DISCUSSION PAPERS IN ECONOMICS

Working Paper No. 02-17

Parallel Imports and Cost Reducing Research and Development

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October 2002

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Parallel Imports and Cost Reducing Research and Development *

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October 22, 2002

Abstract: In this paper, we develop a model of cost-reducing innovation in the context of parallel imports with endogenous investment. It is shown that the difference between the profits when innovation is successful or not takes a U-shaped curve in terms of the cost of parallel imports. This result is very important because the difference between these two levels of profitability reflects the manufacturer's incentives to innovate. Consistent with the existing intuitive analysis, we find that parallel imports or distortions associated with parallel imports inhibit cost-reducing innovation. If parallel trade occurs, then banning parallel imports has ambiguous effect on the expected global welfare; if parallel trade is deterred but there are distortions associated with parallel trade, then the policy of restricting parallel trade raises the expected global welfare.

* We thank Jack Robles, Yongmin Chen, Fank S.T. Hsiao and seminar participants at Department of Economics, University of Colorado at Boulder for their insights and comments.
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Parallel Imports and Cost Reducing Research and Development

1. Introduction

Parallel imports are regarded as the genuine products produced under a protection of trademark, sold into another market without the manufacturer's authorization. Parallel imports have concerned the manufacturers, the distributors and policy makers for many reasons. One of these reasons is that parallel imports possibly reduce the manufacturer's incentives to invest in cost reducing innovation because parallel imports reduce profitability regardless innovation is successful or not. The relationship between parallel trade and innovation has been the subject of many informal analyses. [1] In this paper, I develop a model to analyse this question.

People think that because parallel imports imply a reduction in property right, and they may reduce research and development. However, this result does not necessarily follows, because parallel imports can reduce profits either when the innovation is successful or not. Since it is the difference between these two levels of profitability that determines the manufacturer's incentives to innovate, the consequence of parallel imports is not clear. I find in a formal model that in fact this intuition is correct. In my model, successful process innovation lowers marginal costs. This tell us that parallel imports have a stronger impact upon profitability the lower is the marginal costs. This makes sense because successful innovation raises the profit by less with parallel imports than the amount without parallel imports.

In this paper, we develop a model in which a manufacturer sells his product into another country through a distributor. The distributor may engage in gray market activities by selling the product back to the manufacturer's country. When the distributor engages in gray market activities, she competes with the manufacturer in Cournot fashion and incurs a non-negative transportation cost. The manufacturer offers a two-part tariff to the distributor which must simultaneously create incentives to address two issues. The first is an attempt to assure pricing in the foreign country as efficient as possible. The second is to minimize the level of parallel trade. These objectives are often in conflict. Prior to offering the distributor a take-it or leave-it contract, the manufacturer has the

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[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).

opportunity to conduct research into a cost-reducing technology. Our objective in this paper is to study the impact parallel trade has upon the manufacturer to conduct this research and development.

It is shown that the difference between the profits when innovation is successful or not takes U-shape in terms of cost of parallel trade. This result is important because the difference between these two levels of profitability reflects the manufacturer's incentives to innovate. Most importantly we find that parallel imports or the distortions associated with parallel imports discourage the manufacturer to make investment in process innovation. Our analysis supports the intuitive arguments in the existing literature. After all parallel imports reduce the increase of the manufacturer's profit in process innovation. Our welfare analysis suggests that, when parallel trade occurs, restricting parallel trade has ambiguous effect on the expected global welfare; when parallel trade does not occur but there are distortions in the foreign market, the policy of banning parallel imports increases the expected global welfare.

The rest of the paper is organized as follows: In section two, we present the basic model and we discuss two cases: In the first case we simply prohibit parallel imports; and in the second case we allow parallel trade. In the third section, we compare these two cases in section two and provide our analysis and main results. In the last section, we conclude and point out some possible future extensions. We put most of the graphs and some proofs in the appendix.

2. The model

Assume a manufacturer, M, sells his product in two countries, A and B. M sells his product by himself in country A, and sells his product through an independent distributor, D, in country B. M can not sell his product directly to B, but the distributor may sell the good back to A through gray market activities. M cannot legally ban the gray market. When D sells the product back to A, she competes with M a la Cournot in market A and incurs an additional constant marginal cost $t \geq 0$. The inverse demand in market A is $p_A = 1 - q$, and that in B is $p_B = a - q$. 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 whether he should invest in a cost reducing process innovation, then he makes the distributor a take-it or leave-it offer in the form of (w,T), w is the wholesale price and T is a transfer payment from D to M. Given the contract, the distributor D decides to accept or reject. If D rejects, no good is sold in country B and M sets the optimal output in country A. Let q_{AM} and q_{AD} denote the quantities sold in A by M and D, respectively, q_B is the quantity sold by D in market B. When the distributor accepts the offer, she chooses q_{AD} and q_B simultaneously and M determines his output in A.

One way to model M's investment problem is to set up marginal cost as a function of M's investment k. One problem is that, on one hand we should set marginal cost is the initial value when $k = 0$; On the other hand, marginal cost should be decreasing with k. The other problem is that M's optimal wholesale price and profit will be functions of k, this will make our model very messy. To make our model more tractable, we model it as follows: If M engages in process innovation by investing k, $0 \le k \le k_0$, then M's cost-reducing investment makes his marginal cost level c_L with probability $\Pr ob(c = c_L) = \alpha(k) = -bk^2 + dk$, and marginal cost level c_H with probability $\Pr ob(c = c_H) = 1 - \alpha(k) = 1 + bk^2 - dk$, where $0 \le c_L < c_H$, $b > 0$ and $d > 0$. Suppose $d > 2bk_0$, it is easy to see that $\alpha(k)$ is a continuous and twice differentiable strictly increasing function with $\alpha(0) = 0$. We assume that $\alpha(k_0) = 1$. That is, M's marginal cost level is c_H when he does not invest in process innovation or if the innovation is not successful. However M could reduce his marginal cost to c_L by investing k_0 in cost-reducing innovation.

Throughout this paper, we assume that $0 \le c_L < c_H < \min\{1, a\}$. This assumption is very reasonable because 1 and a are the market sizes of country A and country B. Thus it rules out the case in which the production in country A and country B is inactive.

2.1. The case in which parallel imports are prohibited

Our paper is aimed at the policy question: should governments attempt to prevent parallel trade if they wish to increase cost reducing R&D? To address this question, we first discuss the case in which there is not parallel trade. This happens when the government passes a law to legally ban parallel imports or the government raises the tariff to prevent parallel trade have the impact of increasing the parallel traders' transportation cost.

Let q_A denotes the quantities sold by M in country A, q_B is the quantity sold by D in market B. When the distributor accepts the offer, she chooses her output q_B in market B and M simultaneously determines his output in A. Throughout this paper, subscripts of w_i and c_i will denote the type of the wholesale price and cost, $i = H, L$.

M's profit and D's gross profit through sales in country A and B are

$$\pi_A = (1 - q_A - c_i)q_A \quad (1)$$

$$\pi_B = (a - q_B - w_i)q_B \quad (2)$$

It follows that M needs to choose the optimal contract. Once a contract is accepted, the transfer payment, T is sunk, and does not impact upon D's incentives. Hence, T may be set entirely to extract all D's profit. w_i on the other hand, is D's marginal cost of making sale in country B, it does have an impact upon D's incentives. Consequently, w_i is set only to impact incentives, while T is set only to extract profit.

To get the optimal wholesale price, M should solve

$$\max_{w_i \geq 0} \pi_M(w_i, c_i) = \pi_A(c_i) + \pi_B(w_i) + (w_i - c_i)q_B(w_i) - k \quad (3)$$

Because there are not parallel imports, M's problem in (3) is equivalent to $\max_{w_i \geq 0} \pi_M(w_i, c_i) = \pi_B(w_i) + (w_i - c_i)q_B(w_i) - k$. It is obvious that M should offer $w_i = c_i$ and get the monopoly profit in market B when parallel trade is prevented. [2] M's total profit in both markets is $\pi_M(w_i, c_i) = \frac{(1-c_i)^2}{4} + \frac{(a-c_i)^2}{4} - k$. (4)

Let $R_M(w_L, c_L) = \pi_M(w_L, c_L) + k$ and $R_M(w_H, c_H) = \pi_M(w_H, c_H) + k$ denote M's total revenues when the innovation is successful or not.

When M makes process innovation, his expected profit is

$$E_M = \alpha(k)R_M(w_L, c_L) + [1 - \alpha(k)]R_M(w_H, c_H) - k \quad (5)$$

[2] See appendix A.

Where $R_M(w_L, c_L)$ and $R_M(w_H, c_H)$ are evaluated at the optimal wholesale prices w_L and w_H respectively. Suppose $\alpha'(0) = d$ is large enough to guarantee that it is not optimal to set k=0. Let

$$\Delta R_M = R_M(w_L, c_L) - R_M(w_H, c_H) = \pi_M(w_L, c_L) - \pi_M(w_H, c_H) = \frac{(c_H - c_L)[(1+a) - (c_H + c_L)]}{2}$$

, then the first order condition of the investment problem (5) yields

$$k = \frac{1}{2b}(d - \frac{1}{\Delta R_M}) \qquad (6)$$

To formulate our idea, we make the following assumption:

A1: We assume that $\alpha'(0) = d$ is large enough.

This assumption is one of the conditions that ensure the manufacturer has incentives to invest in process innovation.

2.2. The case in which we allow parallel imports

We have presented the case where there is not parallel trade in the above subsection. Now we focus on the case in which parallel imports are allowed.

M's profit and D's gross profit through sales in country A are

$$\pi_{AM} = [1 - (q_{AM} + q_{AD}) - c_i]q_{AM} \qquad (7)$$

$$\pi_{AD} = [1 - (q_{AM} + q_{AD}) - w_i - t]q_{AD} \qquad (8)$$

By taking the first order conditions with respect to M and D's sales, we get some interesting results. [3] They are interesting for several reasons: First, in the presence of parallel imports, it is not surprising that q_{AM} is increasing in w_i and decreasing in c_i. As w_i increases, the volume of parallel trade, q_{AD}, decreases, under the Cournot competition, the manufacturer's quantity supply increases. Second, however the total sales $q_{AM} + q_{AD}$ decreases in w_i. That is, higher w_i reduces the distributor's sales back to country A, lowers the distortion from sales above monopoly output and decreases the inefficiency from having sales from the higher cost distributor rather than from the manufacturer. Third, as c_i increases, M's sales and the total sales decrease because the price in market A increases.

