Outlaw Innovation, Software Piracy and Parallel Imports in the Video Game Market

Po-Lu Chen
Department of Economics
Tamkang University

October 2012

No.151, Yingzhuan Rd., Tamsui Dist.,
New Taipei City 25137,
Taiwan

Email: 141080@mail.tku.edu.tw
Phone: +886-2-26215656 ext 2975

Abstract

This article analyzes the impact of outlaw innovations on the video game market. Rather than solely focusing on piracy in a closed economy, this study discusses the impact of parallel imports (PI) inspired by outlaw innovations. A simple model with one monopolistic hardware manufacturer and one monopolistic software provider selling complementary products in two countries is developed to show three results that are in contrast to general expectation. First, software piracy could be beneficial for both firms. Second, the hardware manufacturer may benefit from PI. Third, consumers in the PI recipient country are not necessarily better off due to PI.

Keywords: piracy, parallel imports, intellectual property rights
JEL Classification: F15, L11, L82, L86

Outlaw Innovation, Software Piracy and Parallel Imports in the Video Game Market

1. Introduction

Innovations not only can be done by manufacturers but also be realized by users. User innovations aim to add more functions that are not originally provided on the product or to bypass legal or technical safeguards. In particular, electronic manufactures often embed security mechanism in order to prevent users from running unauthorized software or illegally obtained content on their platform. For example, the region code on a DVD player prevents users from buying parallel imported multimedia products. The security mechanism on a game console prevents illegally copied game ROMs from being operated on the platform. Similar examples can also be found in telecommunication industry. Before 2011, Apple's iPhone users could only choose AT&T in United States because of the mechanism that aims to increase firms' market power. Mollick (2004) is the first study that analyzes user innovations that deactivate the security mechanisms. Extending Mollick's research, Flowers (2008) introduces the concept of outlaw innovation and provides case studies of how communities create and distribute outlaw innovations. As defined by Schulz and Wagner (2008), outlaw innovations are user modifications of a product to not only gain unauthorized access to the product's system but to also enable the user to use the system more effectively. Outlaw innovation is an important issue because it may violate manufacturers' intellectual property rights (IPRs) and will restrict manufacturers' market power as well as pricing behaviors. For example, users of a video game console can embed a modification chip (or modchip), which is a device used to run import discs, backup dvd-r/ dvd-rw, or homebrew game ROMs on the game console, to play pirated video games.

This article is motivated by the fact that Sony has decided to make its new generation game console, Playstation 3 (PS3), a region-free game console.[1] In other words, PS3 users can play international version games on the PS3 platform if the hardware is region-free. A PS3 player can run a USA version game on the Japanese hardware and vice versa. As we know, the modification chips encourage video game piracy and parallel imports (PI). When video game piracy is mentioned, it is widely expected that the modification chips will boost sales of game consoles and will reduce the game providers' profit. However, in this study, it is shown that the latter is not necessarily true.

In addition to illegal copy of the software, the modification chips can also undermine manufacturers' international third degree price discrimination by inspiring parallel trade. However, the present model shows that it is premature to claim that the hardware manufacturer will suffer from parallel imports. Why is parallel importation beneficial for the IPR holder? Several models have different explanations. In the literature of PI, studies can be roughly categorized as vertical price control model and horizontal retail price arbitrage model. The vertical price control model of PI, which is first developed by Maskus and Chen (2002, 2004) and Chen and Maskus (2005), assumes that a manufacturer protected by IPR in two markets has an independent distributor in each location. The manufacturer offers the distributors two-part tariff contracts that specify the wholesale prices and a lump-sum fee in order to induce profit-maximizing retail prices. In the framework of vertical price control model, Ganslandt and Maskus (2007) develop a model to show that the manufacturer will prefer to serve a country by PI when trade cost is sufficiently low. The idea behind their result is that the manufacturer would push the distributor in the PI recipient

[1] See "regional lockout" on Wikipedia: http://en.wikipedia.org/wiki/Regional_lockout

country out of the market in order to avoid pro-competitive effect when trade cost is small.

The other framework, horizontal retail price arbitrage model, assumes that PI occurs simply due to retail price differences between two markets. (Ahmadi & Yang, 2000; Malueg & Schwartz, 1994) In general, retail price arbitrage prevents the manufacturer from third-degree price discrimination; however, Anderson and Ginsburg (1999) argue that consumers' arbitrage behaviors provide the manufacturer a channel to second-degree price discrimination. They develop a two-country model with heterogeneous consumers to show that a firm with market power may have an incentive to create a second market in the second country, even though there is no local demand there. The intuition is that consumer's arbitrage between two countries provides the firm a means to price discriminate across consumers in the first country.

The analysis of the present article adopts horizontal retail price arbitrage model and follows the idea of Anderson and Ginsburg (1999). A consumer who purchases a game console from unauthorized channels has a strong tendency to play pirated or illegally obtained games.[2] This kind of consumer has lower willingness to pay and thus parallel imports give the manufacturer a lead to distinguish high-type consumers and low-type consumers; hence second-degree price discrimination in the PI recipient country becomes feasible.

The idea that parallel imports or pirated goods lead to second degree price discrimination is not new. Takeyama (1994) develops a model to discuss the impact of software piracy on software providers in the presence of network externalities. She finds that with network externality, piracy is an efficient means to expand network size and thus the copies are sold at one price (zero) while genuine product buyers are

[2] One report on 2007.04.30 indicates that more than 80% Taiwanese consumers who purchased parallel imported Wii game consoles asked to modify the hardware to play pirated games. See The Sun, Hong Kong.

charged at a higher price. However, her model can't be applied to video game piracy because her model does not take the hardware firm into account. Taking the hardware firm into consideration is pivotal for discussing piracy in the video game market because the video game console is generally a closed platform, which means the hardware is specific for the software. In other words, both hardware and software firms' pricing behaviors will be pinned down by each other given the fact that their products are perfect complements. Thus, the interaction between the hardware firm and the software firm deserves scrutiny. In addition, most articles that discuss software piracy solely consider the story in a closed economy. In other words, they ignore the impact of PI on the hardware manufacturer and the software provider. To have a better understanding of the effect of software piracy in an open video game market, one contribution of the present article is to discuss the nexus between software piracy and parallel imports in the video game market.

Another reason to buttress that video game market is worthy of study is as follows. As pointed out by Fink and Maskus (2005), the welfare consequences of an IPR exhaustion policy differ across industries. Welfare analysis of PI for a particular industry might be inapplicable to another one. To my knowledge, PI-related articles solely discuss the interaction between the monopolist (the IPR holder) and downstream distributors. They do not consider the case that the product sold by the IPR holder may need another component to work. Therefore, welfare implications in those studies may not hold in the video game market. The present article differs from those PI studies in the aspect that this study is the first one that provides welfare analysis of PI in complementary goods. It sheds some lights on pricing by software and hardware firms when they feature complementary products and the hardware can be parallel traded while the other not. This article argues that parallel trade in hardware is a channel used to let consumers reveal their preference for playing video games. Authorized hardware and PI are homogeneous to pirated software users (low type consumers) because after-sale service is not available for modified-hardware users. Therefore, the manufacturer can extract more profits from consumers by serving high type consumers by authorized products with a higher price and serving low type consumers by cheaper PI. Based on this idea, in this article, we develop a simple model with one monopolistic hardware manufacturer and one monopolistic software provider (where the hardware and the software are perfect complements) selling their products in two countries. Starting from the assumption that the hardware is protected by a region code which prevents consumers from using international version software, we show three results that are in contrast to general expectation. First, the software provider and the hardware manufacturer could both benefit from software piracy. Second, the hardware manufacturer may benefit from PI because PI can either become a commit device to raise the hardware price in the PI exporting country or serve as a channel to second-degree price discrimination in the PI recipient country. Third, the consumers in the PI recipient country are not necessarily better off due to PI because the gains from an open policy might be offset if the hardware firm chooses to engage in price discrimination. Then to explain why Sony made its new generation game consoles region-free, we relax the region code assumption and show that, in equilibrium, imposing a region code on the hardware is redundant. All results in this study still hold for region-free hardware.

This article is organized as follows. A simple model is developed in section 2. Welfare analysis is given in section 3. Section 4 offers a short analysis of a region-free hardware and section 5 concludes.

2. The Model

In this section, we develop the basic non-cooperative game with a monopolistic hardware manufacturer and one software provider.[3] We will discuss two cases. First, let's consider the impact of software piracy on the hardware manufacturer and the software provider respectively when parallel importation is not permitted. Second, we will discuss the impact of PI on both firms given software piracy.

There are two countries, A and B. We assume that the total number of consumers in either country is normalized to unity. Consumers are heterogeneous in their value of playing video games. Let v denote a consumer's gross utility of playing video games. The distribution of v in both countries is identical and is assumed to be a uniform distribution with support [0,1]. Here, the hardware is assumed to provide zero utility if it is not utilized with software.

2.1 The Benchmark: The Basic Model with No Piracy

Let's consider the benchmark case: no piracy, no PI. The utility functions in both countries are given by

$$U^i = \begin{cases} v - p^i_{oBM} - p^i_{hBM} & \text{if purchasing the system} \\ 0 & \text{if no adoption} \end{cases}; \; i = A, B \tag{1}$$

p^i_{oBM} denotes the price of official software in country i and p^i_{hBM} is the price of hardware in country i. The subscript BM indicates the variable for the benchmark case.

Without loss of generality, we take country A as the discussing object. A consumer in country A with $v \geq \mathrm{v} \equiv p^A_{oBM} + p^A_{hBM}$ will purchase the system. For simplicity, we also assume that both hardware and software firms' marginal cost are normalized to zero.[4] Because each consumer purchases one unit of the product, the

---

[3] The assumption of non-cooperative game is briefly discussed in section 5.
[4] This seems a stronger assumption on manufacturer's marginal cost. Normalizing the marginal cost to zero helps simplify the analysis. Nevertheless, this simplification is acceptable for two firms producing

quantity demanded can be calculated by $\int_{v}^{1} 1\,\mathrm{d}\,x = 1 - p_{oBM}^{A} - p_{hBM}^{A}$. Now we can obtain both firms' profit earned in country A:

$$\pi_{jBM}^{A} = p_{jBM}^{A}\left(1 - p_{oBM}^{A} - p_{hBM}^{A}\right) \;\; ; j = h, o \tag{2}$$

The optimization of (2) with respect to p_{oBM}^{A} and p_{hBM}^{A} indicates that

$p_{oBM}^{A}{}^{*} = p_{hBM}^{A}{}^{*} = \frac{1}{3}$

Identical argument can be applied to country B and we will have

$p_{oBM}^{B}{}^{*} = p_{hBM}^{B}{}^{*} = \frac{1}{3}$

Therefore, both firms' profits in this benchmark case are identical and equal to the sum of profits in both countries given by $\frac{2}{9}$.

2.2 Software Piracy When PI is Prohibited

In this section, we consider the case where pirated software is available in country A. For simplicity, we assume that consumers in country B are unable to access pirated software. The consumer's utility function in country A now becomes

$$U^{A} = \begin{cases} v - p_{hPN}^{A} - p_{oPN}^{A} & \text{if purchasing legitimate software} \\ (1-\alpha)v - p_{hPN}^{A} - c + \delta & \text{if using illegal software} \\ 0 & \text{if no adoption} \end{cases} \tag{3}$$

The subscript PN indicates that piracy exists while parallel imports do not. $(1-\alpha)$ is a discount factor to the value v if the consumer modifies the hardware.

perfect complements. To see this, following the benchmark setup, supposed that the hardware firm bears a positive marginal cost m, it is easy to check the marginal cost of one firm has equal impact on both firms by verifying that the profit of both the hardware and the software firm equals $((1-m)/3)^2$. Therefore, even though the value of the marginal cost does affect values of the variables, such as the profit level, it will not affect the direction of the change in variables *due to some scenarios* demonstrated in our model. The main interest of this chapter is to discuss how firms' profits and consumer's welfare change and thus it is acceptable to normalize the marginal cost to zero.

Assume that by installing the modification chip on the hardware, users can bypass all security mechanism including region code. Here, $\alpha \in (0,1)$ to capture the fact that any unauthorized modification to the hardware will void warranty. The parameter α can also be interpreted as the probability that a hardware buyer needs after sale service.[5] $c > 0$ refers to a fixed cost of modifying the hardware.[6] $\delta \in (0,1)$ measures the extra benefit along with the hardware modification. For example, more powerful multimedia functions on a modified Microsoft XBOX.[7]

We assume that both firms set price simultaneously. Both firms can either act to accommodate or to deter piracy.[8] To accommodate piracy, both firms will act by assuming that piracy exists in equilibrium. On the other hand, to deter piracy, firms will charge a price as if piracy were not available. There are 4 possible strategy combinations in this game. Let's check the payoff of each strategy:

2.2.1 Both firms accommodate piracy

Let v_1 be the value of one consumer who is indifferent between using official software and pirated copy. Therefore, $\mathrm{v}_1 - p_{oPN}^A - p_{hPN}^A = (1-\alpha)\mathrm{v}_1 - p_{hPN}^A - c + \delta$. A consumer will purchase official software if his valuation $v > \mathrm{v}_1 = \dfrac{p_{oPN}^A - (c-\delta)}{\alpha}$. Thus, the quantity demanded for legitimate software is $\int_{\mathrm{v}_1}^{1} 1\,\mathrm{dx} = 1 - \dfrac{p_{oPN}^A - (c-\delta)}{\alpha}$. It is worthy to note that the quantity demanded for the official software is irrelevant to the hardware price because the hardware price does not play a role in consumer's

---

5 Some studies such as Takeyama (1994) and Bae and Choi (2006) consider $(1-\alpha)$ as a utility discount factor for using pirated software. However, as stated in Peitz and Waelbroeck (2006), for video game piracy, the original and the copy have almost the same quality. Therefore, in this study, we will use $(1-\alpha)$ to represent the utility discount factor due to loss of after-sale service.

