

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[38] $\Delta R_M^p - \Delta R_M = \frac{53}{30576} > 0$

[39] Actually if we pick up $t_y = 0$ and $t_x = \frac{3(1+\beta)}{14}$, there are many $\beta \in (-1, 0)$ such that $\Delta R_M^p > \Delta R_M$.

E. Proof of corollary 6: For the first case of section 3.1, if $t_x = t_y = 0$, then we have

$\Delta R_M^p = \Delta\pi_M^p = \pi_M^p - \pi_{MN}^p = \frac{(1+\beta)(12+13a^2)}{52(1-\beta)}$. However for the model in section 2.1,

we have $\Delta R_M = \Delta\pi_M = \pi_M - \pi_{MN} = \frac{(1+\beta)(1+a^2)}{4(1-\beta)}$. Thus we get $\Delta R_M^p < \Delta R_M$ and

$k^p < k$ because $\Delta R_M^p - \Delta R_M = -\frac{(1+\beta)}{52(1-\beta)} < 0$. ♠

F. Proof of corollary7: If $t_x = t_y \to \frac{3}{14}$, then

$\Delta R_M^p - \Delta R_M = \Delta\pi_M^p - \Delta\pi_M \to -\frac{(1+\beta)}{49(1-\beta)} < 0$. Thus we complete the proof by

getting $\Delta R_M^p < \Delta R_M$ and $k^p < k$. ♠

G. Proof of proposition 3: If $t_x = t_y = t$, then

$\Delta R_M^p - \Delta R_M = \Delta\pi_M^p - \Delta\pi_M = -\frac{(1+\beta)}{52(1-\beta)}(1+8t-36t^2)$. It is easy to see that it gets the

minimum value at $t = \frac{1}{9}$. Thus we just need to examine the values at $t = 0$, $t = \frac{1}{9}$ and

$t \to \frac{3}{14}$. If $t = 0$, then $\Delta R_M^p - \Delta R_M = -\frac{(1+\beta)}{52(1-\beta)} < 0$ and $k^p < k$. This is the case of

corollary 6. If $t = \frac{1}{9}$, then $\Delta R_M^p - \Delta R_M = -\frac{(1+\beta)}{36(1-\beta)} < 0$ and $k^p < k$, and if $t \to \frac{3}{14}$,

then $\Delta R_M^p - \Delta R_M \to -\frac{(1+\beta)}{49(1-\beta)} < 0$ and $k^p < k$. This is the case of corollary 7. Given

the above analysis, we have $\Delta R_M^p - \Delta R_M = -\frac{(1+\beta)}{52(1-\beta)}(1+8t-36t^2) < 0$, $\Delta R_M^p < \Delta R_M$

and $k^p > k$. ♠

H. Proof of proposition 4: When these countries have same market sizes, that is $a = 1$, then we have

$$\Delta R_M^p - \Delta R_M = \Delta\pi_M^p - \Delta\pi_M = \frac{1}{52}[-\frac{(1+\beta)}{1-\beta} - \frac{8(\beta t_x + t_y)}{1-\beta} + \frac{36\beta t_x^2}{1-\beta^2} + \frac{72\beta t_x t_y}{1-\beta^2} + \frac{36 t_y^2}{1-\beta^2}]$$

$$=\frac{1}{52(1-\beta^2)}[-(1+\beta)^2-8(1+\beta)(\beta t_x+t_y)+36\beta t_x^2+72\beta t_x t_y+36t_y^2] \quad \text{(H1)}$$

We need to show (H1) is negative. Remember that $0 \le t_x, t_y < \frac{3}{14}$, hence

(1). If $\beta > 0$, then $\Delta R_M^p - \Delta R_M = \frac{1}{52(1-\beta^2)}[-\beta^2(1+8t_x)-(1-18\beta t_x t_y)$

$$-2\beta(1-18t_x t_y)-2\beta t_y(4-9t_x)-4\beta t_x(2-9t_x)-4t_y(2-9t_y)]<0 \quad \text{(H2)}$$

(2). If $\beta = 0$, then $\Delta R_M^p - \Delta R_M = \frac{-1}{52(1-\beta^2)}[1+4t_y(2-9t_y)]<0$ (H3)

Thus we have we have $\Delta R_M^p < \Delta R_M$ and $k^p < k$. ♠

I. Proof of proposition 5: if $\beta = 0$, then

$\Delta R_M^p - \Delta R_M = \Delta\pi_M^p - \Delta\pi_M = -\frac{1}{52}[1+4t_y(2-9t_y)]<0$ and $k^p < k$ because

$0 \le t_y < \frac{3}{14}$. ♠

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