[3] See Appendix B.

We should make clear that parallel imports stop at a certain point of transportation cost. This introduces a kink in all of these expressions, such as q_{AM} , q_{AD} , $q_{AM} + q_{AD}$, w_i , T , π_{AM} and π_{AD} .

In country B, D maximizes $\max_{q_B} \pi_B = (a - q_B - w_i)q_B$ (9)

The manufacturer's problem is to solve

$$\max_{w_i \geq 0} \pi_M(w_i, c_i) = \pi_{AM}(w_i, c_i) + \pi_{AD}(w_i, c_i) + \pi_B(w_i, c_i) + (w_i - c_i)[q_{AD}(w_i, c_i) + q_B(w_i, c_i)] - k^p \tag{10}$$

The manufacturer's expected profit becomes [4]

$$E_M^p = \alpha(k^p)R_M^p(w_L, c_L) + [1 - \alpha(k)]R_M^p(w_H, c_H) - k^p \tag{11}$$

Where $R_M^p(w_{L,} c_L)$ and $R_M^p(w_{H,} c_H)$ are M's respective total revenues when cost-reducing innovation is successful or not in the presence of parallel trade. They are evaluated at the optimal wholesale prices w_L and w_H respectively. Let $\Delta R_M^p = R_M^p(w_L, c_L) - R_M^p(w_H, c_H) = \pi_M^p(w_L, c_L) - \pi_M^p(w_H, c_H)$, then the first order condition of the investment problem yields

$$k^p = \frac{1}{2b}(d - \frac{1}{\Delta R_M^p}) \tag{12}$$

To show that whether parallel imports reduce the manufacturer's incentives to invest in innovation, we need to compare (6) and (12) and show whether $k \geq k^p$ by comparing ΔR_M with ΔR_M^p. That is, if $\Delta R_M > \Delta R_M^p$, then $k > k^p$. Parallel imports reduce the manufacturer's incentive to innovate. If $\Delta R_M < \Delta R_M^p$, then $k < k^p$. Parallel imports encourage the manufacturer to engage in process innovation. If $\Delta R_M = \Delta R_M^p$, then $k = k^p$. Parallel trade does not matter for the manufacturer's incentive to make investment in process innovation.

3. Analysis

3.1. The optimal wholesale price

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[4] As we show below, it is possible that there is not parallel trade if innovation is not successful but there is parallel trade if innovation is successful.

When the manufacturer offers his contract to the distributor, he needs to decide the optimal wholesale price and the transfer payment. To get the optimal wholesale price, M should solve the problem in (10)

$$\max_{w_i \geq 0} \pi_M(w_i, c_i) = \pi_{AM}(w_i, c_i) + \pi_{AD}(w_i, c_i) + \pi_B(w_i, c_i) + (w_i - c_i)[q_{AD}(w_i, c_i) + q_B(w_i, c_i)] - k^p$$

$$= \frac{(1 + w_i + t - 2c_i)^2}{9} + \frac{(1 - 2w_i - 2t + c_i)^2}{9} + \frac{(a - w_i)^2}{4} + (w_i - c_i)(\frac{1 - 2w_i - 2t + c_i}{3} + \frac{a - w_i}{2}) - k^p \quad (13)$$

(1). If $0 \leq t < \frac{3(1 - c_i)}{14}$, then the first order condition of (13) is given by

$2 - 13w_i + 8t + 11c_i = 0$ and $w_i = \frac{2 + 8t + 11c_i}{13}$, there are parallel imports in this case.

If we take a look at w_i, it is increasing in t. It seems counterintuitive. There are two effects here: First, the bigger is t, the less does M have to worry about parallel imports. Obviously this would imply that w_i is decreasing in t. Also, as t increases, the total sales in country A must be getting closer to the monopoly output. So that reduces the need to increase w_i, since the closer the output is to the monopoly level, the less is marginal profits in absolute value. Second, the bigger is t, the higher is the cross-hauling waste per unit of volume of parallel trade and the more does M have to worry about parallel imports. The manufacturer needs to balance these two effects, together with the impact of higher wholesale price on market B, and exercises optimal wholesale price. With the increase of t, the second effect dominates the first one, and M hopes to offer higher w_i.

w_i is also increasing in c_i. Intuitively M is willing to offer higher wholesale price to cover the cost of production if his marginal cost is higher, the market effect is that higher c_i results in higher wholesale price that lowers the possibility of gray market activities at the cost of raising the distortion in market B,

Another interesting issue is, when the production in market A is active, i.e. $c_i < 1$, the optimal wholesale price w_i is always higher than c_i. This is reasonable because M always offers his optimal wholesale price higher than his marginal cost. If $c_i \geq 1+4t$, then the marginal cost is larger than one which is the market size of country A. Hence the production in market A is inactive. Under the assumption 1, this case never happens.

Proposition 1: *The relationship between T and c_i is not monotonic.* [5]

It is a little bit surprising that T_i does not decrease with c_i. Intuitively, while the higher c_i forces M to offer higher wholesale price w_i, this raises the distortion in market B and reduces the profit in market B. There are two effects in market A, one is the lower volume of parallel trade because of the higher wholesale price; the other one is the higher sale price. One effect could dominate the other. If the effect of higher sale price outweighs the effect of lower sales, then D gets higher profit from parallel imports. Otherwise D gets lower profit from his gray market activities. Thus T_i could be increasing or decreasing with c_i.

M's profit becomes

$$\pi_{M1}^{p} = \frac{1}{52}(12+13a^2-26ac_i-8t+36t^2-24c_i+8tc_i+25c_i^2)-k^p \qquad (14)$$

(2). If $\frac{3(1-c_i)}{14} \leq t < \frac{1-c_i}{2}$, then the first order condition of (13) with respect to w_i is positive, [6] Mathematically it is better for M to offer w_i as large as possible so long as $2(w_i+t) \leq 1+c_i$. The intuition here is that M's incentive to restrict parallel trade is so strong that it pushes up to the corner solution. We prefer to call this deterrence equilibrium. That is $w_i = \frac{1+c_i}{2}-t$. M has no need to offer w higher than $\frac{1+c_i}{2}-t$ because parallel trade is deterred. Otherwise his profit in market B and accordingly his total profit will be lower.

$$\pi_{M2}^{p} = \frac{1}{16}(4a^2+3-8ac_i+4t-4t^2-6c_i-4tc_i+7c_i^2)-k^p \qquad (15)$$

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[5] See appendix C.

[6] FOC of (13) = $[2+21t-13(w_i+t)+11c_i] > [2+21\times\frac{3(1-c_i)}{14}-\frac{13(1+c_i)}{2}+11c_i]=0$

(3). If $t \ge \frac{1-c_i}{2}$, then M's problem in (13) becomes

$$\max_{w_i \ge 0} \pi_M = \frac{(1-c_i)^2}{4} + \frac{(a-w_i)^2}{4} + \frac{(w_i - c_i)(a-w_i)}{2} - k^p \tag{16}$$

It is easy to get $w_i = c_i$ and $\pi_M = \frac{(1-c_i)^2}{4} + \frac{(a-c_i)^2}{4} - k^p$. (17)

In this case, the optimal wholesale price and M's profit are the same as in the model in section 2.1. But we have different reasons. Here it is the high transportation cost that prevents parallel trade. The manufacturer could offer the wholesale price equal to his marginal cost and achieve vertical pricing efficiency. We call this blocked equilibrium. In the model in section 2.1, it is the government policy that bans parallel imports.

To summarize

Proposition 2: The optimal wholesale price is piecewise linear in t and c_i. [7]

(Insert figure 1 and 2 here)

When M makes a take-it or leave-it offer by using contract C_i, the wholesale price increases in t when $0 \le t < \frac{3(1-c_i)}{14}$. In this case, parallel imports occur. When $\frac{3(1-c_i)}{14} \le t < \frac{1-c_i}{2}$, it is better for the manufacturer to offer wholesale price high enough to prevent parallel trade. Accordingly we get the deterrence equilibrium. When $t \ge \frac{1-c_i}{2}$, the cost of engaging parallel imports is so high that it allows the manufacturer to charge wholesale price equal to his marginal cost and achieve vertical pricing efficiency. Parallel imports are blocked when $t \ge \frac{3(1-c_i)}{14}$. This is the blocked equilibrium.

[7] See appendix D.

Corollary 1. There exists a unique t^*, $0 \le t^* < \frac{3(1-c_i)}{14}$ *such that* π_M *decreases in* t *when* $0 \le t < t^*$, *increases in* t *when* $t^* \le t < \frac{1-c_i}{2}$ *and is constant when* $t \ge \frac{1-c_i}{2} > t^*$.

The proof of this corollary is in appendix E. It is clear that π_M is U-shaped in terms of transportation cost. This is shown in figure 3.

(Insert Figure 3 here)

Thus the manufacturer's *profit curve* takes U-shape with respect to the cost of engaging in parallel importing. This result is similar to Maskus and Chen (2000), who find a similar U-shaped *global welfare curve.* [8] Though our model is different, [9] we share the same intuition with theirs. When the trade cost t is low, there are parallel imports. Parallel trade forces the manufacturer to raise the wholesale price, which creates a distortion in vertical pricing. On one hand, high wholesale price increases the cost of parallel trade, reduces the gray marketer's competition ability in country A and increases the manufacturer's profit in country A; On the other hand, high wholesale price lowers the sale and profit in market B. The net effect on the manufacturer's profit could be negative. Thus when $0 \le t < t^*$, the effect of high wholesale price on market A is dominated by the effect on market B, and the manufacturer's profit decreases with t.

However when $t^* \le t < \frac{3(1-c_i)}{14}$, as t increases, the effect of high wholesale price on market A outweighs that on market B, and the net effect on the manufacturer's profit is positive. π_M increases with t. When $\frac{3(1-c_i)}{14} \le t < \frac{1-c_i}{2}$, M chooses the wholesale price $w_i = \frac{1+c_i}{2} - t$ that is high enough to block parallel trade. It is important to note that w_i decreases with t. Higher t has no impact on the profit of market A, but it reduces the distortion in market B and raises M's total profit by lowering the wholesale price. When

[8] Global welfare is the combined industry profits and consumer surplus in two countries.
[9] For example, we allow positive marginal cost. Actually this difference plays very important roles in next section.