6 For example, a modification chip or a recordable DVD that is required to make and play a homebrew pirated Wii game.

7 For more detail discussions on XBOX modification, see Schulz and Wagner (2008).

8 For example, even when piracy is available, the hardware firm still can charge p_{hPN}^A such that $v - p_{hPN}^A - p_{oPN}^A > 0 > (1-\alpha)v - p_{hPN}^A - c + \delta$ to deter piracy.

choice between legitimate software and pirated software.

The software provider maximizes his profit in country A:

$$\max_{p_{oPN}^A} \pi_{oPN}^A = \left(1 - \frac{p_{oPN}^A - c + \delta}{\alpha}\right) p_{oPN}^A \quad (4)$$

The optimization problem indicates that the optimal official software price in country A is $p_{oPN}^{A\ *} = \frac{\alpha + c - \delta}{2} \in (0,1)$

Both official software buyers and pirated software users need to purchase the hardware. Let v_2 be the value of a consumer who is indifferent between using the system and no adoption. Therefore, consumers with $v \geq v_2 = \frac{p_{hPN}^A + c - \delta}{1-\alpha}$ will buy the hardware. The hardware manufacturer maximizes its profit in country A:

$$\max_{p_{hPN}^A} \pi_{hPN}^A = \left(1 - \frac{p_{hPN}^A + c - \delta}{1-\alpha}\right) p_{hPN}^A \quad (5)$$

Solving (5) to find the optimal hardware price in country A, we will have $p_{hPN}^{A\ *} = \frac{1-\alpha-c+\delta}{2} > 0$. It is natural to assume that v_1 is greater than v_2. Because $\alpha \in (0,1)$, this inequality implies that $c < \delta$.[9]

In short, the payoff of the hardware firm and the software firm can be easily calculated and are equal to $\pi_{hPN}^{A\ *} = \frac{(1-\alpha-c+\delta)^2}{4(1-\alpha)}$ and $\pi_{oPN}^{A\ *} = \frac{(\alpha+c-\delta)^2}{4\alpha}$ respectively.

2.2.2 The hardware firm deters piracy while the software firm does not

In this case, the software firm sets price in the same way as what was described in section 2.2.1. i.e. $p_{oPN}^{A\ \prime\prime} = \frac{\alpha + c - \delta}{2}$. However, the hardware firm sets a price to deter piracy. In this case, the quantity demanded for the hardware equals

9 The derivation of this inequality is demonstrated in the appendix A1.

$q_{hPN}^A = 1 - p_{hPN}^A - p_{oPN}^A$. By setting optimal price $p_{hPN}^A{''} = \frac{1}{2}\left(1 - p_{oPN}^A{''}\right)$ and substituting $p_{oPN}^A{''} = \frac{\alpha + c - \delta}{2}$ into the profit function, it is easy to show that the hardware firm's profit in this case can be denoted by $\pi_{hPN}^A{''} = \frac{(2 - \alpha - c + \delta)^2}{16}$. Similarly, the profit of the software firm equals $\pi_{oPN}^A{''} = (1 - p_{oPN}^A{''} - p_{hPN}^A{''})\, p_{oPN}^A{''} = \frac{(2 - \alpha - c + \delta)(\alpha + c - \delta)}{8}$. Obviously, this case is not a Nash equilibrium. When piracy is deterred by the hardware firm, the software firm will deviate by setting $p_{oPN}^A = (1 - p_{hPN}^A)/2$ to maximize profits as described in section 2.1, the benchmark case.

2.2.3 The hardware firm accommodates piracy while the software firm does not

According to section 2.2.1, if the hardware firm accommodates piracy, he will charge $p_{hPN}^A{'''} = \frac{1 - \alpha - c + \delta}{2}$. Suppose that the software firm acts as if piracy were not available, then the software firm will set $p_{oPN}^A{'''} = \frac{1}{2}(1 - p_{hPN}^A{'''})$. Therefore, the profit of the hardware firm equals $\pi_{hPN}^A{'''} = \frac{(1 - \alpha - c + \delta)^2}{4(1 - \alpha)}$ and the profit of the software firm becomes $\pi_{oPN}^A{'''} = \frac{(-1 + 3(\alpha + c - \delta))(1 + \alpha + c - \delta)}{16\alpha}$.

2.2.4 Both firms deter piracy

This case is identical to the benchmark case (section 2.1). The payoff in country A will be (1/9,1/9).

Table 1 summarizes the payoff of two firms.

[Insert Table 1 here]

Supposed that hardware firm chooses {Accommodate Piracy}, because $\frac{(-1 + 3(\alpha + c - \delta))(1 + \alpha + c - \delta)}{16\alpha} < \frac{(\alpha + c - \delta)^2}{4\alpha}$, {Deter Piracy} is a dominated strategy for the software firm. Therefore, (Accommodate Piracy, Accommodate Piracy) constitutes a Nash equilibrium if $\frac{(1-\alpha-c+\delta)^2}{4(1-\alpha)} > \frac{(2-\alpha+\delta-c)^2}{16}$.

Simplifying the inequality yields $\alpha > \delta - c > \frac{1}{\alpha+3}\left(\alpha+\alpha^2-2+2\sqrt{1-\alpha}\right)$. Otherwise, both firms to deter piracy (i.e. both firms set price equal to 1/3) is the Nash equilibrium. We summarize this finding in proposition 1.

Proposition 1. *When piracy is available, the Nash equilibrium is*

$$\left(p_{hPN}^{A}, p_{oPN}^{A}\right)=\begin{cases}\left(\frac{1-\alpha-c+\delta}{2},\frac{\alpha+c-\delta}{2}\right) & \text{if } \alpha>\delta-c>\frac{1}{\alpha+3}\left(\alpha+\alpha^2-2+2\sqrt{1-\alpha}\right)>0\\ \left(\frac{1}{3},\frac{1}{3}\right) & \text{otherwise}\end{cases}$$

Proposition 1 claims that if $\alpha > \delta - c > \frac{1}{\alpha+3}\left(\alpha+\alpha^2-2+2\sqrt{1-\alpha}\right) > 0$ is violated, then piracy won't exist in equilibrium, even though people have access to pirated software. Therefore, to make our further analysis nontrivial, let's assume $\alpha > \delta - c > \frac{1}{\alpha+3}\left(\alpha+\alpha^2-2+2\sqrt{1-\alpha}\right) > 0$. More findings are provided in proposition 2 and proposition 3.

Proposition 2. *The hardware manufacturer can sell more units when software piracy exists in equilibrium.*

<Proof> If piracy is not available, the value v such that one consumer is indifferent between buying the system and no adoption is equal to $2/3$. In other words, total quantity sold by the hardware manufacturer is $1/3$ of the total population. However, when software piracy is introduced, total hardware quantity sold is $1-v_2 = 1-\left(\frac{\frac{1-\alpha-c+\delta}{2}+c-\delta}{1-\alpha}\right) = \frac{1}{2}\left(1+\frac{\delta-c}{1-\alpha}\right) > \frac{1}{3}$ for $\delta - c > 0$. Q.E.D

The profits that both firms can obtain in country B are identical to the benchmark case discussed in section 2.1. Total profits of the software provider can be calculated by substituting ${p_{oPN}^{A}}^{*}$ into π_{oPN}^{A} and then plus the profit from country B. Let π_{oPN} denote the profit of the software provider under the situation where software piracy exists while PI do not. We have ${\pi_{oPN}}^{*} = \frac{1}{9} + \frac{(\alpha+c-\delta)^2}{4\alpha}$. The combined profit function of the hardware manufacturer becomes[10]

$$ {\pi_{hPN}}^{*} = \frac{1}{9} + \frac{(1-\alpha-c+\delta)^2}{4(1-\alpha)} \text{ for } 1 > v_1 > v_2 \geq 0 \quad (6) $$

Now we can compare the profits obtained in this section to those calculated in the benchmark case to see the impact of software piracy on the hardware manufacturer and the software provider. The hardware manufacturer can (weakly) benefit from software piracy if ${\pi_{hPN}}^{*} \geq {\pi_{hBM}}^{*} = 2/9$. Solving this inequality along with $\alpha > \delta - c > \frac{1}{\alpha+3}\left(\alpha+\alpha^2-2+2\sqrt{1-\alpha}\right) > 0$, we have

$$ \begin{cases} 2\sqrt{\frac{1-\alpha}{(3+\alpha)^2}} + \frac{(\alpha-1)(\alpha+2)}{3+\alpha} < \delta - c < \alpha & \text{if } 0<\alpha \leq \frac{1}{2} \\ 2\sqrt{\frac{1-\alpha}{(3+\alpha)^2}} + \frac{(\alpha-1)(\alpha+2)}{3+\alpha} < \delta - c \leq 1-\alpha & \text{if } \frac{1}{2} < \alpha \leq \frac{3}{4} \\ \frac{2\sqrt{1-\alpha}-3}{3} + \alpha < \delta - c \leq 1-\alpha & \text{if } \frac{3}{4} < \alpha < \frac{8}{9} \end{cases} \quad (7) $$

[10] It is easy to verify that $1 > v_1 > v_2 \geq 0$. Any other situations do not hold. When $v_2 \leq 0$, the market is fully served by the hardware manufacturer. However, v_2 will never be strictly less than zero because the hardware manufacturer has an incentive to increase the hardware price.

Similarly, the software provider can earn a higher profit if $\pi_{oPN}{}^{*} \geq \pi_{oBM}{}^{*} = 2/9$. This inequality is tedious and thus the reduced form won't be provided. Let's look at the finding graphically in figure 1. The combination of $(\alpha, \delta - c)$ where the hardware manufacturer (software provider) can benefit from piracy is depicted by the light (dark) area in figure 1. The medium dark area is the intersection of dark area and light area, which indicates the combination of $(\alpha, \delta - c)$ where both hardware manufacturer and software provider benefit from software piracy.

Proposition 3. *Software piracy is not always beneficial (harmful) for hardware (software) firm. In addition, there exist several combinations of* α *and* $\delta - c$ *such that both hardware and software firms can benefit from piracy. i.e. the medium dark area in figure 1.*

[Insert Figure 1 here]

The colored area indicates the parameter set such that piracy exists in equilibrium. Two interesting findings are present in proposition 3. The first one is that for certain parameter sets, the software firm can even benefit from piracy. To see this, let's go back to the derivation of quantity demanded for the legitimate software. In the benchmark case, where no piracy exists, the marginal consumer compares the surplus between buying the system and no adoption. Both hardware price and software price affect his/her choice. The inverse demand function for software in the benchmark case is $p_{oBM} = 1 - q_{oBM} - p_{hBM}$, which is a linear inverse demand with slope -1 and intercept $(1 - p_{hBM})$. However, in a model with piracy, hardware price won't affect the choice of the marginal consumer who considers whether to buy the legitimate software or to pirate the software. The inverse demand function for the software in the case with piracy is $p_{oPN} = \alpha\left(1-q_{oPN}\right)-\left(\delta-c\right)$, which is a linear inverse demand with slope $-\alpha$ and intercept $\left(\alpha-\left(\delta-c\right)\right)$. The parameter α can measure how elastic the software demand is. Because $\alpha<1$, the inverse demand function for the software in the case with piracy is flatter than the benchmark. However, the inverse demand function is also controlled by the intercept. With a sufficiently small number of $\left(\delta-c\right)$, i.e. $\left(\delta-c\right)$ is sufficiently closed to zero, such that $\left(\delta-c\right)$ is smaller than p_{hBM}, the software provider in fact faces a larger market in the case with piracy than in the benchmark case as long as α is not too small. In other words, comparing the result in this section to the benchmark case, if the "disadvantage" due to elasticity (α) can be covered by the gain from consumer's willingness to pay (larger intercept captured by small $\left(\delta-c\right)$), the software firm can benefit from piracy.

The second interesting finding is that it is possible for the hardware firm to suffer from piracy. This result seems surprising; however, it becomes clear when we check the payoff matrix. The dark area in figure 1 implies that for α and $\delta-c$ in this area, we have $\frac{(2-\alpha+\delta-c)^2}{16} < \frac{(1-\alpha-c+\delta)^2}{4(1-\alpha)} < \frac{1}{9}$. This means that the payoff matrix (table 1) constitutes a coordination game. Hence, we can't rule out the possibility that the hardware firm may suffer from piracy.