$t \geq \frac{1-c_i}{2}$, t is so high that it prevents parallel imports. The manufacturer could charge wholesale price equal to his marginal cost and achieves vertical pricing efficiency. M gets the monopoly profit in both markets. Accordingly the profit of the manufacturer becomes constant.

Corollary 2: *The volume of parallel imports is linear in transportation cost when* $0 \leq t < \frac{3(1-c_i)}{14}$.

Proof: When $0 \leq t < \frac{3(1-c_i)}{14}$, $w_i = \frac{2+8t+11c_i}{13}$. Plug w_i into $q_{AD}(w_i, c_i)$, we have $q_{AD} = \frac{1}{13}(3-14t-3c_i)$. Thus q_{AD} is linear in t. ♠

Corollary 2 implies that the volume of parallel trade is negatively related to the transportation cost. It is a linear function. The intuition is very easy. The higher t increases the marginal cost of gray market activities, and leads to lower volume of parallel trade. This is given by figure 4.

(Insert Figure 4 here)

Corollary 3: *The volume of parallel imports is linear in wholesale price when* $0 \leq t < \frac{3(1-c_i)}{14}$.

It is easy to get the proof of this corollary from the proof corollary 2. This corollary suggests that the volume of parallel trade is deceasing in wholesale price. That is, M's successful cost-reducing innovation reduces wholesale price and encourages parallel imports by lowering the marginal cost of gray market activities. The relation between wholesale price and volume of parallel trade is described in figure 5.

(Insert Figure 5 here)

3.2. The manufacturer's incentive to innovate

One question we need to answer: why the manufacturer has the incentive to invest in cost-reducing innovation? To answer this question, we must show that the profit when M gets success in process innovation is larger than that when he fails the innovation. Given assumption 1, we only need to show that $\pi_M^p(w_L, c_L) \geq \pi_M^p(w_H, c_H)$ or $R_M^p(w_L, c_L) \geq R_M^p(w_H, c_H)$. In other words, we should prove that, for every $c_j \in [c_L, c_H]$, we have $\pi_M^p(w_j, c_j)$ or $R_M^p(w_j, c_j)$ decreases with c_j. We provide our results with two propositions.

To simplify our analysis, we make another assumption:

Assumption 2: Assume that $4 - 7c_H + 3c_L > 0$.

As usual assumption plays the role in simplifying our analysis. It is a reasonable assumption if the marginal costs are much smaller that the market sizes of country A.

Proposition 3: $\dfrac{\partial \pi_M^p(w_j, c_j)}{\partial c_j} < 0 \;\; all \;\; t \geq 0$.

We put the proof of proposition 3 in appendix F. This proposition tells us that the manufacturer's profit function is decreasing in his marginal cost. Thus, to increase his profit, the manufacturer does have incentives to engage in process innovation. Hence proposition 4 follows immediately.

Proposition 4: *Given assumption 1, the manufacturer has incentives to make investment in cost-reducing innovation.*

If $0 \leq t < \dfrac{3(1 - c_H)}{14}$, then M sets the optimal wholesale price $w_H = \dfrac{2 + 8t + 11c_H}{13}$, parallel trade occurs. M may wish to reduce the marginal cost by engaging process innovation. Lower marginal cost, on one hand, reduces the distortion in market B because it enables the manufacturer to offer lower wholesale price; on the other hand, it increases the total sales and profit in market A. However, lower wholesale price strengthens D's competition ability in market A and encourages parallel imports. Provided assumption 1, the second effect is dominated by the first effect in this case. Therefore the manufacturer's profit decreases with marginal cost, it is better for the manufacturer to invest in cost-reducing activity.

If $\frac{3(1-c_H)}{14} \le t < \frac{1-c_H}{2}$, then the optimal wholesale price is $w_H = \frac{1+c_H}{2} - t$, parallel imports are deterred. As the marginal cost decreases, it both raises the profit in market A because of the higher sales, and increases the profit in market B by reducing the distortion. Accordingly M's total profit goes up as marginal cost goes down. M has the incentive to invest in cost reducing innovation.

If $t \ge \frac{1-c_H}{2}$, then parallel trade is blocked by the high transportation cost. This enables M to offer the wholesale price equal to the marginal cost and gets monopoly profits in both markets. Lower marginal cost raises M's total profit. Surely M is motivated to invest in cost-reducing innovation.

Given the transportation cost t, our analysis suggests that not only $\pi_M^p(w_L, c_L)$ takes the similar U-shape as $\pi_M^p(w_H, c_H)$ but also $\pi_M^p(w_L, c_L) > \pi_M^p(w_H, c_H)$. Figure 6 has presented the relation between $\pi_M^p(w_L, c_L)$ and $\pi_M^p(w_H, c_H)$.

(Insert Figure 6 here)

It is very important to notice that the difference between the profit functions represents the manufacturer's incentives to engage in cost-reducing innovation. Thus M's incentives to innovate vary with the transportation costs. We will discuss it in detail in the following subsection.

3.3. The manufacturer's incentive variation

We can use figure 7 to list all the above cases in detail.

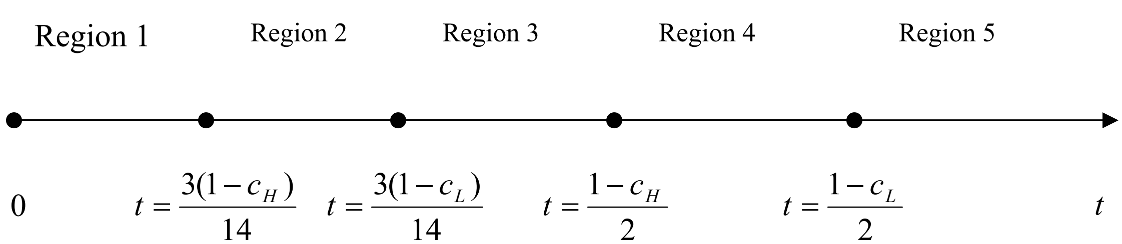

Figure 7

In region 1, there are parallel imports regardless process innovation is successful. In region 2, parallel trade occurs when M gets success in innovation but parallel trade is deterred when M fails innovation. In region 3, parallel imports are deterred by the high wholesale price in the case of either innovation is successful or not. In region 4, parallel imports are blocked by the high transportation cost when M does not succeed in innovation and parallel imports are deterred by the high wholesale price when M succeeds in innovation. In region 5, transportation cost is so high that it blocks parallel trade no matter process innovation is successful or not.

The intuition tells us successful process innovation should lower the wholesale price and reduce the distortions in market B. Is it true? The next proposition formally investigates this possibility.

Proposition 5: *Successful cost-reducing innovation is helpful in reducing the wholesale price.* [10]

Because the difference between the profit functions when the innovation is successful or not represents the manufacturer's incentive to innovate, so it is important to analyse these two levels of profitability. Based on the notation before, the result is generated in the following proposition.

Proposition 6: *There is a unique* t^{**}, $\frac{3(1-c_H)}{14} < t^{**} < \frac{3(1-c_L)}{14}$ *such that* ΔR_M^p *decreases in* t *when* $0 \le t < t^{**}$, *increases in* t *when* $t^{**} \le t < \frac{1-c_L}{2}$ *and is constant when* $t \ge \frac{1-c_L}{2} > t^{**}$.

The proof is in appendix H. This proposition implies that ΔR_M^p is continuous and takes a U-shaped curve in terms of the transportation cost. The relationship between ΔR_M^p and t is given in Figure 8.

(Insert Figure 8 here)

[10] See appendix G for the proof.

This proposition says that the difference between the profits when process innovation is successful and not first becomes smaller and smaller as t increases, however the decline of the difference between these two levels of profitability stops at a certain point t^{**}. Once we have $t^{**} \leq t < \frac{1-c_L}{2}$, the difference between these two profits increases with t. If transportation cost is high enough ($t \geq \frac{1-c_L}{2}$) to block parallel imports no matter innovation is successful or not, the difference in these two profit levels is constant.

Proposition 6 implies that the manufacturer's incentives in cost-reducing R&D vary according to transportation cost t. If t is small, then M's incentives to innovate decrease as t increases. After a certain point t^{**}, M's incentives to engage in process innovation increase with the increase in t. When t is so high that it blocks parallel imports regardless innovation, then M's incentives to innovate are independent in t.

For a calibrated model, by assuming that $a=1$, $c_H = \frac{1}{2}$ and $c_L = 0$, we have drawn a graph that has the difference between the profit functions on the vertical axis and transportation cost on the horizontal axis. This is presented in figure 9 which shows the relationship between $\pi_M^p(w_L, c_L) - \pi_M^p(w_H, c_H)$ and t.

(Insert Figure 9 here)

3.4. Does the parallel trade reduce the manufacturer's incentive to innovate?

The existing literature on parallel imports argues that parallel imports reduce the manufacturer's incentives to make innovation. The basic logic behind those arguments is that parallel traders free ride on the manufacturer's innovation. While these arguments sounds reasonable, M's incentive to innovate is the difference between profits. Hence we need to know if the profits with parallel trade are reduced by more or less than the amount by which profits without parallel trade are reduced.

It follows that we should answer the central question of this paper that whether parallel imports reduce the manufacturer's incentive to innovate. Actually proposition 6 and

Figure 8 are very illuminating. To address our question, we need to show the distance between the profit functions when $t \geq \frac{1-c_L}{2}$ [11] is higher than those in other cases.

Proposition 7: *Under assumption 1 and 2, parallel imports or the distortions associated with parallel imports discourage the manufacturer to make investment in process innovation.*

The proof of this proposition can be found at appendix I. The proposition is very interesting for several reasons. First, in region 1, the transportation cost can be neglected for our result and it contributes a little to our proof. It is a little bit surprising to see that the manufacturer's incentives to invest in process innovation are independent with the distributor's market size. The more important determinants are the manufacturer's market size and marginal costs when innovation is successful or not. While process innovation reduces the wholesale price and lowers the distortion in market B, what contributes most to the manufacturer's incentives to innovate are the competition effect in country A and the waste of parallel imports.

Second, in region 2, parallel trade is deterred by the high wholesale price if innovation is not successful. But parallel trade occurs if innovation is successful. Both the possible parallel imports and distortion in market B reduce the manufacturer's incentives to innovate.

Third, in region 3, while there are not parallel imports no matter M gets success in innovation or not, there is distortion in market B. It is the distortion that discourages M to make investment in process innovation.

Fourth, in region 4, although parallel trade is blocked by the high transportation cost if M does not succeed in his innovation, there is distortion in market B if M does succeed in his innovation. It is the possible distortion in market B inhibits the manufacturer's research and development.

What the most important of our finding is that parallel imports or the distortion associated with parallel imports reduce the manufacturer's incentive to innovate. This result confirms the existing theories on parallel trade. Based on intuitive analysis, the previous literatures argue that gray market activities introduce intra-brand product

[11] This case is equivalent to the case in which parallel trade is simply forbidden.

competition, free ride on the manufacturer's investment and lower the manufacturer's incentive to innovate. We have modeled this issue and our results support these arguments. Intuitively if there is not parallel trade or distortions associated with parallel trade regardless the innovation is successful, the manufacturer's profit is higher than that with parallel imports, successful cost-reducing innovation results in higher increase in M's total profits through more sales in both countries than that with parallel trade. It is obvious that, in the case of no parallel imports or no distortions associated with parallel imports, the manufacturer is willing to make more investment in cost-reducing innovation.

Proposition 6 is about the difference between the profit functions for different transportation cost when process innovations is successful or not. Proposition 7 tells us the manufacturer's incentive variation with the change in transportation cost t. Given transportation cost t, I turn to figure out the manufacturer's optimal investment levels by discussing M's expected profits with and without parallel imports. Also the analysis on M's expected profit is very useful when we analyse the expected welfare comparison in the following subsection.

Corollary 4: *For every $k \in [0, k_0]$, we have $E_M > E_M^p$.*

The proof of corollary 4 can be found in appendix J. This corollary implies that, given investment, the manufacturer's expected profit is higher in the case of no parallel trade than that with parallel trade.

One may wonder whether the equilibrium expected profit is higher in the case of without parallel imports than that with parallel imports. The next corollary formally investigates this possibility.

Corollary 5: *The equilibrium expected profit is higher without parallel imports than that with parallel imports.*

The proof of corollary 5 is pretty straightforward. If we use k_1^{p*} and k^* to denote the equilibrium investment levels with and without parallel trade, then we have $E_M(k^*) \geq E_M(k_1^{p*}) > E_M^p(k_1^{p*})$. The first inequality is resulted from the optimal investment k^*. The second inequality is due to corollary 4. Thus $E_M(k^*) > E_M^p(k_1^{p*})$.

From proposition 7 and corollary 4 and 5, we can easily know the relationship between E_M and E_M^p. This is provided by figure 10.

(Insert Figure 10 here)

3.5. Impact of restricting parallel imports on expected welfare

It is obvious that process innovation could change expected global welfare and expected welfare of both countries. It is easy to imagine that gray market activities should have impact on the changes of expected welfare. In this subsection, we will focus on this question and discuss the effect of restricting parallel imports on the changes of expected welfare. The results are summarized in following proposition.

Proposition 8: *Under assumption 1 and 2, restricting parallel imports*

(i). reduces the expected consumer surplus in country A, raises the expected consumer surplus in country B and has ambiguous impact on expected global welfare when

$$0 \le t < \frac{3(1-c_H)}{14};$$

(ii). lowers the expected consumer surplus in country A, increases the expected consumer surplus in country B and has ambiguous impact on expected global welfare when

$$\frac{3(1-c_H)}{14} \le t < \frac{3(1-c_L)}{14};$$

(iii). does not impact on the expected consumer surplus in country A, but raises the expected consumer surplus in country B and increases expected global welfare when

$$\frac{3(1-c_L)}{14} \le t < \frac{1-c_H}{2};$$

(iv). has no impact on the expected consumer surplus in country A, but increases the expected consumer surplus in country B and raises the expected global welfare when

$$\frac{1-c_H}{2} \le t < \frac{1-c_L}{2};$$

(v). does not impact on the expected consumer surplus in both countries and the expected global welfare when $t > \dfrac{1-c_L}{2}$.

The proof of this proposition is in appendix K.

In region 1 of figure 7, the transportation cost is relatively small, there are parallel imports either innovation is successful or not. Restricting parallel trade will raise the sale price in country A and reduce the expected consumer surplus of country A, but it will reduce the sale price in country B and raises the expected consumer surplus of country B. The effect of restricting parallel trade on the expected global welfare is ambiguous.

In region 2 of figure 7, there is no parallel trade if innovation is unsuccessful, but there is if innovation is successful. Parallel trade is helpful in raising the expected consumer surplus in country A but is harmful to increase the expected consumer surplus in country B. Thus restricting parallel trade raises the expected consumer surplus in country B at the cost of reducing the expected consumer surplus in country A, it may increase or decrease the expected global welfare.

In region 3 of figure 7, parallel trade is deterred by the high wholesale price no matter innovation is successful or not, so restricting gray market activities does not impact on the expected consumer surplus in country A, but it raises the expected consumer surplus in country B through correcting the distortion, and it results in higher expected global welfare.

In region 4 of figure 7, parallel trade does not occur regardless M succeeds in process innovation. Hence preventing parallel imports has no impact on the expected consumer surplus in country A, however it increases the expected consumer surplus in country B by making the distortion disappear, and it leads to higher expected global welfare.

The case in region 5 of figure 7 is equivalent to the case where parallel trade is prevented. Thus restricting parallel imports does not impact on the expected consumer surplus and global welfare.

4. Conclusion

In this paper, we contribute to the literature of parallel imports by reviewing the debate concerning cost-reducing innovation in the context of parallel trade with endogenous investment choice. Most of the previous work on innovation with parallel imports is less formal. We have made one step further by developing a theoretical model of process innovation in the presence of parallel imports with vertical price control and have offered some insights. The model was chosen to be as simple as possible, and could be easily managed.

Our first result implies that if the cost of parallel imports, i.e. the transportation cost, varies, then the manufacturer's profit curve appears to be U-shaped. The variation of transportation cost can affect parallel trade by changing the gray marketer's competition ability; it can also affect the manufacturer's incentive in setting the wholesale price. When the transportation cost is small, parallel trade forces the manufacturer to raise wholesale price to control the gray market activities. However, higher wholesale price increases the distortion in the distributor's market, the net effect on the manufacturer's profit could be negative. As the increase of the transportation cost, the manufacturer can offer lower wholesale price to improve vertical pricing efficiency, especially when the transportation cost is high enough to prevent the parallel imports, then the manufacturer's profit achieves maximum.

Our second result suggests that successful cost-reducing innovation is helpful in lowering the wholesale price. Our discussions indicate that, for any given positive transportation cost, successful cost-reducing innovation allows the manufacturer to reduce the distortion in the distributor's market by choosing lower wholesale price, and it also raises the profit in the manufacturer's market through more sales.

The third result of this paper suggests that the difference between profits when innovation is successful or not takes U-shape in terms of the cost of parallel trade. This is a very important finding because the difference between the two profits reflects the manufacturer's incentives to innovate. That is, the manufacturer's incentive in research and development first decreases as the cost of parallel trade decreases, then it increases with the cost of parallel imports, and finally it remains constant.

Our main contribution of this paper is that, if the production is active in the manufacturer's market, then parallel imports inhibit process innovation. That is the most important result of the present paper. This finding is quite consistent with the existing intuitive analysis in the literature. Intuitively, by engaging in process innovation, the manufacturer gets higher expected profit without parallel trade than that with parallel trade. It should therefore not be a surprise to see that parallel imports or distortions associated with parallel import could discourage cost-reducing innovation.

Our welfare analysis indicates that, if there is parallel trade, then restricting parallel trade raises the expected consumer surplus in country B at the cost of reducing the expected consumer surplus in country A, the expected global welfare may be higher or lower; if there is no parallel trade because of the high wholesale price, then the policy of preventing parallel trade does not impact on the expected consumer surplus in country A, but it raises the expected consumer surplus in country B and the expected global welfare

Of course, the simple model of this paper limits the scope of our results. It would be interesting, for example, to extend our analysis to the case of more general functions. Another interesting extension of this paper is to develop a model of product innovation in the content of parallel trade and see if parallel imports or distortions associated with parallel imports could affect the manufacturer's incentive to make investment. Still another possible direction of the extension of this paper is to find data and test our results in this paper.

Appendix

A. If we do *not* allow parallel imports, then M's profit and D's gross profit through sales in country A and B are

$$\pi_A = (1 - q_A - c_i)q_A \tag{A1}$$

$$\pi_B = (a - q_B - w_i)q_B \tag{A2}$$

Where $i = L, H$. The first order conditions yield

$$q_A(c_i) = \frac{1-c_i}{2}, \quad p_A(c_i) = \frac{1+c_i}{2} \quad \text{and} \quad \pi_A(c_i) = \frac{(1-c_i)^2}{4} \tag{A3}$$

$$q_B(w_i) = \frac{a-w_i}{2}, \quad p_B(w_i) = \frac{a+w_i}{2} \quad \text{and} \quad \pi_B(w_i) = \frac{(a-w_i)^2}{4} \tag{A4}$$

To get the optimal wholesale price, M should solve

$$\max_{w_i \geq 0} \pi_M(w_i, c_i) = \pi_A(c_i) + \pi_B(w_i) + (w_i - c_i)q_B(w_i) - k$$

$$= \frac{(1-c_i)^2}{4} + \frac{(a-w_i)^2}{4} + \frac{(a-w_i)(w_i-c_i)}{2} - k \tag{A5}$$

The first order condition is $\frac{-(w_i - c_i)}{2} = 0$, thus M tends to choose $w_i = c_i$.

$$T_i = \frac{(a-c_i)^2}{4} \quad \text{and} \quad \pi_M(w_i, c_i) = \frac{(1-c_i)^2}{4} + \frac{(a-c_i)^2}{4} - k\,. \tag{A6}$$