2.3 Software Piracy When PI is Considered

In this section, let's consider the case such that consumers in country A can choose to buy the hardware from either country A or country B. The hardware purchased from country B is called a parallel import. We can imagine that there are many traders who purchase the hardware from retail markets in country B and sell the product in country A. Eventually, PI traders earn zero profit with free entry assumption. However, if a consumer purchases a PI hardware, some modifications to the hardware are required to bypass the region code safeguard. In addition, because the regulation on multimedia product is stronger in reality, we assume that the parallel importation of software is prohibited between two countries.[11] Because we assume that the hardware is protected by a region code, it will be one-way PI from country B to country A for the reason that the modification chip is not available in country B. Given our model specification, we would claim that all PI hardware buyers will pirate the software. The reason is straightforward because if a consumer purchases PI hardware but buys official software, his utility is $(1-\alpha)v - p_h^B - c - t + \delta - p_o^A$, which is strictly smaller than $(1-\alpha)v - p_h^B - c - t + \delta$, the utility obtained by pirating software. Here, a nonnegative parameter t represents the international shipping cost.[12]

The hardware manufacturer has two options to serve country A. The first option is to serve all consumers in country A only by authorized products and charging a single price p_h^A. The other option is to fulfill the demand in country A by both authorized products and parallel imports simultaneously. In the later case, there will be two different prices, the price of the authorized hardware (p_h^A) and the price of PI ($p_h^B + t$). Let's discuss both cases in section 2.3.1 and section 2.3.2.

2.3.1 Regime DP: The hardware manufacturer serves country A by authorized products only (setting $p_h^A = p_h^B + t$ to deter PI):

Because we assume that the hardware is protected by a region code, in this case, it

[11] For example, parallel imports of copyrighted works are considered to be a copyright infringement. See Article 87(4) , Taiwan Copyright Law.

[12] We do not assume search cost on PI because we assume there are many PI traders in the economy. This is particularly true for small open economies such as Taiwan and Hong Kong, where PI are very common and popular. Thus, we assume the extra search cost for PI is insignificant and can be ignored.

will be one-way PI from B to A given the assumption that the modification chip is not available in country B. The manufacturer will maximize his profit by solving the following optimization problem:[13]

$$\begin{aligned} &\max_{\{p_h^A, p_h^B\}} \pi_{hDP} = p_{hDP}^A \left(1 - \frac{p_{hDP}^A + c - \delta}{1-\alpha}\right) + p_{hDP}^B \left(1 - p_{hDP}^B - p_{oDP}^B\right) \\ &s.t. \quad p_{hDP}^A = p_{hDP}^B + t \\ &\qquad \alpha > \delta - c > \frac{1}{\alpha+3}\left(\alpha + \alpha^2 - 2 + 2\sqrt{1-\alpha}\right) > 0 \\ &\qquad \frac{1-\alpha-c+\delta}{2} \geq \frac{1}{3} + t \end{aligned} \tag{8}$$

In other words, the hardware firm maximizes profits by setting two prices in two countries to prevent consumers from buying the hardware from unauthorized channels.

The software provider's profit maximization problem is

$$\max_{\{p_o^A, p_o^B\}} \pi_{oDP} = p_{oDP}^A \left(1 - \frac{p_{oDP}^A - c + \delta}{\alpha}\right) + p_{oDP}^B \left(1 - p_{hDP}^B - p_{oDP}^B\right) \tag{9}$$

Solving the optimization problem of both firms simultaneously, we have

$$\begin{aligned} p_{oDP}^{A\ *} &= \frac{\alpha + c - \delta}{2} \\ p_{hDP}^{A\ *} &= \frac{3(1-\alpha) - 2(c-\delta) - 4t}{7-3\alpha} + t \\ p_{hDP}^{B\ *} &= \frac{3(1-\alpha) - 2(c-\delta) - 4t}{7-3\alpha} \\ p_{oDP}^{B\ *} &= \frac{2 + c - \delta + 2t}{7-3\alpha} \end{aligned}$$

It is premature to claim that the hardware manufacturer will suffer from DP. By drawing a 3D graph on the space of α, t and $c-\delta$, we can verify that the hardware manufacturer will benefit from DP. Figure 2 (figure 3) shows the region where the hardware manufacturer benefits (suffers) from DP. We get an empty set in

[13] If $\frac{1-\alpha-c+\delta}{2} < \frac{1}{3} + t$, PI in this regime won't occur and the result is identical to section 2.2.1.

figure 3 suggesting that the profit of the hardware manufacturer will increase if the hardware manufacturer sets the prices to deter PI.

[Insert Figure 2 here]

[Insert Figure 3 here]

The reason for the hardware manufacturer to benefit from an open policy on parallel importation even when he chooses to deter PI is that when parallel importation is allowed, parallel imports in this scenario make the prices of hardware in two countries convergent. The software provider will respond to the increase[14] of p_h^B by cutting the price of the software in country B. Because the hardware and the software are complements, parallel trade is a commitment device for the hardware manufacturer to raise the hardware price in country B and thus parallel trade enables the hardware firm to extract profits from the software provider. In short, even though the hardware firm suffers in the PI recipient country by deterring PI, the complementarity between the hardware and the software enables the hardware firm to benefit in the parallel exporting country. As consequence, the benefit in country B dominates the loss in country A.

The software provider's profit in country A will not change. However, given our parameter restriction, $\frac{1-\alpha-c+\delta}{2} \geq \frac{1}{3}+t$, the software provider's profit will decrease in country B because both price and quantity demanded for the software in country B decrease.[15]

---

[14] It is easy to check that $p_{hDP}^{B}{}^{*} = \frac{3(1-\alpha)-2(c-\delta)-4t}{7-3\alpha} \geq \frac{1}{3}$ given $\frac{1-\alpha-c+\delta}{2} \geq \frac{1}{3}+t$.

[15] $p_{hDP}^{B}{}^{*} + p_{oDP}^{B}{}^{*}$ is greater than $\frac{2}{3}$ (the value in the benchmark case) and $p_{oDP}^{B}{}^{*} = \frac{2+c-\delta+2t}{7-3\alpha} < \frac{1}{3}$ (the price charged by the software firm in the benchmark case) provided that $\frac{1-\alpha-c+\delta}{2} \geq \frac{1}{3}+t$.

2.3.2 Regime AP: The hardware manufacturer serves country A by both authorized products and PI (Accommodate PI):

If $\frac{1-\alpha-c+\delta}{2}<\frac{1}{3}$, DP won't occur. However, parallel importation is still possible in another scenario which is the one we will discuss in this section. The hardware manufacturer can utilize parallel imports as a channel to price discrimination. Because illegal software users have to modify the hardware, after-sale service is not available even if they purchase the hardware from authorized channels. The only concern that illegal software users have in mind in choosing where to buy the hardware is the price of the hardware. If authorized hardware is cheaper than PI, no consumers will purchase PI, which is either an uninteresting case or has been discussed in section 2.3.1. Therefore, in this section, we will consider the case where the hardware price in country A is higher than the price of PI, which is the hardware price in country B plus international shipping cost. The price gap sustains even when parallel importation exists because PI is now a channel to separating different types of consumers. In our specification, all illegal software users will buy PI and only those consumers who purchase official software will buy the authorized hardware. Consumer's preference in country A and country B can be described by

$$U^A=\begin{cases} v-p_h^A-p_o^A & \text{if purchasing the legitimate system} \\ (1-\alpha)v-p_h^B-t-c+\delta & \text{if using pirated software and PI} \\ 0 & \text{if no adoption} \end{cases}$$

$$U^B=\begin{cases} v-p_h^B-p_o^B & \text{if purchasing the system} \\ 0 & \text{if no adoption} \end{cases}$$

We can now obtain the profit functions of both hardware and software firms. The hardware manufacturer's profit maximization problem is

$$\max_{\{p_{hAP}^A, p_{hAP}^B\}} \pi_{hAP} = p_{hAP}^B \left(1 - p_{oAP}^B - p_{hAP}^B\right) + p_{hAP}^B \left(\frac{p_{oAP}^A + p_{hAP}^A - p_{hAP}^B - t - c + \delta}{\alpha} - \frac{p_{hAP}^B + t + c - \delta}{1-\alpha} \right) + p_{hAP}^A \left(1 - \frac{p_{oAP}^A + p_{hAP}^A - p_{hAP}^B - t - c + \delta}{\alpha} \right) \tag{10}$$

$$s.t.\ 1 > \frac{p_{oAP}^A + p_{hAP}^A - p_{hAP}^B - t - c + \delta}{\alpha} > \frac{p_{hAP}^B + t + c - \delta}{1-\alpha} \geq 0$$

$$p_{hAP}^A > p_{hAP}^B + t$$

$$\alpha > \delta - c > \frac{1}{\alpha+3}\left(\alpha + \alpha^2 - 2 + 2\sqrt{1-\alpha}\right) > 0$$

The derivation of (10) is shown in appendix A2. The first term in the profit function is the profit obtained in country B where piracy is absent. The second term describes the profit from PI and the last term in the profit function is the profit from selling authorized hardware in country A. $\left(\frac{p_{oAP}^A + p_{hAP}^A - p_{hAP}^B - t - c + \delta}{\alpha} - \frac{p_{hAP}^B + t + c - \delta}{1-\alpha} \right)$ represents the PI volume while $\left(1 - \frac{p_{oAP}^A + p_{hAP}^A - p_{hAP}^B - t - c + \delta}{\alpha} \right)$ describes the quantity demanded for the authorized hardware in country A. The inequality $p_{hAP}^A > p_{hAP}^B + t$ comes from the assumption that the hardware manufacturer serves country A by both authorized products and parallel imports. If it were violated, the result will be identical to regime DP.

Similarly, the software provider maximizes his profit

$$\pi_{oAP} = p_{oAP}^B \left(1 - p_{oAP}^B - p_{hAP}^B\right) + p_{oAP}^A \left(1 - \frac{p_{oAP}^A + p_{hAP}^A - p_{hAP}^B - t - c + \delta}{\alpha} \right) \tag{11}$$

The solution to the optimization problem (10) and (11) is

$$p_{oAP}^{A\ *} = \frac{\alpha + c - \delta + t}{3}$$
$$p_{oAP}^{B\ *} = \frac{2 + c - \delta + t}{7 - 3\alpha}$$
$$p_{hAP}^{A\ *} = \frac{9 - 2\alpha - 3\alpha^2 + (1 - 3\alpha)(c - \delta + t)}{3(7 - 3\alpha)}$$
$$p_{hAP}^{B\ *} = \frac{3 - 3\alpha - 2(c - \delta + t)}{7 - 3\alpha}$$

subject to[16]

$$0 \le t < \min\left[\frac{\alpha + c - \delta}{2}, \frac{7(c - \delta) - \alpha(6\alpha - 5)(-1 + \alpha + c - \delta)}{-7 + \alpha(6\alpha - 5)}\right]$$

Comparing this set of prices to that in the case of DP, given the constraints on *t*, we have the following results: $p_{hAP}^{A\ *} > p_{hDP}^{A\ *}$, $p_{hAP}^{B\ *} > p_{hDP}^{B\ *}$, $p_{oAP}^{A\ *} < p_{oDP}^{A\ *}$, and $p_{oAP}^{B\ *} < p_{oDP}^{B\ *}$. In other words, the hardware firm charges higher prices whereas the software provider reduces the prices in both countries if the hardware manufacturer chooses AP. The reason for an increase in hardware price in country B builds on an increase in demand for country B's hardware since consumers who pirate the software will purchase the hardware from country B. One should note that the extra demand for hardware from country B does not accompany with an increase in the demand for country B's official software. Actually, the increase in demand for country B's hardware could be harmful for the software provider in country B. Since PI may raise the price of country B's hardware, fewer consumers in country B are willing to purchase the system (hardware plus software) and thus the demand for the software in country B decreases. Therefore, the price of software in country B falls. It is not surprising to see that the price of authorized hardware in country A increases. But now,

---

16 $t < \frac{\alpha + c - \delta}{2}$ because $p_h^A > p_h^B + t$; $t < \frac{7(c - \delta) - \alpha(6\alpha - 5)(-1 + \alpha + c - \delta)}{-7 + \alpha(6\alpha - 5)}$ because $v_1^{AP} > v_2^{AP}$.

the software price in country A is affected by the price of hardware because by checking (10), we can see that the marginal consumer is considering the price gap between the authorized hardware and PI. The same argument in the analysis of a decrease in software price can be applied to country A, which is an increase in the hardware price leads to a decrease in software price.

[Insert Table 2 here]

Table 2 summarizes the strategies that the hardware firm can adopt in different situations. When $p_{hPN}^{A\,*} \geq p_{hPN}^{B\,*} + t$ (i.e. $\frac{1-\alpha-c+\delta}{2} \geq \frac{1}{3}+t$), autarky equilibrium is not sustainable, and thus the hardware firm can choose between DP and AP. Whether AP dominates DP or not depends on the values of parameters. Figure 4 shows the region where AP is the hardware firm's profit-maximizing pricing behavior for $p_{hPN}^{A\,*} \geq p_{hPN}^{B\,*} + t$. On the other hand, when $p_{hPN}^{A\,*} < p_{hPN}^{B\,*} + t$, the hardware firm can choose either AP or autarky pricing. The region where AP dominates autarky pricing is presented in figure 5. The reason why the hardware firm can benefit from AP is that the hardware firm can utilize PI as a channel to distinguishing two types of consumers and obtain higher profits. Price discrimination is possible because illegal software users do not care about after-sale service and thus are more sensitive to hardware price. Cheaper PI help the hardware firm identify two types of consumers. Let's summarize the conditions such that each strategy to be adopted by the hardware firm by the tree map in figure 6.