B. When we *allow* parallel imports, M's profit and D's gross profit through sales in country A are

$$\pi_{AM} = [1 - (q_{AM} + q_{AD}) - c_i]q_{AM} \tag{B1}$$

$$\pi_{AD} = [1 - (q_{AM} + q_{AD}) - w_i - t]q_{AD} \tag{B2}$$

Where $i = L, H$. The first order conditions yield

$$q_{AM}(w_i, c_i) = \begin{cases} \dfrac{1 + w_i + t - 2c_i}{3} & if\, 2(w_i + t) < 1 + c_i \\ \dfrac{1-c_i}{2} & if\, 2(w_i + t) \geq 1 + c_i \end{cases} \tag{B3}$$

$$q_{AD}(w_i,c_i)=\begin{cases}\dfrac{1-2w_i-2t+c_i}{3} & if\, 2(w_i+t)<1+c_i \\ 0 & if\, 2(w_i+t)\geq 1+c_i\end{cases} \tag{B4}$$

$$p_A(w_i,c_i)=\begin{cases}\dfrac{1+w_i+t+c_i}{3} & if\, 2(w_i+t)<1+c_i \\ \dfrac{1+c_i}{2} & if\, 2(w_i+t)\geq 1+c_i\end{cases} \tag{B5}$$

$$\pi_{AM}(w_i,c_i)=\begin{cases}\dfrac{(1+w_i+t-2c_i)^2}{9} & if\, 2(w_i+t)<1+c_i \\ \dfrac{(1-c_i)^2}{4} & if\, 2(w_i+t)\geq 1+c_i\end{cases} \tag{B6}$$

$$\pi_{AD}(w_i,c_i)=\begin{cases}\dfrac{(1-2w_i-2t+c_i)^2}{9} & if\, 2(w_i+t)<1+c_i \\ 0 & if\, 2(w_i+t)\geq 1+c_i\end{cases} \tag{B7}$$

In country B, D maximizes $\max_{q_B} \pi_B = (a-q_B-w_i)q_B$ (B8)

$$q_B(w_i,c_i)=\frac{a-w_i}{2},\quad p_B(w_i,c_i)=\frac{a+w_i}{2} \text{ and } \pi_B(w_i,c_i)=\frac{(a-w_i)^2}{4} \tag{B10}$$

Thus the quantity demand by the distributor is

$$Q(w_i,c_i)=q_{AD}(w_i,c_i)+q_B(w_i,c_i)=\frac{1-2w_i-2t+c_i}{3}+\frac{a-w_i}{2} \tag{B11}$$

C. If $0\leq t<\dfrac{3(1-c_i)}{14}$, then

$$T_i=\frac{1}{676}(40-52a+169a^2-304t-208at+848t^2-28c_i-286ac_i+512tc_i+157c_i^2) \tag{C1}$$

D. When M offers contract $C_i=(w_i,T_i)$, $i=L,H$, then

$$w_i=\begin{cases}\dfrac{2+8t+11c_i}{13} & if \quad 0\leq t<\dfrac{3(1-c_i)}{14} \\ \dfrac{1+c_i}{2}-t & if \quad \dfrac{3(1-c_i)}{14}\leq t<\dfrac{1-c_i}{2} \\ c_i & if \quad t\geq\dfrac{1-c_i}{2}\end{cases} \text{ and}$$

$$T_i = \begin{cases} (C1) & if \quad 0 \le t < \frac{3(1-c_i)}{14} \\ \frac{(2a+2t-1-c_i)^2}{16} & if \quad \frac{3(1-c_i)}{14} \le t < \frac{1-c_i}{2} \\ \frac{(a-c_i)^2}{4} & if \quad t \ge \frac{1-c_i}{2} \end{cases}$$

M's profit is

$$\pi_M = \begin{cases} \frac{1}{52}(12+13a^2-26ac_i-8t+36t^2-24c_i+8tc_i+25c_i^2)-k^p & if \quad 0 \le t < \frac{3(1-c_i)}{14} \\ \frac{1}{16}(4a^2+3-8ac_i+4t-4t^2-6c_i-4tc_i+7c_i^2)-k^p & if \quad \frac{3(1-c_i)}{14} \le t < \frac{1-c_i}{2} \\ \frac{(1-c_i)^2+(a-c_i)^2}{4}-k^p & if \quad t \ge \frac{1-c_i}{2} \end{cases}$$

E. Proof of corollary 1: (1) If $0 \le t < \frac{3(1-c_i)}{14}$, then $\frac{\partial \pi_M}{\partial t} = \frac{-8+72t+8c_i}{52} \ge or < 0$.

Thus if $t^* = \frac{1-c_i}{9}$ then $\frac{\partial \pi_M}{\partial t}|_{t=t^*} = 0$ and $\frac{\partial^2 \pi_M}{\partial t^2} > 0$. When $0 \le t < t^*$,

$\frac{\partial \pi_M}{\partial t} = \frac{-8+72t+8c_i}{52} < 0$, π_M is decreasing in t. When $t^* \le t < \frac{3(1-c_i)}{14}$,

$\frac{\partial \pi_M}{\partial t} = \frac{-8+72t+8c_i}{52} > 0$, π_M is increasing in t.

$$\lim_{t \to (\frac{3(1-c_i)}{14})_-} \pi_M = \frac{1}{196}(45+49a^2-98ac_i-90c_i+94c_i^2).$$

(2) If $\frac{3(1-c_i)}{14} \le t < \frac{1-c_i}{2}$, then $\frac{\partial \pi_M}{\partial t} = \frac{1}{2}(\frac{1-c_i}{2}-t) > 0$, π_M is increasing in t.

$\frac{\partial^2 \pi_M}{\partial t^2} < 0$. $\lim_{t \to (\frac{3(1-c_i)}{14})_+} \pi_M = \frac{1}{196}(45+49a^2-98ac_i-90c_i+94c_i^2) = \pi_M(t = \frac{3(1-c_i)}{14})$ and

$$\lim_{t \to (\frac{1-c_i}{2})_-} \pi_M = \frac{(1-c_i)^2+(a-c_i)^2}{4} = \pi_M(t = \frac{1-c_i}{2}).$$

(3) If $t \ge \frac{1-c_i}{2} > t^*$, then $\pi_M = \frac{(1-c_i)^2 + (a-c_i)^2}{4}$ and $\frac{\partial \pi_M}{\partial t} = 0$. Thus π_M is constant. $\lim_{t \to (\frac{1-c_i}{2})_+} \pi_M = \frac{(1-c_i)^2 + (a-c_i)^2}{4} = \pi_M (t = \frac{1-c_i}{2}) = \lim_{t \to (\frac{1-c_i}{2})_-} \pi_M$.

From (1), (2) and (3), we know that π_M is continuous in t and π_M *decreases in* t *when* $0 \le t < t^*$, *increases in* t *when* $t^* \le t < \frac{1-c_i}{2}$ *and is constant when* $t \ge \frac{1-c_i}{2} > t^*$.

♠

F. Proof of proposition 3: We prove this proposition with three lemmas.

For every $c_j \in [c_L, c_H]$, we have

Lemma 1: $\frac{\partial \pi_M^p (w_j, c_j)}{\partial c_j} < 0$ *when* $0 \le t < \frac{3(1-c_j)}{14}$.

Proof: If $0 \le t < \frac{3(1-c_j)}{14}$, then

$$\frac{\partial \pi_M^p}{\partial c_j} = \frac{-13a - 12 + 4t + 25c_j}{26} < -\frac{1}{26}[13a + 12 - 4 \times \frac{3(1-c_j)}{14} - 25c_j]$$

$$= -\frac{1}{182}(91a + 78 - 169c_j) = -\frac{1}{182}[91(a-c_j) + 78(1-c_j)] < 0 .$$

♠

Lemma 2: $\frac{\partial \pi_M^p (w_j, c_j)}{\partial c_j} < 0$ when $\frac{3(1-c_j)}{14} \le t < \frac{1-c_j}{2}$.

Proof: If $\frac{3(1-c_j)}{14} \le t < \frac{1-c_j}{2}$, then

$$\frac{\partial \pi_M^p}{\partial c_j} = -\frac{1}{8}(4a + 3 + 2t - 7c_j) < -\frac{1}{8}[4a + 3 + 2 \times \frac{3(1-c_j)}{14} - 7c_j]$$

$$= -\frac{1}{14}[7(a-c_j) + 6(1-c_j)] < 0 .$$

♠

Lemma 3: $\frac{\partial \pi_M^p (w_j, c_j)}{\partial c_j} < 0$ when $t \ge \frac{1-c_j}{2}$.

Proof: If $t \geq \frac{1-c_j}{2}$, then $\frac{\partial \pi_M^p}{\partial c_j} = -\frac{1}{2}[(a-c_j)+(1-c_j)] < 0$. ♠

G. Proof of proposition 5: we proceed with 5 lemmas.

Lemma 4: *Successful cost-reducing innovation is helpful in lowering wholesale price when* $0 \leq t < \frac{3(1-c_H)}{14}$.

The proof of lemma 4 is obvious because we have $w_H = \frac{2+8t+11c_H}{13}$ and $w_L = \frac{2+8t+11c_L}{13}$ when $0 \leq t < \frac{3(1-c_H)}{14}$.

Lemma 5: *Successful cost-reducing innovation helps to reduce wholesale price when* $\frac{3(1-c_H)}{14} \leq t < \frac{3(1-c_L)}{14}$.

Proof: When $\frac{3(1-c_H)}{14} \leq t < \frac{3(1-c_L)}{14}$, the optimal wholesale price changes from $w_H = \frac{1+c_H}{2} - t$ to $w_L = \frac{2+8t+11c_L}{13}$. Thus we have

$$w_H - w_L = \frac{1+c_H-2t}{2} - \frac{2+8t+11c_L}{13} = \frac{1}{26}(9-42t+13c_H-22c_L)$$

$$\geq \frac{1}{26}[9-42\times\frac{3(1-c_L)}{14}+13c_H-22c_L] = \frac{1}{2}(c_H-c_L) > 0$$ ♠

Lemma 6: *Successful cost-reducing innovation decreases wholesale price when* $\frac{3(1-c_L)}{14} \leq t < \frac{1-c_H}{2}$.

Lemma 6 is true because of $w_H = \frac{1+c_H}{2} - t$ and $w_L = \frac{1+c_L}{2} - t$.

Lemma 7: *Successful process innovation enables the manufacturer to offer lower wholesale price when* $\frac{1-c_H}{2} \leq t < \frac{1-c_L}{2}$.

Proof: If M is not succeeding in process innovation, then the wholesale price is $w_H = c_H$. However, if M gets success in the innovation, then the wholesale price becomes $w_L = \frac{1+c_L}{2} - t$. When $\frac{1-c_H}{2} \le t < \frac{1-c_L}{2}$, we have

$$w_L = \frac{1+c_L}{2} - t \le \frac{1+c_L}{2} - \frac{1-c_H}{2} = \frac{c_H + c_L}{2} < c_H .$$ [12] ♠

Lemma 8: *Successful cost-reducing innovation reduces wholesale price when* $t \ge \frac{1-c_L}{2}$.

The proof of lemma 8 is straightforward since the wholesale price decreases from $w_H = c_H$ to $w_L = c_L$ through the innovation.

Hence we complete the proof of proposition 5.

H. Proof of proposition 6:

(1) If $0 \le t < \frac{3(1-c_H)}{14}$, then $\Delta R_{M1}^p = \frac{1}{52}(c_H - c_L)[26a + 24 - 8t - 25(c_H + c_L)]$ (H1)

Obviously ΔR_{M1}^p is decreasing in t.

$$\lim_{t \to (\frac{3(1-c_H)}{14})-} \Delta R_{M1}^p = \frac{1}{364}(156c_H + 182ac_H - 163c_H^2 - 156c_L - 182ac_L - 12c_H c_L + 175c_L^2)$$

(2). If $\frac{3(1-c_H)}{14} \le t < \frac{3(1-c_L)}{14}$, then

$$\Delta R_{M2}^p = \frac{1}{208}[9 + 104a(c_H - c_L) - 84t + 196t^2 + 78c_H - 96c_L + 52tc_H + 32tc_L - 91c_H^2 + 100c_L^2]$$

(H2)

$\frac{\partial \Delta R_{M2}^p}{\partial t} = \frac{1}{208}(-84 + 392t + 52c_H + 32c_L) \ge or < 0$. Thus if $t^{**} = \frac{21 - 13c_H - 8c_L}{98}$, then

$\frac{\partial \Delta R_{M2}^p}{\partial t}|_{t=t^{**}} = 0$ and $\frac{\partial^2 \Delta R_{M2}^p}{\partial t^2} > 0$. When $\frac{3(1-c_H)}{14} \le t < t^*$,

$\frac{\partial \Delta R_{M2}^p}{\partial t} = \frac{1}{208}(-84 + 392t + 52c_H + 32c_L) < 0$. ΔR_{M2}^p is decreasing in t. When

$t^* \le t < \frac{3(1-c_L)}{14}$, $\frac{\partial \Delta R_{M2}^p}{\partial t} = \frac{1}{208}(-84 + 392t + 52c_H + 32c_L) > 0$, ΔR_{M2}^p is increasing in

t.

---

[12] When $\frac{1-c_H}{2} \le t < \frac{1-c_L}{2}$, $w_L = \frac{1+c_L}{2} - t \ge \frac{1+c_L}{2} - \frac{1-c_L}{2} = c_L$.

$$\lim_{t\to(\frac{3(1-c_H)}{14})+}\Delta R_{M2}^{p}=\frac{1}{364}(156c_H+182ac_H-163c_H^2-156c_L-182ac_L-12c_Hc_L+175c_L^2)=\lim_{t\to(\frac{3(1-c_H)}{14})-}\Delta R_{M1}^{p}$$

$$\lim_{t\to(\frac{3(1-c_L)}{14})-}\Delta R_{M2}^{p}=\frac{1}{112}(48c_H+56ac_H-49c_H^2-48c_L-56ac_L-6c_Hc_L+55c_L^2)$$

(3). If $\frac{3(1-c_L)}{14}\le t<\frac{1-c_H}{2}$, then $\Delta R_{M3}^{p}=\frac{1}{16}(c_H-c_L)[8a+6-7(c_H+c_L)+4t]$ (H3)

It is easy to see that ΔR_{M3}^{p} is increasing in t.

$$\lim_{t\to(\frac{3(1-c_L)}{14})+}\Delta R_{M3}^{p}=\frac{1}{112}(48c_H+56ac_H-49c_H^2-48c_L-56ac_L-6c_Hc_L+55c_L^2)=\lim_{t\to(\frac{3(1-c_L)}{14})-}\Delta R_{M2}^{p}$$

and $\lim_{t\to(\frac{1-c_H}{2})-}\Delta R_{M3}^{p}=\frac{1}{16}(8c_H+8ac_H-9c_H^2-8c_L-8ac_L+2c_Hc_L+7c_L^2)$.

(4). If $\frac{1-c_H}{2}\le t<\frac{1-c_L}{2}$, then

$$\Delta R_{M4}^{p}=\frac{1}{16}[8a(c_H-c_L)-1+4t(1-c_L)+8c_H-8c_H^2-4t^2-6c_L+7c_L^2] \quad \text{(H4)}$$

$\frac{\partial \Delta R_{M4}^{p}}{\partial t}=\frac{1}{4}(1-c_L-2t)>0$ since $\frac{1-c_H}{2}\le t<\frac{1-c_L}{2}$. Thus ΔR_{M3}^{p} is increasing in t.

$$\lim_{t\to(\frac{1-c_H}{2})+}\Delta R_{M4}^{p}=\frac{1}{16}(8c_H+8ac_H-9c_H^2-8c_L-8ac_L+2c_Hc_L+7c_L^2)=\lim_{t\to(\frac{1-c_H}{2})-}\Delta R_{M3}^{p}.$$

$$\lim_{t\to(\frac{1-c_L}{2})-}\Delta R_{M4}^{p}=\frac{1}{2}(c_H-c_L)[(1+a)-(c_H+c_L)].$$

(5). If $t\ge\frac{1-c_L}{2}$, then $\Delta R_{M5}^{p}=\frac{1}{2}(c_H-c_L)[(1+a)-(c_H+c_L)]=\lim_{t\to(\frac{1-c_L}{2})-}\Delta R_{M4}^{p}$. (H5)

Combining all the above five cases, we complete our proof. ♠

I. Proof of proposition 7:

(1). If $0\le t<\frac{3(1-c_H)}{14}$, then

$$\Delta R_M-\Delta R_{M1}^{p}=\frac{(c_H-c_L)[(1+a)-(c_H+c_L)]}{2}-\frac{(c_H-c_L)[26a+24-8t-25(c_H+c_L)]}{52}$$

$= \frac{1}{52}(c_H - c_L)[2 + 8t - (c_H + c_L)] > 0$. Thus we have $\Delta R_M > \Delta R_{M1}^p$ and $k > k_1^p$.

(2). If $\frac{3(1-c_H)}{14} \le t < \frac{3(1-c_L)}{14}$, then $\Delta R_M - \Delta R_{M2}^p = \frac{(c_H - c_L)[(1+a)-(c_H + c_L)]}{2}$

$- \frac{1}{208}[9 + 104a(c_H - c_L) - 84t + 196t^2 + 78c_H - 96c_L + 52tc_H + 32tc_L - 91c_H^2 + 100c_L^2]$

$$= \frac{1}{208}(-9 + 26c_H - 8c_L - 13c_H^2 + 4c_L^2 + 84t - 196t^2 - 52tc_H - 32tc_L) \qquad \text{(I1)}$$

Because $\frac{\partial(\Delta R_M - \Delta R_{M2}^p)}{\partial t} = 84 - 392t - 52c_H - 32c_L \ge or < 0$, we have if

$t^{**} = \frac{21 - 13c_H - 8c_L}{98}$, then $\frac{\partial(\Delta R_M - \Delta R_{M2}^p)}{\partial t}|_{t=t^{**}} = 0$ and $\frac{\partial^2(\Delta R_M - \Delta R_{M2}^p)}{\partial t^2} < 0$. Thus

$\Delta R_M - \Delta R_{M2}^p$ gets maximum at t^{**}. If $\frac{3(1-c_H)}{14} \le t < t^*$, $\frac{\partial(\Delta R_M - \Delta R_{M2}^p)}{\partial t} > 0$, then

$$\Delta R_M - \Delta R_{M2}^p > (\Delta R_M - \Delta R_{M2}^p)\Big|_{t=\frac{3(1-c_H)}{14}} = \frac{1}{364}(c_H - c_L)[19(1-c_H) + 7(1-c_L) > 0 \qquad \text{(I2)}$$

If $t^* \le t < \frac{3(1-c_L)}{14}$, $\frac{\partial(\Delta R_M - \Delta R_{M2}^p)}{\partial t} < 0$, then we have

$$\Delta R_M - \Delta R_{M2}^p > (\Delta R_M - \Delta R_{M2}^p)\Big|_{t=\frac{3(1-c_L)}{14}} = \frac{1}{112}(c_H - c_L)[7(1-c_H) + (1-c_L) > 0 \qquad \text{(I3)}$$

Combining (I2) and (I3), we have $\Delta R_M > \Delta R_{M2}^p$ and $k > k_2^p$ if $\frac{3(1-c_H)}{14} \le t < \frac{3(1-c_L)}{14}$.

(3). If $\frac{3(1-c_L)}{14} \le t < \frac{1-c_H}{2}$, then $\Delta R_M - \Delta R_{M3}^p = \frac{(c_H - c_L)[(1+a)-(c_H + c_L)]}{2}$

$- \frac{1}{16}(c_H - c_L)[8a + 6 - 7(c_H + c_L) + 4t] = \frac{1}{16}(c_H - c_L)[2 - (c_H + c_L) - 4t]$

$\ge \frac{1}{16}(c_H - c_L)[2 - (c_H + c_L) - 4(\frac{1-c_H}{2})] = \frac{1}{16}(c_H - c_L)^2 > 0$. So we have $\Delta R_M > \Delta R_{M3}^p$

and $k > k_3^p$.