[Insert Figure 4 here]

[Insert Figure 5 here]

[Insert Figure 6 here]

Proposition 4. *Parallel imports are never harmful to the hardware manufacturer.*

When $p_{hPN}^{A\ *} \geq p_{hPN}^{B\ *} + t$, PI is always beneficial for the hardware firm because in section 2.3.1, we have shown that the hardware firm can always raise the profit by DP. Figure 4 also shows that AP can even dominate DP for certain parameters. On the other hand, when $p_{hPN}^{A\ *} < p_{hPN}^{B\ *} + t$, in certain circumstances which are demonstrated in figure 5, AP is more desirable than autarky pricing. In sum, the hardware firm can adopt a proper strategy such that his profit is guaranteed to be greater or equal to autarky.

We can then discuss the impact of hardware manufacturer's second degree price discrimination behavior on the software provider's profit. For $\frac{1-\alpha-c+\delta}{2} \geq \frac{1}{3} + t$, if the manufacturer chooses AP, the software provider faces a smaller (relative to DP) demand in country A. To see this, let's compare the inverse demand function for the legitimate software in country A for two regimes:

$q_{oAP}^{A} = \left(1 - \frac{p_o^A + p_{hAP}^A - p_{hAP}^B - t - c + \delta}{\alpha}\right) < \left(1 - \frac{p_o^A - t - c + \delta}{\alpha}\right) = q_{oDP}^{A}$, where q_{oAP}^{A} and q_{oDP}^{A} denote the quantity demanded for the legitimate software in country A for regime AP and DP, respectively. The same results can be obtained in country B as well. When comparing the software provider's profit in country B for AP and DP, because $p_{hAP}^{B\ *} > p_{hDP}^{B\ *}$, the demand for legitimate software in country B (i.e. $1 - p_o^B - p_h^B$) decreases in AP relative to DP. In short, the demand for the legitimate software decreases in both countries when the hardware firm chooses AP. Therefore, the profit of the software provider will decrease if the hardware manufacturer accommodates PI. On the other hand, for $\frac{1-\alpha-c+\delta}{2} < \frac{1}{3} + t$, if the hardware firm chooses AP, unlike the autarky case, where the software firm can behave as a monopolist (see equation 4) in country A, the software firm is pinned down by the hardware firm in regime AP. In sum, parallel trade in hardware is harmful for the software firm even though PI in software is prohibited.

3. Welfare Analysis

We will first demonstrate a comparison of consumer surplus with and without software piracy. Subsequently, we will discuss the impact of PI on consumer's welfare.

3.1 Consumer's welfare change with software piracy when hardware PI is prohibited

To compare changes in consumer surplus (*CS*) due to software piracy, let's first calculate the *CS* in both countries for the benchmark case. i.e. the consumer welfare when piracy and PI are not available.

$$CS_{NN}^{A} = CS_{NN}^{B} = \int_{\frac{2}{3}}^{1}\left(v - \frac{1}{3} - \frac{1}{3}\right)\mathrm{d}v = \frac{1}{18} \tag{12}$$

where the subscript *NN* denotes "No piracy" and "No PI".

If there is illegal software copy in country A, the welfare in country A becomes

$$CS_{PN}^{A} = \int_{\mathrm{v}_2}^{\mathrm{v}_1}\left(\left(1-\alpha\right)v - p_{hPN}^{A}{}^{*} - c + \delta\right)\mathrm{d}v + \int_{\mathrm{v}_1}^{1}\left(v - p_{hPN}^{A}{}^{*} - p_{oPN}^{A}{}^{*}\right)\mathrm{d}v \tag{13}$$

where

$$\mathrm{v}_1 = \frac{\frac{\alpha+c-\delta}{2} - \left(c-\delta\right)}{\alpha},\ \mathrm{v}_2 = \frac{\frac{1-\alpha-\left(c-\delta\right)}{2} + c - \delta}{1-\alpha},\ p_{hPN}^{A}{}^{*} = \frac{1-\alpha-\left(c-\delta\right)}{2},\ p_{oPN}^{A}{}^{*} = \frac{\alpha+c-\delta}{2}$$

and the subscript PN denotes "Piracy" and "No PI".

Let the consumer's welfare change in country A be $\Delta CS_{PN}^{A} = CS_{PN}^{A} - CS_{NN}^{A}$. We can verify that the consumer's surplus will increase by checking figure 7. From the graph, we see ΔCS_{PN}^{A} is always positive on the same domain of figure 1 suggesting that consumers are always better off when software piracy exists. In section 2.2, we have explained that both firms might be better off due to piracy in certain circumstances. (i.e. the medium dark area in figure 1.) Combining the results in section 2.2 and the present section, we can say that software piracy could be Pareto improving. Lemma 1 summarizes this finding.

Lemma 1. *If hardware parallel importation is not permitted, the existence of software piracy can be Pareto improving.*

[Insert Figure 7 here]

The reason for firms to be better off when piracy exists has been discussed in section 2.2 and thus we won't repeat it here. The intuition for an increase in consumer's welfare is as what follows. Software piracy can lower consumers' threshold of adoption and hence low type consumers can also be served by the hardware manufacturer.

3.2 Welfare change due to parallel imports given software piracy

In this section, we are going to discuss welfare change in both countries due to parallel imports. Because the manufacturer has two options to serve country A (DP and AP), we will discuss two scenarios respectively.

Scenario 1: Deterring PI (DP)

Let the consumer's surplus in country A and B when the manufacturer deters PI be

$$CS_{DP}^{A} = \int_{v_2^{DP}}^{v_1^{DP}} \left((1-\alpha) v - p_{hDP}^{A}{}^{*} - c + \delta \right) \mathrm{d} v + \int_{v_1^{DP}}^{1} \left(v - p_{hDP}^{A}{}^{*} - p_{oDP}^{A}{}^{*} \right) \mathrm{d} v \qquad (14)$$

$$CS_{DP}^{B} = \int_{p_{oDP}^{B}{}^{*}+p_{hDP}^{B}{}^{*}}^{1} \left(v - p_{oDP}^{B}{}^{*} - p_{hDP}^{B}{}^{*}\right) \mathrm{d}v \tag{15}$$

where

$$\mathrm{v}_1^{DP} = \frac{\frac{\alpha+c-\delta}{2} - c + \delta}{\alpha}, \ \mathrm{v}_2^{DP} = \frac{\frac{3(1-\alpha)-2(c-\delta)-4t}{7-3\alpha} + t + c - \delta}{1-\alpha},$$

$$p_{hDP}^{A}{}^{*} = \frac{3(1-\alpha)-2(c-\delta)-4t}{7-3\alpha} + t, \ p_{hDP}^{B}{}^{*} = \frac{3(1-\alpha)-2(c-\delta)-4t}{7-3\alpha},$$

$$p_{oDP}^{A}{}^{*} = \frac{\alpha+c-\delta}{2}, \ p_{oDP}^{B}{}^{*} = \frac{2+c-\delta+2t}{7-3\alpha}$$

The consumer's welfare change due to PI in country A is now $\Delta CS_{DP}^{A} = CS_{DP}^{A} - CS_{PN}^{A}$. We can conclude that if DP is the manufacturer's best choice, consumer's surplus in country A will increase. If, in equilibrium, the manufacturer chooses DP, he needs to cut the hardware price in the PI recipient country. In addition, the software provider will not change his pricing behavior because, for the same reason stated in section 2.2, v_1 is independent of the hardware price p_{hDP}^{A}. In short, consumers in country A face a lower hardware price and an unchanged software price, and hence, consumer's welfare increases in country A.

The consumer's welfare in country B can be calculated through the change of the system price, which is the sum of hardware price and software price, because by the assumption that there's no piracy in country B, consumers in country B purchase the hardware and the legitimate software together. The consumer's surplus in country B will decrease because of the increase of hardware price p_{hDP}^{B}. Even though the software firm responses to the increase of hardware price by cutting software price, as described in footnote 15, the sum of hardware price and software price in country B still goes up. In sum, if the hardware manufacturer deters PI, consumers in country A will benefit whereas consumers in country B will be worse off.

The software provider won't be affected in country A but will suffer in country B as we analyzed in section 2.3.1. Thus, if the hardware manufacturer chooses DP, the software provider will be worse off.

Scenario 2: Accommodating PI (AP)

If the hardware manufacturer chooses to accommodate PI, the consumer's surplus in country A and B will be

$$CS_{AP}^{A} = \int_{v_2^{AP}}^{v_1^{AP}} \left((1-\alpha)v - p_{hAP}^{B\ *} - t - c + \delta \right) \mathrm{d}v + \int_{v_1^{AP}}^{1} \left(v - p_{hAP}^{A\ *} - p_{oAP}^{A\ *} \right) \mathrm{d}v \qquad (16)$$

$$CS_{AP}^{B} = \int_{p_{hAP}^{B\ *} + p_{oAP}^{B\ *}}^{1} \left(v - p_{hAP}^{B\ *} - p_{oAP}^{B\ *} \right) \mathrm{d}v \qquad (17)$$

Because AP is feasible for both $\frac{1-\alpha-c+\delta}{2} \geq \frac{1}{3}+t$ and $\frac{1-\alpha-c+\delta}{2} < \frac{1}{3}+t$, yet two cases have different equilibrium conditions, to explain the impact of AP on consumer welfare, we need to discuss two cases separately:

Case 1: $\frac{1-\alpha-c+\delta}{2} \geq \frac{1}{3}+t$

In this case, the hardware firm has two options: DP and AP. AP is optimal for the hardware firm if $\pi_{hAP}{}^{*} > \pi_{hDP}{}^{*}$. Therefore, to discuss how consumer's surplus changes when the hardware firm chooses accommodating PI, $\pi_{hAP}{}^{*} > \pi_{hDP}{}^{*}$ is a preliminary condition. Figure 8 (figure 9) shows the region where consumers in country A benefit (suffer) from PI if the hardware firm chooses AP. We can see that both sets are nonempty. They indicate that the impact of AP on consumer's welfare in country A is ambiguous. Applying the same technique to the analysis of consumer's welfare change in country B, we find that the region for consumers in country B to be better off is empty suggesting that consumer's surplus decreases in country B.

[Insert Figure 8 here]

[Insert Figure 9 here]

Case 2: $\frac{1-\alpha-c+\delta}{2}<\frac{1}{3}+t$

In this case, the hardware manufacturer will choose either autarky pricing or AP. If the hardware firm chooses AP, consumers in country A are worse due to PI. Figure 10 shows the region where consumers in country A suffer from AP. We do not provide the region where consumers in country A benefit from AP because it is an empty set.

[Insert Figure 10 here]

The welfare change of consumers in country B is ambiguous in this case. Figure 11 (figure 12) depicts the region where consumers in country B benefit (suffer) from AP.

[Insert Figure 11 here]

[Insert Figure 12 here]

Table 3 summarizes welfare change due to software piracy and table 4 summarizes welfare change due to parallel imports.

[Insert Table 3 here]

[Insert Table 4 here]

In this section, we demonstrate welfare implication of PI. It should be noted that unlike piracy which creates extra demand for hardware, the way for the hardware manufacturer to benefit from PI is to extract profits from the software firm. The intuition of firm's profit change has been discussed in previous sections and thus we won't repeat it here. Consumer's welfare implication is also intuitive. Firstly, DP lowers the hardware price in country A suggesting that the consumers in country A are better off; however, consumers in the parallel exporting country will be worse off due to price convergence between two countries as stated in Malueg and Schwartz (1994).

Secondly, the impact of AP on consumer's welfare depends on the autarky price of the hardware. As stated in most economic textbooks, cēterīs paribus, price discrimination is harmful for consumers. When the closed-economy hardware price in country A is high, allowing PI is generally beneficial for consumers in country A; however, the benefits could be eroded if the hardware firm chooses to utilize PI as the channel to achieving price discrimination. Therefore, when the autarky hardware price in country A is high, the impact of AP on consumer's welfare in country A is ambiguous. On the other hand, when the autarky hardware price in country A is low, consumers in country A can't obtain any benefits from an open policy but need to bear the welfare loss due to price discrimination. Hence, consumers in country A are worse off in the case of AP when the autarky hardware price in country A is low.

The analysis of consumer's welfare change in country B in the case of AP is provided below. For $\frac{1-\alpha-c+\delta}{2}\geq\frac{1}{3}+t$, we have argued that consumers in country B are worse off if the hardware firm chooses DP. In addition, because $CS_{AP}^{B}=\frac{\left(2+c-\delta+t\right)^{2}}{2\left(7-3\alpha\right)^{2}}<\frac{\left(2+c-\delta+2t\right)^{2}}{2\left(7-3\alpha\right)^{2}}=CS_{DP}^{B}$, consumers in country B must be worse off due to AP. The intuition behind this result is that when $\frac{1-\alpha-c+\delta}{2}\geq\frac{1}{3}+t$, modified hardware is more attractive, and thus the hardware firm can serve country A by high price PI. As a consequence, the hardware price in the PI exporting country raises and thus consumers in country B are worse off. On the other hand, for $\frac{1-\alpha-c+\delta}{2}<\frac{1}{3}+t$, it should be noted that in this case, parallel trade will occur only in the form of AP. Intuitively, To make PI possible, the hardware manufacturer may need to reduce the price in country B to attract low type consumers in country A. Therefore, if the autarky hardware price in country A is low, it is still possible for consumers in country B to be better off due to AP.