(4). If $\frac{1-c_H}{2} \le t < \frac{1-c_L}{2}$, then $\Delta R_M - \Delta R_{M4}^p = \frac{(c_H - c_L)[(1+a)-(c_H + c_L)]}{2}$

$- \frac{1}{16}[8a(c_H - c_L) - 1 + 4t(1-c_L) + 8c_H - 8c_H^2 - 4t^2 - 6c_L + 7c_L^2]$

Because $\frac{\partial(\Delta R_M - \Delta R_{M4}^p)}{\partial t} = -4 + 8t + 4c_L = \frac{1}{8}(t - \frac{1-c_L}{2}) < 0$, Thus $\Delta R_M - \Delta R_{M2}^p$ gets minimum at $t = \frac{1-c_L}{2}$. Hence we have $\Delta R_M - \Delta R_{M2}^p > (\Delta R_M - \Delta R_{M2}^p)\Big|_{t=\frac{1-c_L}{2}} = 0$,

$\Delta R_M > \Delta R_{M4}^p$ and $k > k_4^p$.

(5). If $t \geq \frac{1-c_L}{2}$, then $\Delta R_M = \Delta R_{M5}^p$ and $k = k_5^p$.

Together all the five cases above, we complete the proof. ♠

J. Proof of corollary 4:

We have $\pi_M(w_i, c_i) > \pi_M^p(w_i, c_i)$ and $R_M(w_i, c_i) > R_M^p(w_i, c_i)$, $i = H, L$. Thus

$$\begin{aligned} E_M - E_M^p &= \{\alpha(k)R_M(w_L, c_L) + [1-\alpha(k)]R_M(w_H, c_H) - k\} \\ &\quad - \{\alpha(k)R_M^p(w_L, c_L) + [1-\alpha(k)]R_M^p(w_H, c_H) - k\} \\ &= \{\alpha(k)[R_M(w_L, c_L) - R_M^p(w_L, c_L)] + [1-\alpha(k)][R_M(w_H, c_H) - R_M^p(w_H, c_H)] > 0 \end{aligned}$$

That is, $E_M > E_M^p$. ♠

K. Proof of proposition 8:

Throughout the proof of this proposition, we use ECS_A, ECS_B, ECS, E_M and EW to represent the expected consumer surplus in country A, B, expected total consumer surplus, expected producer surplus and expected global welfare respectively when government prevents parallel imports; ECS_A^p, ECS_B^p, ECS^p, E_M^p and EW^p represent the expected consumer surplus in country A, B, expected total consumer surplus, expected producer surplus and expected global welfare respectively when government does not prevent parallel imports.

If the government prevents parallel trade, then

$$ECS_A = \frac{1}{8}(1-c_L)^2\alpha(k) + \frac{1}{8}(1-c_H)^2[1-\alpha(k)] \text{ and} \tag{K1}$$

$$ECS_B = \frac{1}{8}(a-c_L)^2\alpha(k) + \frac{1}{8}(a-c_H)^2[1-\alpha(k)]. \tag{K2}$$

We already have $E_M > E_M^p$ (K3)

(i). If $0 \leq t < \frac{3(1-c_H)}{14}$, then

$$ECS_{A1}^{p} = \frac{1}{328}(8-7t-8c_L)^2\alpha(k) + \frac{1}{328}(8-7t-8c_H)^2[1-\alpha(k)] \text{ and}$$

$$ECS_{B1}^{p} = \frac{1}{1352}(13a-2-8t-11c_L)^2\alpha(k) + \frac{1}{1352}(13a-2-8t-11c_H)^2[1-\alpha(k)].$$

First, because $\frac{1}{8}(1-c_i)^2 - \frac{1}{328}(8-7t-8c_i)^2$ is increases in t, thus

$$\frac{1}{8}(1-c_i)^2 - \frac{1}{328}(8-7t-8c_i)^2 \le [\frac{1}{8}(1-c_i)^2 - \frac{1}{328}(8-7t-8c_i)^2]\Big|_{t=\frac{3(1-c_H)}{14}} = 0 \text{ and}$$

$$\frac{1}{8}(1-c_i)^2 \le \frac{1}{328}(8-7t-8c_i)^2. \tag{K4}$$

Second, because $\frac{1}{8}(a-c_i)^2 - \frac{1}{1352}(13a-2-8t-11c_i)^2$ is increases in t and $13a \ge 2+8t+11c_i \ge 2+11c_i$, thus we have

$$\frac{1}{8}(a-c_i)^2 - \frac{1}{1352}(13a-2-8t-11c_i)^2 \ge [\frac{1}{8}(a-c_i)^2 - \frac{1}{1352}(13a-2-8t-11c_i)^2]\Big|_{t=0}$$

$$= \frac{(1-c_i)}{338}(-1-12c_i+13a) \ge \frac{(1-c_i)^2}{338} \ge 0 \text{ and } \frac{1}{8}(a-c_i)^2 \ge \frac{1}{1352}(13a-2-8t-11c_i)^2 \tag{K5}$$

Hence $ECS_A \le ECS_{A1}^{p}$, $ECS_B \ge ECS_{B1}^{p}$, $ECS_1 \ge or \le ECS_1^{p}$ and $EW_1 \ge or \le EW_1^{p}$. [13]

(ii). If $\frac{3(1-c_H)}{14} \le t < \frac{3(1-c_L)}{14}$, then

$$ECS_{A2}^{p} = \frac{1}{328}(8-7t-8c_L)^2\alpha(k) + \frac{1}{8}(1-c_H)^2[1-\alpha(k)] \text{ and}$$

$$ECS_{B2}^{p} = \frac{1}{1352}(13a-2-8t-11c_L)^2\alpha(k) + \frac{1}{32}(2a+2t-1-c_H)^2[1-\alpha(k)].$$

[13] The number in the subscript here and in the following represents the case number.

On one hand, because $\frac{1}{8}(1-c_L)^2 - \frac{1}{328}(8-7t-8c_L)^2$ is increases in t, thus

$$\frac{1}{8}(1-c_L)^2 - \frac{1}{328}(8-7t-8c_L)^2 \geq [\frac{1}{8}(1-c_L)^2 - \frac{1}{328}(8-7t-8c_L)^2]\Big|_{t=\frac{3(1-c_L)}{14}} = 0 \text{ and}$$

$$\frac{1}{8}(1-c_L)^2 \geq \frac{1}{328}(8-7t-8c_L)^2. \tag{K6}$$

On the other hand,

$$\frac{1}{8}(a-c_H)^2 - \frac{1}{32}(2a+2t-1-c_H) = \frac{1}{32}(1-c_H-2t)[2(a-c_H)+(2a+2t-1-c_H)>0$$

and $\frac{1}{8}(a-c_H)^2 > \frac{1}{32}(2a+2t-1-c_H)$ (K7)

Therefore $ECS_A \leq ECS_{A2}^p$, $ECS_B \geq ECS_{B2}^p$, $ECS_2 \geq or \leq ECS_2^p$ and $EW_2 \geq or \leq EW_2^p$.

(iii). If $\frac{3(1-c_L)}{14} \leq t < \frac{1-c_H}{2}$, then $ECS_{A3}^p = \frac{1}{8}(1-c_L)^2\alpha(k) + \frac{1}{8}(1-c_H)^2[1-\alpha(k)]$ and

$ECS_{B3}^p = \frac{1}{32}(2a-1+2t-c_L)^2\alpha(k) + \frac{1}{32}(2a+2t-1-c_H)^2[1-\alpha(k)]$. Hence we have

$ECS_A = ECS_{A3}^p$, $ECS_B \geq ECS_{B3}^p$, $ECS_3 \geq ECS_3^p$ and $EW_3 \geq EW_3^p$.

(iv). If $\frac{1-c_H}{2} \leq t < \frac{1-c_L}{2}$, then $ECS_{A4}^p = \frac{1}{8}(1-c_L)^2\alpha(k) + \frac{1}{8}(1-c_H)^2[1-\alpha(k)]$ and

$ECS_{B4}^p = \frac{1}{32}(2a-1+2t-c_L)^2\alpha(k) + \frac{1}{8}(a-c_H)^2[1-\alpha(k)]$. Hence we have

$ECS_A = ECS_{A4}^p$, $ECS_B \geq ECS_{B4}^p$, $ECS_4 \geq ECS_4^p$ and $EW_4 \geq EW_4^p$.

(v). When $t \geq \frac{1-c_L}{2}$, this case is exactly as the case in which parallel imports are prevented. ♠

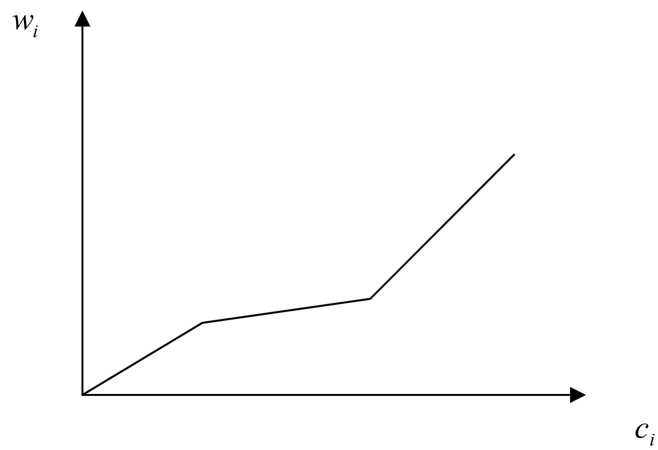

Figure 1

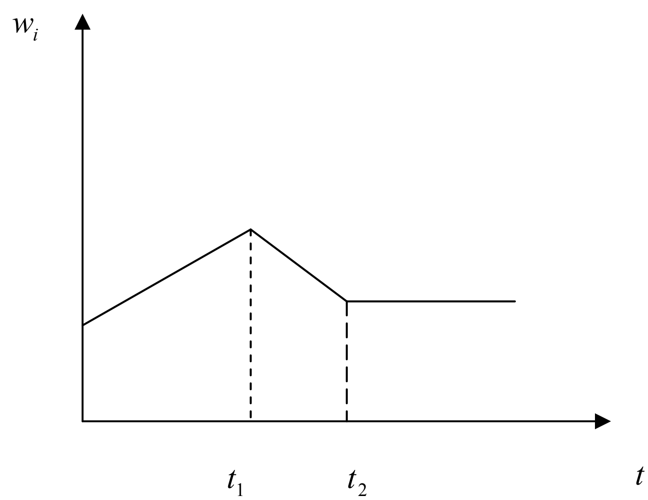

Figure 2

In figure 2, $t_1 = \frac{3(1-c_i)}{14}$ and $t_2 = \frac{1-c_i}{2}$.