4. Region-free Hardware

If the hardware is region-free, the PI recipient country could be country A or country B. Suppose that country A is the PI recipient country, the claim that all consumers who purchase PI hardware will pirate the software still holds. The reason is as follows. Because the hardware manufacturer does not provide after-sale service to a PI buyer, an official software consumer who purchases PI hardware has a surplus of $(1-\alpha)v - p_h^B - t - p_o^A$, which is smaller than $(1-\alpha)v - p_h^B - t - c + \delta$ given the fact that $c - \delta < 0 < p_o^A$. Therefore, if country A is the PI recipient country, the result won't change even though the hardware is region-free.

However, is it possible for country B to be the PI recipient country when the hardware is region-free? The following analysis shows that country B can't be the PI recipient country. First, we will claim that serving country B only by authorized products (deterring PI) is not feasible by adopting proof by contradiction. Suppose that country B is the PI recipient country. Let v_1^B be the valuation of the marginal consumer who is indifferent between authorized hardware and PI in country B. v_1^B must satisfy $\mathrm{v}_1^B - p_h^B - p_o^B = (1-\alpha)\mathrm{v}_1^B - \left(p_h^A + t\right) - p_o^B$ and is equal to $\frac{1}{\alpha}\left(p_h^B - p_h^A - t\right)$. Similarly, let v_2^B be the valuation of the marginal consumer who is indifferent between PI and no adoption. We have $\mathrm{v}_2^B = \frac{1}{1-\alpha}\left(p_h^A + t + p_o^B\right)$. Because $\mathrm{v}_1^B > \mathrm{v}_2^B$, we have $\frac{1}{\alpha}\left(p_h^B - p_h^A - t\right) > \frac{1}{1-\alpha}\left(p_h^A + t + p_o^B\right)$. Solving this inequality implies $p_h^B - \left(p_h^A + t\right) > \alpha\left(p_h^B + p_o^B\right)$. However, deterring PI implies that $p_h^B = p_h^A + t$, which is a contradiction to $p_h^B - \left(p_h^A + t\right) > \alpha\left(p_h^B + p_o^B\right) > 0$ given positive prices assumptions.

We have shown that $p_h^B = p_h^A + t$ does not hold, but on the other hand, in equilibrium, can we have $p_h^B > p_h^A + t$, which is the case that the hardware manufacturer serves country B by both authorized products and PI simultaneously? The work in the appendix A3 proves that this is still infeasible for the hardware manufacturer. In summary, even though the hardware is region free, it is still a one-way PI outcome from country B to country A. This result can explain why Sony makes its new game console region-free. As stated above, embedding a region code on the hardware is redundant because the region code does not play any role. Parallel trade occurs from country B to country A no matter whether there is region code or not.

5. Discussion and Conclusions

This article analyzes the impact of outlaw innovations on the video game market. We obtain three results that are different from general expectation. Firstly, we discuss the existence of software piracy in a closed economy. Our benchmark model indicates that the hardware manufacturer may benefit from piracy as expected by most people. However, we also find that software piracy may also be beneficial to the software provider. Secondly, we extend our closed-economy analysis to a two-country model where the modification chips are available in one country but are unavailable in the other. We show that the existence of hardware parallel imports is beneficial to the hardware manufacturer but is harmful to the software provider. Thirdly, our welfare analysis shows that the consumers in the PI recipient country are not necessarily better off. If the hardware manufacturer deters PI, consumers in the PI recipient country will benefit as expected. However, if the hardware provider chooses to serve the country by both authorized products and parallel imports, PI provide the manufacturer a key to second-degree price discriminating the consumers in the PI recipient country. In this case, consumers in the PI recipient country may be worse off.

This article considers a non-cooperative game; however, some may argue that it is possible for both software and hardware firms to cooperate and offer a bundle of hardware and software to prevent piracy. In appendix A4, it is shown that there does not exist a way to distribute the joint profit such that both firms are willing to join the coalition. Consequently, bundling won't be utilized to prevent piracy.

It should be noted that the results of this article base on the assumption that both the hardware manufacturer and the software provider are monopoly. If there are two or more firms who produce homogeneous products in the market, price competition leads to zero profits. If firms are differentiated vertically, it will be difficult to set up consumers' preference order. For example, if authorized product *i* is superior to authorized product *j*, then whether PI of *i*th product are inferior to *j*th authorized products or not is crucial for the analysis. Unfortunately, we do not have a judgment on preference order. As the number of firms increases, it becomes too complicated to analyze. Therefore, we assume one hardware manufacturer and one software provider in the model. Although this assumption is somewhat strong, it is still acceptable because in the realistic world, different brands of game consoles or software are reasonably differentiated in several dimensions, and thus firms have market power even though the inverse demand will become flatter due to competition. Hence, our analysis may still work for explaining the change in region-code strategy adopted by the hardware manufacturer.

The result of the model suggests that piracy is welfare improving for consumers.

However, this result could only be true in a static model. In the present analysis, we show that piracy could sometimes be beneficial for the software provider; however, it is more common to see that the software firm suffers from piracy. In a dynamic model, even though consumers can be better off due to software piracy in the short run, piracy would be harmful for the software firm's investment incentive in quality improvement or development of new software. As a consequence, with software piracy, the consumer's welfare would decrease in the long run.

As aforementioned, we adopt horizontal retail price arbitrage framework in the analysis. Parallel to the case of accommodating PI, applying this idea to vertical price control framework, we expect that the manufacturer will charge a higher wholesale price in country A and a lower wholesale price in country B to encourage PI and get benefits from price discrimination. Although we do not provide vertical price control model in the present article, it will be interesting for future analysis. In addition, in this model, the utility discount factor $\left(1-\alpha\right)$ is assumed to be exogenous. Because α can be interpreted as the probability that a consumer needs after-sale service for the hardware, for future research, it would be interesting to endogenize this parameter.

The article aims to provide some policy implications regarding IPR exhaustion policy in the video game market. In contrast to general expectation that consumers are better off in the presence of PI, it is shown in this article that the impact of PI on consumer's welfare in the PI-recipient country is ambiguous if the parallel imported product is complementary to other goods. An open policy in parallel importation is not necessarily good for consumers in the video game market or analogous industries that feature complementarity.

Appendix

A1. The derivation of $c < \delta$

$$\mathrm{v}_1 = \frac{p_{oPN}^A - (c-\delta)}{\alpha} = \frac{\frac{\alpha + c - \delta}{2} - (c-\delta)}{\alpha} = \frac{1}{2} - \frac{c-\delta}{2\alpha} \text{ and}$$

$$\mathrm{v}_2 = \frac{p_{hPN}^A + c - \delta}{1-\alpha} = \frac{\frac{1-\alpha-c+\delta}{2} + c - \delta}{1-\alpha} = \frac{1}{2} + \frac{c-\delta}{2(1-\alpha)}.$$

Because $\mathrm{v}_1 > \mathrm{v}_2$, we have $\frac{1}{2} - \frac{c-\delta}{2\alpha} > \frac{1}{2} + \frac{c-\delta}{2(1-\alpha)}$. This inequality is equivalent to $\frac{(c-\delta)(1-\alpha)+\alpha(c-\delta)}{2\alpha(1-\alpha)} < 0$. Given $\alpha \in (0,1)$, the inequality can be reduced to $(c-\delta)(1-\alpha)+\alpha(c-\delta) < 0$, which is the inequality $c < \delta$.

A2. The derivation of (10)

$$U^A = \begin{cases} v - p_h^A - p_o^A \\ (1-\alpha)v - p_h^B - t - c + \delta \\ 0 \end{cases} ; \quad U^B = \begin{cases} v - p_h^B - p_o^B \\ 0 \end{cases}$$

For simplicity, we ignore the subscript AP. A consumer with valuation v_1 in country A is indifferent between legitimate software and illegal software if $\mathrm{v}_1 - p_h^A - p_o^A = (1-\alpha)\mathrm{v}_1 - p_h^B - t - c + \delta$. Solving for v_1, we can say that consumers with $v > \mathrm{v}_1 = \frac{p_o^A + p_h^A - p_h^B - t - c + \delta}{\alpha}$ will purchase the authorized hardware and official software. Similarly, A consumer with valuation v_2 in country A will be indifferent between illegal software and no adoption if $(1-\alpha)v - p_h^B - t - c + \delta = 0$. Thus, $\mathrm{v}_2 = \frac{p_h^B + t + c - \delta}{1-\alpha}$. Consumers with valuation between v_2 and v_1 will purchase the PI hardware. The quantity demanded for the authorized hardware in country A can be calculated by

$$\int_{v_1}^{1} 1\,\mathrm{d}x = 1 - \frac{p_o^A + p_h^A - p_h^B - t - c + \delta}{\alpha},$$

whereas the quantity demanded for the PI hardware is

$$\int_{v_2}^{v_1} 1\,\mathrm{d}x = \frac{p_o^A + p_h^A - p_h^B - t - c + \delta}{\alpha} - \frac{p_h^B + t + c - \delta}{1-\alpha}.$$

Therefore, the profit of the hardware manufacturer is the sum of profit from authorized channels in both countries and the profit from PI. The profit from authorized channel in country B is shown in the benchmark, which is equal to $p_h^B\left(1 - p_o^B - p_h^B\right)$.

The profit from authorized channel in country A is $p_h^A\left(1 - \frac{p_o^A + p_h^A - p_h^B - t - c + \delta}{\alpha}\right)$.

The profit generated from PI is $p_h^B\left(\frac{p_o^A + p_h^A - p_h^B - t - c + \delta}{\alpha} - \frac{p_h^B + t + c - \delta}{1-\alpha}\right)$.

Summing these terms up leads to (10).

A3. Country B won't be the PI recipient country

Suppose that country B is the PI recipient country. The quantity demanded for the authorized hardware is $\int_{v_1^B}^{1} 1\,\mathrm{d}x = 1 - \frac{p_h^B - p_h^A - t}{\alpha}$. Similarly, the quantity demanded for the PI hardware can be represented by $\int_{v_2^B}^{v_1^B} 1\,\mathrm{d}x = \frac{p_h^B - p_h^A - t}{\alpha} - \frac{p_h^A + t + p_o^B}{1-\alpha}$. Because all buyers in country B purchase legitimate software, the quantity demanded for the software is $\int_{v_2^B}^{1} 1\,\mathrm{d}x = 1 - \frac{p_h^A + t + p_o^B}{1-\alpha}$.

The hardware manufacturer faces the following profit maximization problem:

$$\max_{\{p_h^A, p_h^B\}} \pi_{hRF} = p_h^B\left(1 - \frac{p_h^B - p_h^A - t}{\alpha}\right) + p_h^A\left(\frac{p_h^B - p_h^A - t}{\alpha} - \frac{p_h^A + t + p_o^B}{1-\alpha}\right) + p_h^A\left(1 - \frac{p_h^A + c - \delta}{1-\alpha}\right)$$

where RF indicates region free. The first term is the profit from selling authorized products in country B. The second term is the profit from PI while the third term is the profit of authorized products in country A. The software provider's profit maximization problem is now

$$\max_{\{p_o^A, p_o^B\}} \pi_{oRF} = p_o^B\left(1-\frac{p_h^A+t+p_o^B}{1-\alpha}\right)+p_o^A\left(1-\frac{p_o^A-c+\delta}{\alpha}\right)$$

The first (second) term is the profit from country B (country A).

Solving the optimization problem of both firms with respect to p_h^A, p_h^B, p_o^A, and p_o^B, we have

$$p_h^{A*}=\frac{3-3\alpha-2(c-\delta)-t}{7},\ p_h^{B*}=\frac{6+\alpha-4(c-\delta)+5t}{14},$$
$$p_o^{A*}=\frac{\alpha+c-\delta}{2},\ p_o^{B*}=\frac{2-2\alpha+c-\delta-3t}{7}$$

Substituting p_h^{A*}, p_h^{B*}, p_o^{A*}, and p_o^{B*} into v_1^B and v_2^B and imposing the assumption that $\mathrm{v}_1^B > \mathrm{v}_2^B$, we have

$$\mathrm{v}_1^B=\frac{p_h^{B*}-p_h^{A*}-t}{\alpha}=\frac{\frac{6+\alpha-4(c-\delta)+5t}{14}-\left(\frac{3-3\alpha-2(c-\delta)-t}{7}+t\right)}{\alpha}>$$
$$\mathrm{v}_2^B=\frac{p_h^{A*}+t+p_o^{B*}}{1-\alpha}=\frac{\frac{3-3\alpha-2(c-\delta)-t}{7}+t+\frac{2-2\alpha+c-\delta-3t}{7}}{1-\alpha}$$

Given $\alpha\in(0,1)$ and $t\geq 0$, solving the above inequality yields

$$c-\delta>\frac{3\alpha(1-\alpha)+t(7-\alpha)}{2\alpha}>0.$$

This contradicts to the result that $c-\delta<0$, which has been proven in A1.

A4. Bundling won't be utilized to prevent piracy

When both firms cooperate and offer a bundle of hardware and software, the equilibrium price of the bundle can be derived by solving the following profit maximization problem:

$$\max_{p} \pi_{BU}(p) = p(1-p)$$

The equilibrium price of the bundle is 1/2 and joint profit is 1/4. Let $s \in [0,1]$ be the fraction of the joint profit that goes to the hardware manufacturer. When piracy exists, the hardware manufacturer would prefer to cooperate with the software firm if $\frac{(1-\alpha-c+\delta)^2}{4(1-\alpha)} < \frac{s}{4}$. Similarly, the software firm would prefer to offer a bundle by cooperating with the hardware firm if $\frac{(\alpha+c-\delta)^2}{4\alpha} < \frac{1-s}{4}$. Given α and $(c-\delta)$, if we can find an s such that both inequalities hold, then cooperation can be the equilibrium. In other words, by definition of the core of a coalition game, the core is nonempty if $\frac{(1-\alpha-c+\delta)^2}{4(1-\alpha)} < \frac{s}{4}$ and $\frac{(\alpha+c-\delta)^2}{4\alpha} < \frac{1-s}{4}$ simultaneously hold. Accordingly, the core is nonempty if $\frac{(1-\alpha-c+\delta)^2}{1-\alpha} < s < 1 - \frac{(\alpha+c-\delta)^2}{\alpha}$. However, this double inequality never holds because

$$1 - \frac{(\alpha+c-\delta)^2}{\alpha} - \frac{(1-\alpha-c+\delta)^2}{1-\alpha} = \frac{-(c-\delta)^2}{\alpha(1-\alpha)} < 0 \quad \text{for} \quad \alpha \in (0,1),$$

which is a contradiction to the condition for the core to exist. In other words, with aforementioned restrictions on parameters, we have

$$\left\{(\alpha, c-\delta, s) \mid \left\{\frac{(1-\alpha-c+\delta)^2}{4(1-\alpha)} < \frac{s}{4}\right\} \cap \left\{\frac{(\alpha+c-\delta)^2}{4\alpha} < \frac{1-s}{4}\right\}\right\} \in \varnothing$$

It suggests that there is no way to find a method to distribute the joint profit such that both firms agree to join the coalition. Hence, bundling won't be adopted to prevent piracy.

Reference

Ahmadi, R., & Yang, B. R. (2000). Parallel Imports: Challenges from Unauthorized Distribution Channels. *Marketing Science, 19*(3), 279-294.

Anderson, S., & Ginsburgh, V. A. (1999). International Pricing with Costly Consumer Arbitrage. *Review of International Economics, 7*(1), 126-139.

Bae, S. H., & Choi, J. P. (2006). A Model of Piracy. *Information Economics and Policy, 18*(3), 303-320.

Chen, Y., & Maskus, K. E. (2005). Vertical Pricing and Parallel Imports. *The Journal of International Trade & Economic Development, 14*(1), 1-18.

Fink, C., & Maskus, K. E. (Eds.). (2005). *Intellectual Property and Development : Lessons from Recent Economic Research* Washington D.C.: The World Bank.

Flowers, S. (2008). Harnessing the Hackers: The Emergence and Exploitation of Outlaw Innovation. *Research Policy, 37*(2), 177-193.

Ganslandt, M., & Maskus, K. E. (2007). Vertical Distribution, Parallel Trade, and Price Divergence in Integrated Markets. *European Economic Review, 51*(4), 943-970.

Malueg, D. A., & Schwartz, M. (1994). Parallel Imports, Demand Dispersion, and International Price Discrimination. *Journal of International Economics, 37*(3-4), 167-195.

Maskus, K. E., & Chen, Y. (2002). Parallel Imports in a Model of Vertical Distribution: Theory, Evidence and Policy. *Pacific Economic Review, 7*(2), 319-334.

Maskus, K. E., & Chen, Y. (2004). Vertical Price Control and Parallel Imports: Theory and Evidence. *Review of International Economics, 12*(4), 551-570.

Mollick, E. (2004). *Innovations from the Underground : towards a Theory of Parasitic Innovation.* Unpublished Master's Thesis, MIT, Cambridge, MA.

Peitz, M., & Waelbroeck, P. (2006). Piracy of Digital Products: A Critical Review of the Theoretical Literature. *Information Economics and Policy, 18*(4), 449-476.

Schulz, C., & Wagner, S. (2008). Outlaw Community Innovations. *International Journal of Innovation Management 12*(3), 399-418.

Takeyama, L. N. (1994). The Welfare Implications of Unauthorized Reproduction of Intellectual Property in the Presence of Demand Network Externalities. *The Journal of Industrial Economics, 42*(2), 155-166.

Figures

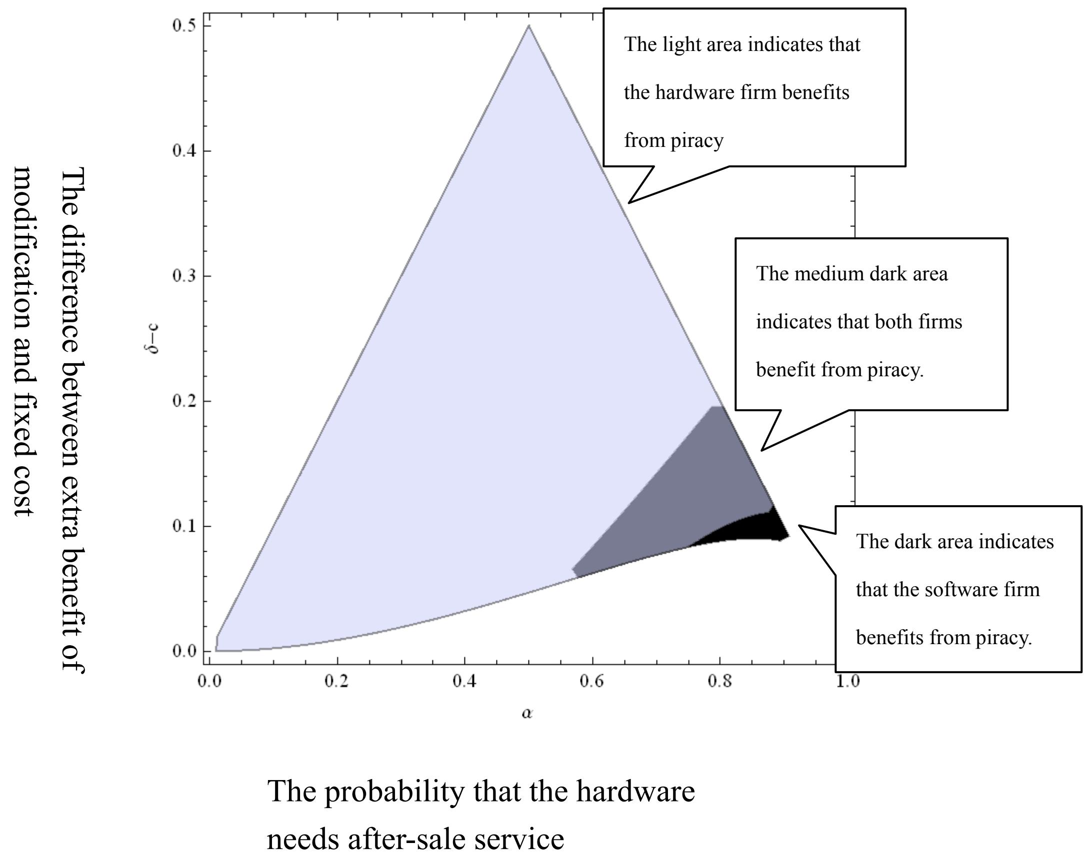

Figure 1: The area where the firms can benefit from piracy

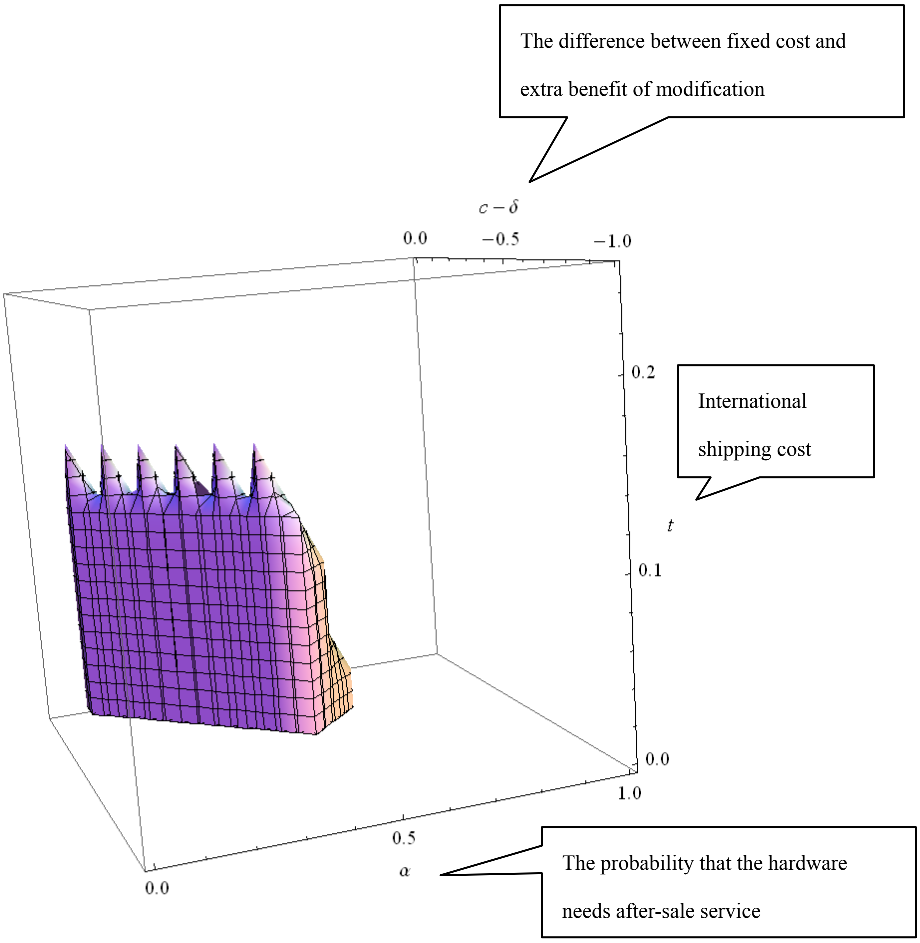

Figure 2 The region where the hardware firm can benefit from DP

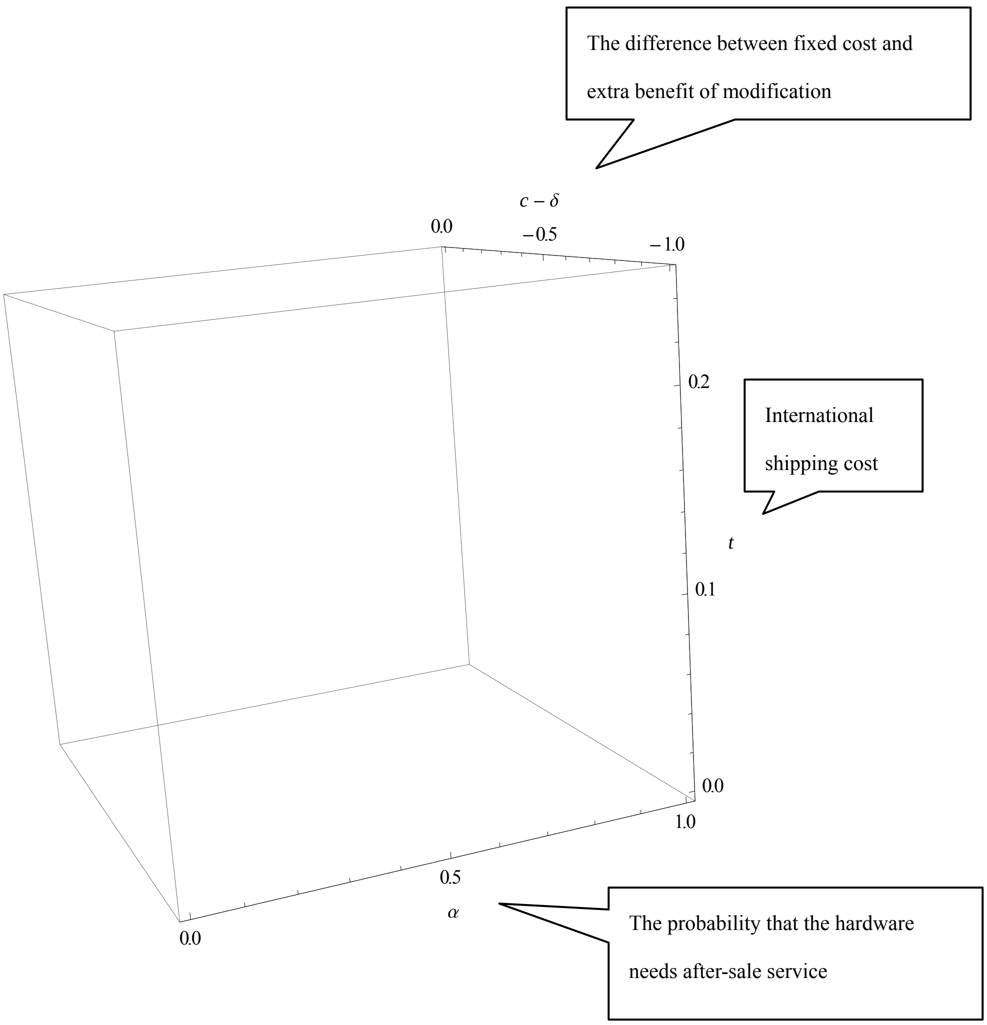

Figure 3 The region where the hardware manufacturer suffers from DP (Empty Set)