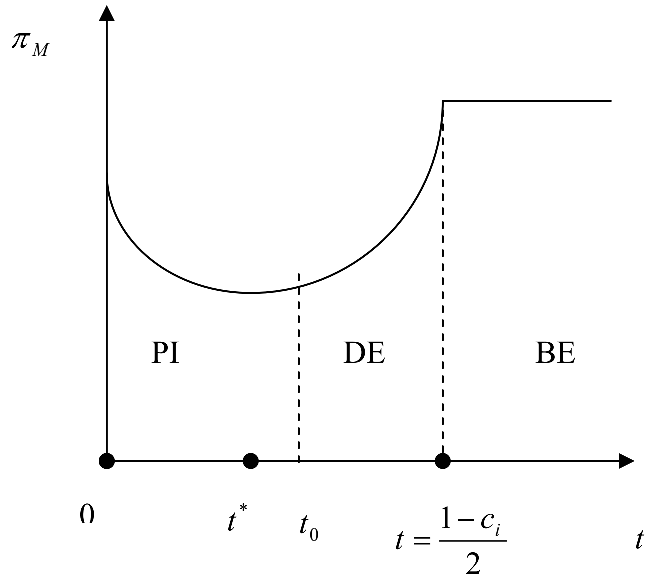

Figure 3: the U-shape of π_M

In figure 3, PI denotes parallel imports. DE represents deterrence equilibrium. BE is the blocked equilibrium. $t^* = \frac{1-c_i}{9}$ and $t_0 = \frac{3(1-c_i)}{14}$.

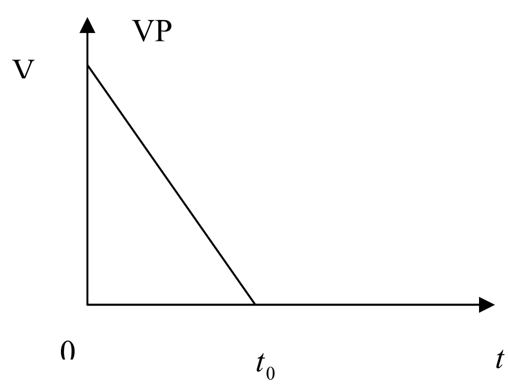

Figure 4

In figure 4, V=$\frac{3(1-c_i)}{13}$ and $t_0 = \frac{3(1-c_i)}{14}$. VP is the volume of parallel imports.

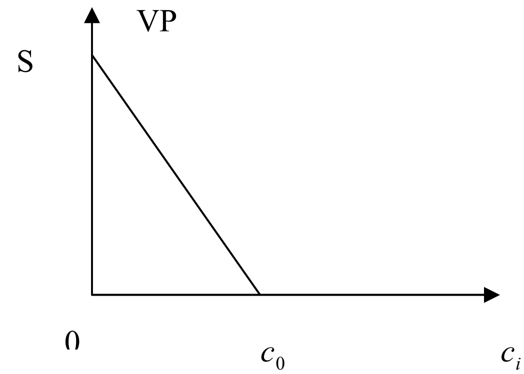

Figure 5

In figure 5, S=$\frac{3-14t}{13}$ and $c_0 = 1 - \frac{14t}{3}$. VP is the volume of parallel trade.

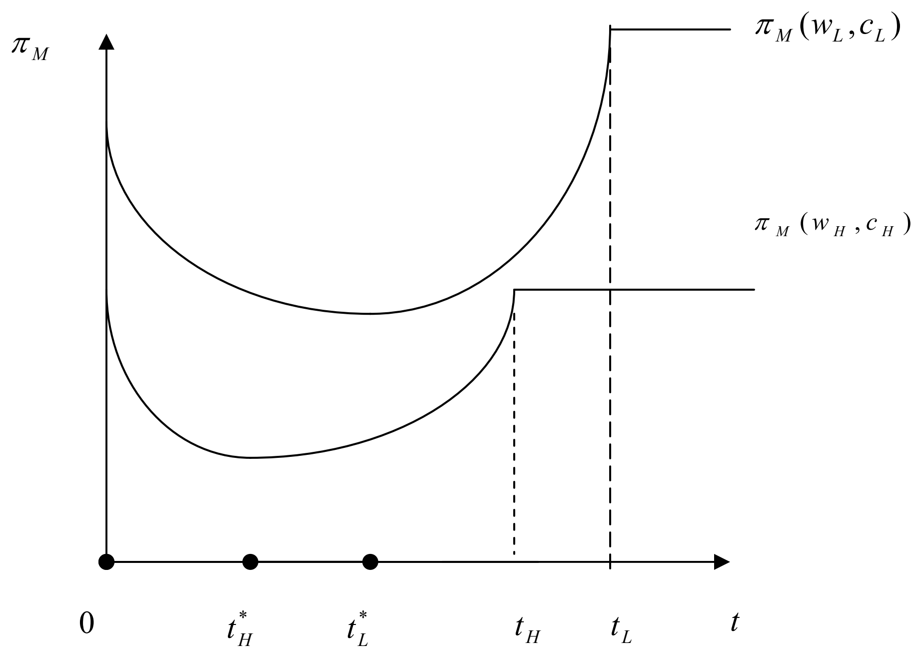

Figure 6

In figure 6, $t_H^* = \frac{1-c_H}{9}$, $t_L^* = \frac{1-c_L}{9}$, $t_H = \frac{1-c_H}{2}$ and $t_L = \frac{1-c_L}{2}$.

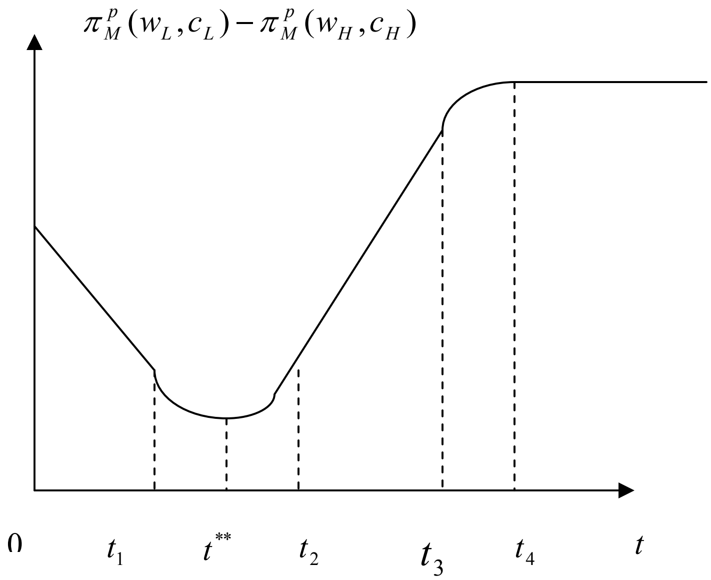

Figure 8

In figure 8, $t_1 = \dfrac{3(1-c_H)}{14}$, $t^{**} = \dfrac{21 - 13c_H - 8c_L}{98}$, $t_2 = \dfrac{3(1-c_L)}{14}$, $t_3 = \dfrac{1-c_H}{2}$ and $t_4 = \dfrac{1-c_L}{2}$.

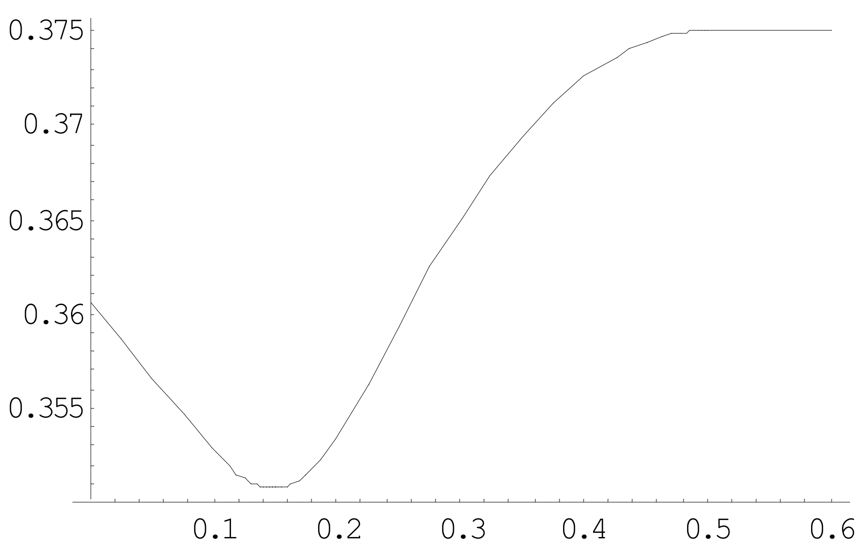

Figure 9

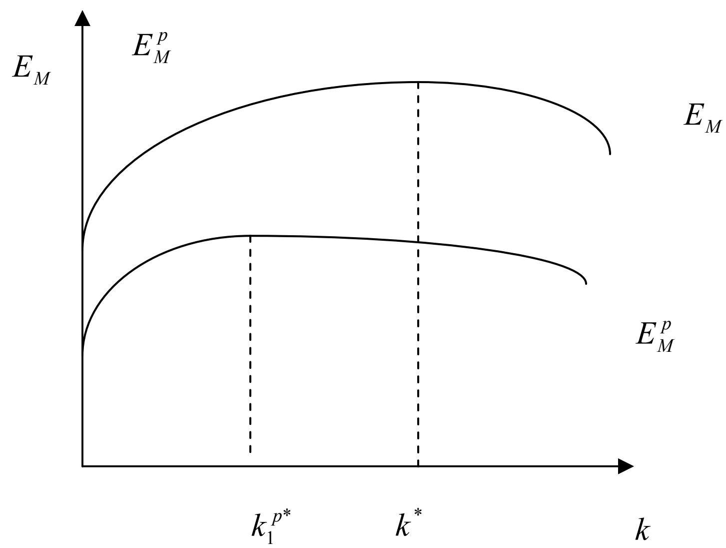

Figure 10

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