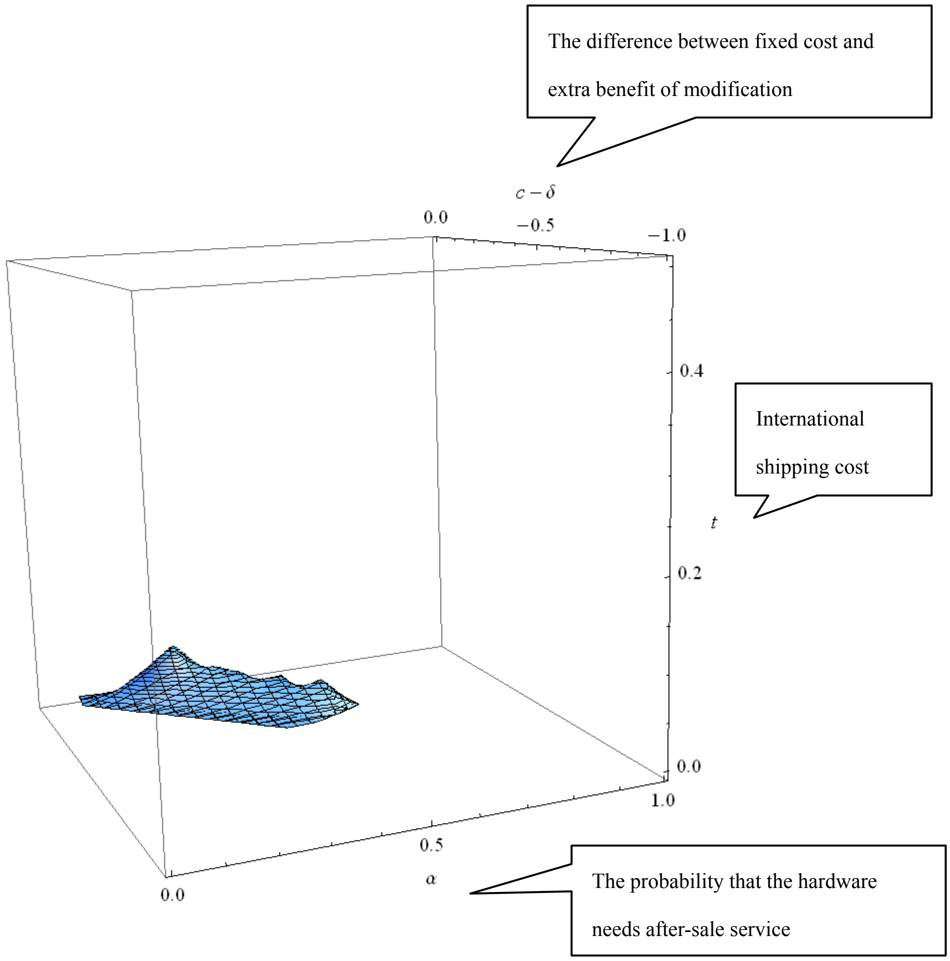

Figure 4 The region where AP dominates DP

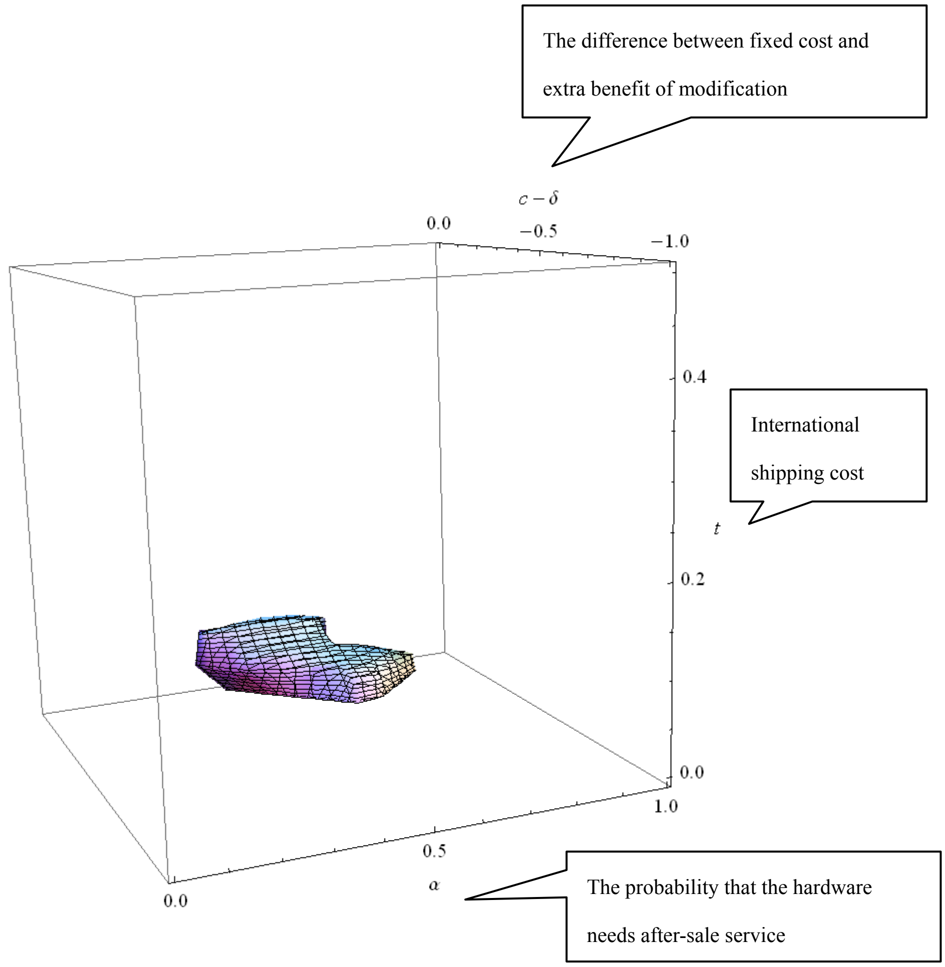

Figure 5 The region where AP dominates Autarky

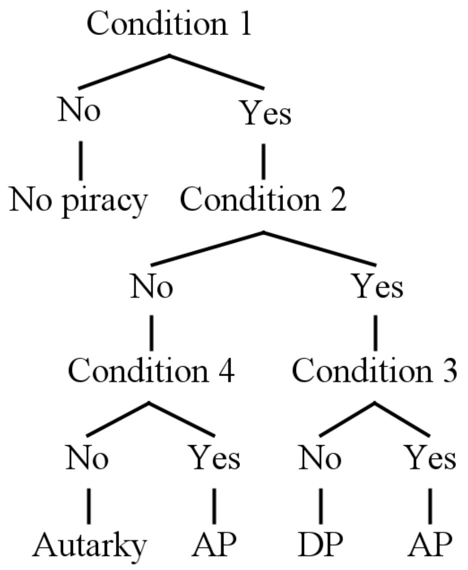

Figure 6 Conditions for different equilibrium strategies

Note:

Condition 1: $\alpha > \delta - c > \left(\alpha + \alpha^2 - 2 + 2\sqrt{1-\alpha}\right) / (\alpha + 3) > 0$

Condition 2: $\left(1 - \alpha - c + \delta\right) / 2 \geq 1/3 + t$

Condition 3: $\pi_{hAP} \geq \pi_{hDP}$

Condition 4: $\pi_{hAP} \geq \left(1/9\right) + \left(1 - \alpha - c + \delta\right)^2 / 4\left(1 - \alpha\right)$

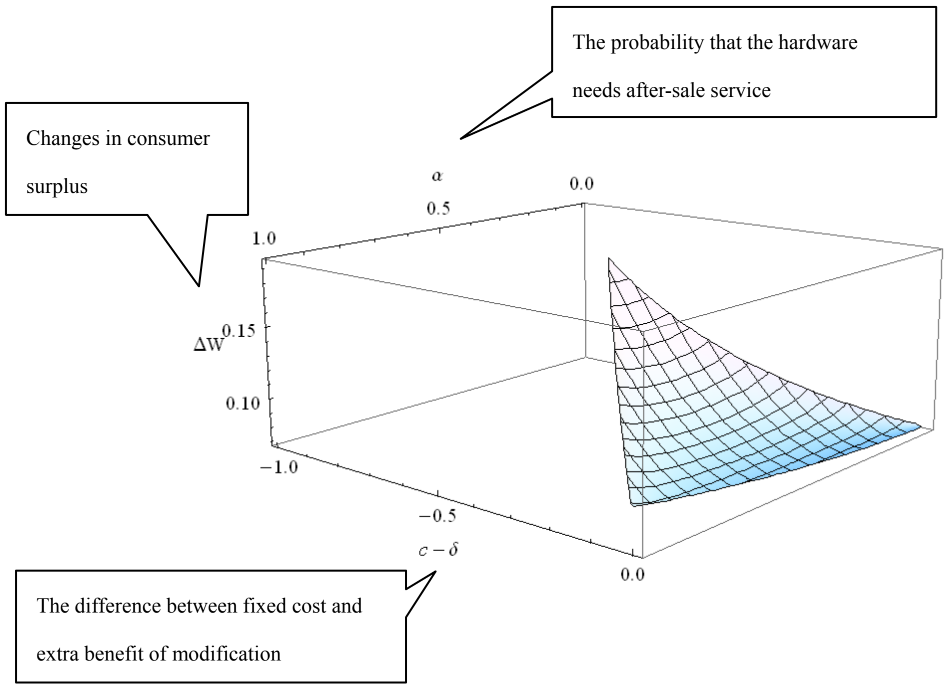

Figure 7 Consumer's welfare change is positive when software piracy is present.

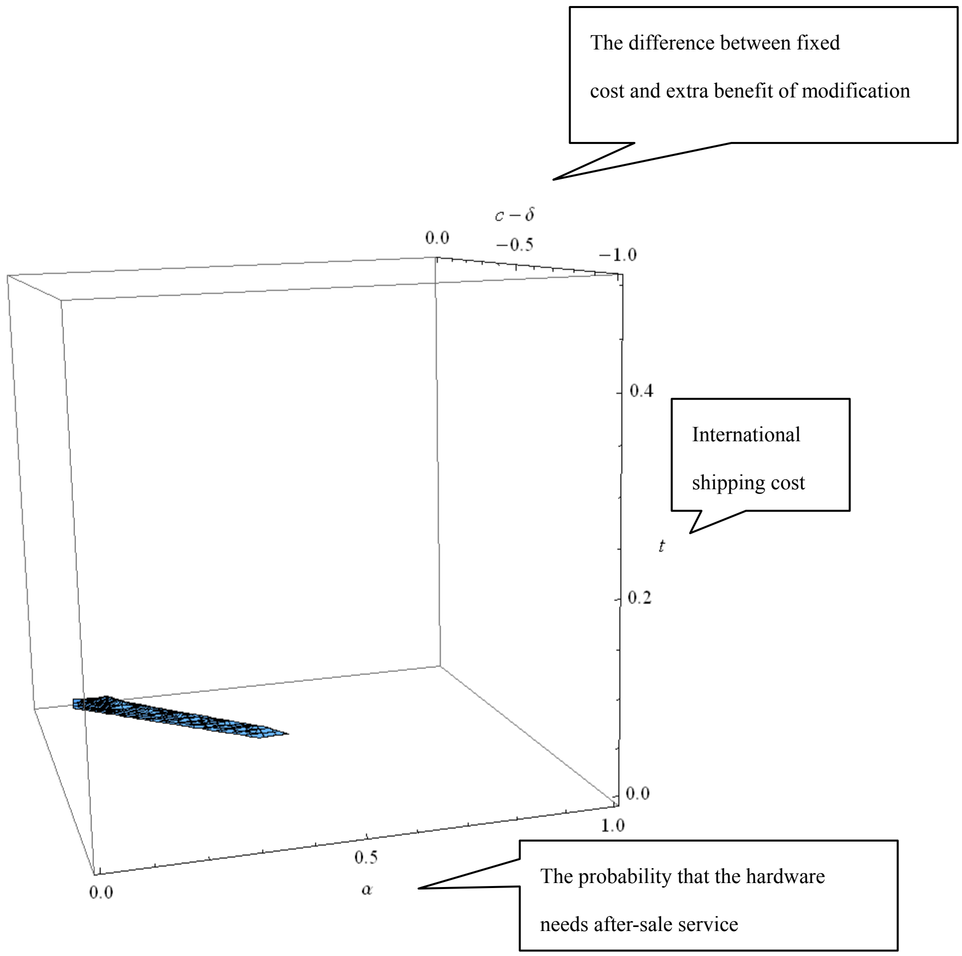

Figure 8 The region where consumers in country A are better off if the manufacturer chooses AP for $\frac{1-\alpha-c+\delta}{2} \geq \frac{1}{3}+t$

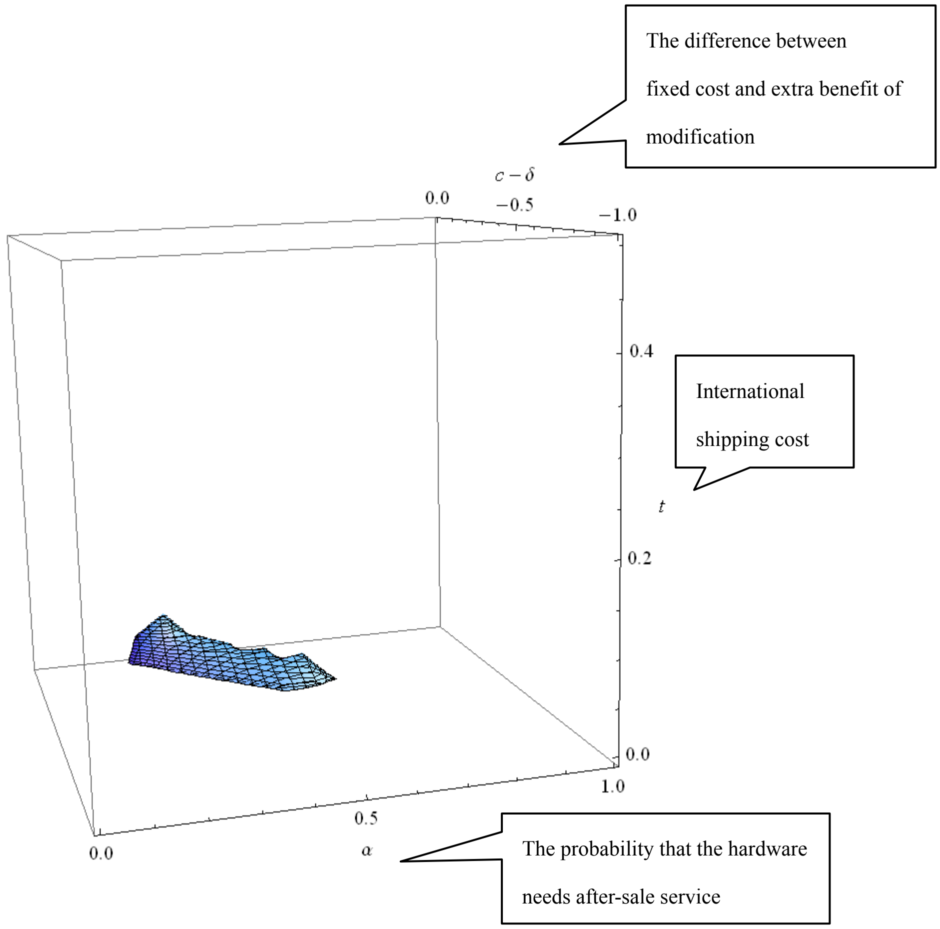

Figure 9 The region where consumers in country A are worse off due to PI if the manufacturer chooses AP for $\frac{1-\alpha-c+\delta}{2} \geq \frac{1}{3}+t$

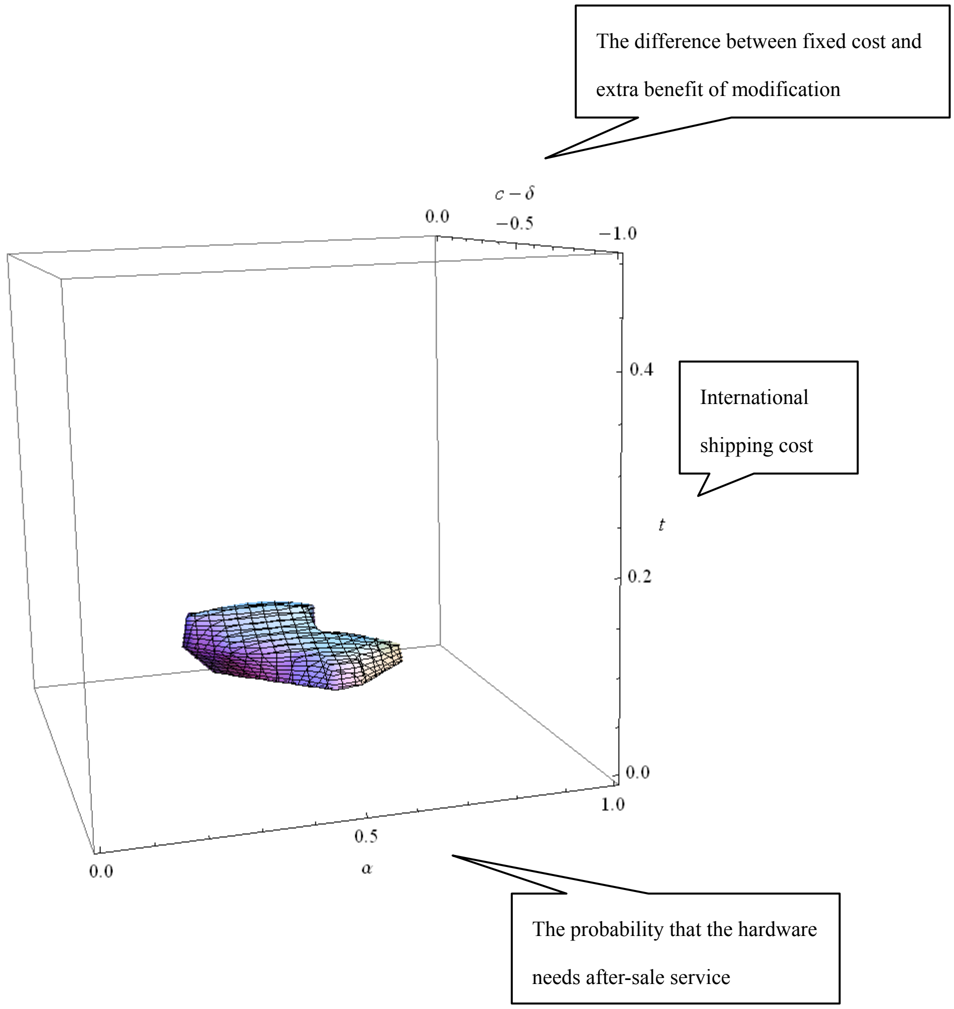

Figure 10 The region where consumers in country A suffer from AP for $\frac{1-\alpha-c+\delta}{2}<\frac{1}{3}+t$

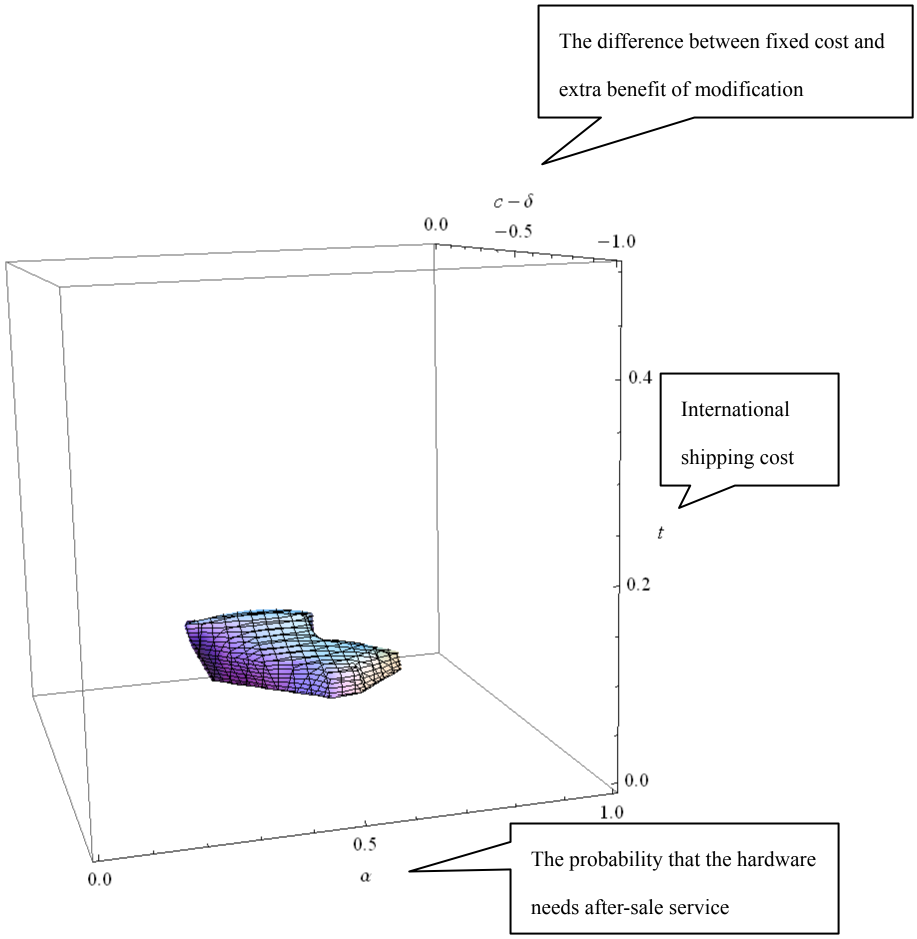

Figure 11 The region where consumers in country B benefit from AP for $\frac{1-\alpha-c+\delta}{2}<\frac{1}{3}+t$

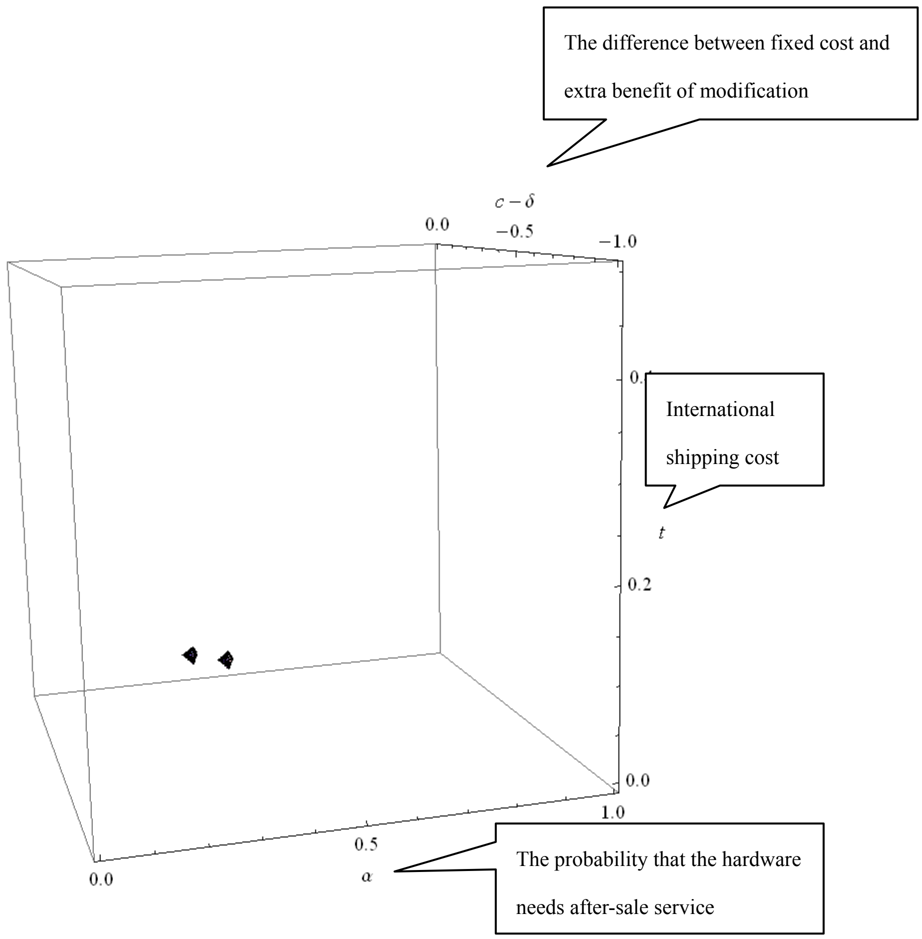

Figure 12 The region where consumers in country B suffer from AP for $\frac{1-\alpha-c+\delta}{2}<\frac{1}{3}+t$

Tables

Table 1 Payoff matrix of two firms			
		O	
	Strategy	Deter Piracy	Accommodate Piracy
H	Deter Piracy	$\frac{1}{9},\frac{1}{9}$	$\frac{(2-\alpha+\delta-c)^2}{16}$, $\frac{(2-\alpha-c+\delta)(\alpha+c-\delta)}{8}$
	Accommodate Piracy	$\frac{(1-\alpha-c+\delta)^2}{4(1-\alpha)}$, $\frac{(-1+3(\alpha+c-\delta))(1+\alpha+c-\delta)}{16\alpha}$	$\frac{\left(1-\alpha-c+\delta\right)^2}{4\left(1-\alpha\right)}$, $\frac{\left(\alpha+c-\delta\right)^2}{4\alpha}$

Table 2 The strategies that are available for the manufacturer to adopt			
	Strategy		
Condition	**Closed economy**	**Deter PI**	**Accommodate PI**
$\frac{1-\alpha-c+\delta}{2}\geq\frac{1}{3}+t$	No	Yes	Yes
$\frac{1-\alpha-c+\delta}{2}<\frac{1}{3}+t$	Yes	No	Yes

Table 3 Welfare Change Due to Piracy	
	Piracy in country A (Closed Economy)
Hardware Firm	+/-
Software Firm	+/-
Consumer in A	+
Consumer in B	unchanged

Table 4 Welfare Change Due to PI			
		Deter PI	**Accommodate PI**
$\frac{1-\alpha-c+\delta}{2} \geq \frac{1}{3}+t$	**Hardware Firm**	+	+
	Software Firm	-	-
	Consumer in A	+	+/-
	Consumer in B	-	-
$\frac{1-\alpha-c+\delta}{2} < \frac{1}{3}+t$	**Hardware Firm**	N/A	+
	Software Firm	N/A	-
	Consumer in A	N/A	-
	Consumer in B	N/A	+/-