

# Research on Quality Selection and Anti-Piracy Policy of Vendors under Network Externalities

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## Abstract

In view of the existence of pirated products in the market, this paper studies the pirate manufacturers, genuine manufacturers and consumer game models, and discusses the impact of the existence of pirate manufacturers on the quality selection of genuine manufacturers under the condition of network externalities. The study found that network externality enhancement will enable genuine manufacturers to improve product quality to bring more utility to consumers. Under certain conditions, the level of counterfeiting of pirated manufacturers is the key to whether a genuine manufacturer chooses a regulatory policy; when the level of counterfeiting is low, the role of the market mechanism itself can effectively protect legitimate manufacturers, and when the level of counterfeiting is high, the adjustment of the market mechanism is not enough to protect the genuine manufacturers. At this time, the genuine manufacturers will implement the policy of combating piracy to protect the genuine.

## Keywords

Network Externalities, Information Products, Product Quality

## 1. Introduction

Information products, such as: Windows operating system, CAD drawing, game software, etc., are scattered throughout the work and life of consumers. Information products have low marginal costs (sometimes just copying), which allows information product providers to make huge profits. With the development of the Internet platform, the cost of disseminating information products has been greatly reduced, which has led to the emergence of a large number of pirated products. Consumers can enjoy almost all the functions of genuine products at a small cost. On the one hand, piracy reduces the sales revenue of information product provid-

ers, erodes the brand value of products, and reduces the motivation of the innovation and R&D of information product providers [1]. Statistics from the Recording Industry Association of America (RIAA) shows that from 2000 to 2006, sales of US genuine records declined year by year, from \$13.2 billion to \$9.2 billion [2]. The proliferation of piracy not only damages the development of the genuine industry, but also brings serious harm to knowledge innovation and economic growth. Therefore, the protection of intellectual property rights and the fight against piracy have become hot issues of universal concern throughout the world.

On the other hand, piracy has also brought positive effects. Piracy products have expanded the user base of information products and improved the externality of information products. For example, genuine Office software charges higher, and fewer consumers buy. There is little chance of achieving information sharing and compatibility. However, pirated Office software is cheaper or free, so more users will choose to use pirated software, which expands the user base, increases the possibility of users sharing information with others, and enhances the value of products to users. Based on this background, this paper attempts to explore when genuine manufacturers fight piracy, and how piracy affects the quality and pricing decisions of genuine manufacturers.

## 2. Literature Review

In order to prevent piracy, there are usually two measures. One is the government's intellectual property protection policy and measures to combat piracy, such as improving the legal system for intellectual property protection, increasing the intensity of combatting piracy, and consumption subsidies for genuine products; Second, the pricing strategy of the genuine manufacturer and the anti-piracy technology to carry out measures to combat piracy. Correspondingly, the issue of piracy of information products at home and abroad is mainly concentrated on product pricing, copyright protection and government policies [1]. At present, the research on anti-piracy issues is mainly from enterprises and the anti-piracy behavior of the government. The former research focuses on the use of genuine enterprises as the main body to prevent piracy and the government's intellectual property protection policy as an exogenous environmental variable of the enterprise [2]. Study the preventive efforts, pricing strategies and government policy parameters of the legitimate enterprise, the pricing of the manufacturer, the profit and the impact on the consumer [3] [4]. The latter study focuses on the government as the anti-piracy subject, research. The government's policy tools such as supervision, fines, hardware taxation and genuine consumption subsidies affect manufacturers, consumers, social welfare and how the government chooses the best regulatory policy [5]. In foreign studies, Banerjee *et al.* is more systematic. The literature [6] studies the pricing decisions of genuine manufacturers and pirated manufacturers in the software market through the four-party game model. The research shows that the genuine manufacturers monopolize the market and the genuine manufacturers and pirated manufac-

turers coexist in the market. It may be sub-optimal. When the manufacturer implements the anti-piracy method, the revenue is greater. When the cost is, the genuine manufacturer monopolizes the market is a balanced structure. At this time, the government does not supervise the optimal strategy. Otherwise, the equilibrium result of the market is that the genuine manufacturer and the pirate manufacturer coexist in the market, and the supervision is the government's optimal strategy; the literature [7]. On this basis, the legitimate manufacturers' lobbying activities for the government's interests are included in the model analysis framework. It is concluded that the legitimate enterprises often use the lobbying activities to induce the government to change the social welfare objective function, so that the government finally makes a policy of strengthening supervision.

The above literature studies the impact of government anti-piracy behavior on its pricing strategy and consumer behavior from different aspects. One of their common features is that market factors such as piracy and government regulation will not affect the quality level of products provided by genuine manufacturers (such as upgrades and update levels of product features, services, etc.) [8]. The quality level of genuine manufacturers is an established static parameter. It is fixed throughout the game process and analysis framework. No matter how the market environment changes, the genuine manufacturers only provide the established Product quality and version of the product. The product innovation and upgrade policy is not in the analysis framework [9] [10]. However, the reality is not always the case, many manufacturers, such as some software vendors will also fight piracy, such as Microsoft When piracy is serious, it will adopt its own policy of attack [11] [12]. At the same time, it will continue to introduce new versions or better services according to market changes (such as piracy or government supervision). On the one hand, it will maintain product differentiation, leadership, and anti-piracy. Attracting customers, on the other hand, if a large number of pirates promote enterprises If the industry protects against piracy or if the government protects it, it can gain greater economic benefits through product upgrades or service innovation [13] [14]. If the anti-piracy policy is not adopted, the existence of a large number of pirates will seriously inhibit the enthusiasm of genuine manufacturers for technological innovation and product upgrades. It can only be maintained at a lower quality level. Therefore, genuine manufacturers have the responsibility to crack down on piracy, encourage themselves to improve product quality, and continuously provide higher quality products that meet consumer needs. Then, pirated and genuine providers to what extent does the anti-piracy behavior affect the quality of genuine manufacturers? What are the key factors that determine the choice of genuine vendors for anti-piracy? What is the impact of anti-piracy on its own quality decisions? This article attempts to study these issues.

Based on the research of Banerjee *et al.*, this paper starts from the consumer utility function and considers the product quality in the behavior choice of the manufacturer. When the cyber externality of the pirate manufacturer exists, we

will study the relationship between the anti-piracy behavior of genuine manufacturers and the quality of products in the market structure composed of a consumer, genuine manufacturer and pirated manufacturer, and explore the quality decision-making effect of genuine manufacturers with the goal of maximizing profits.

### 3. Model Establishment

This paper first examines a simple market situation. Reference to previous literature [5] [15] [16], there is only one genuine manufacturer in the market. Under the full protection of the government, piracy does not exist. The genuine manufacturer (recorded as 1) is a monopoly oligopoly, providing consumers with a level of quality. For the genuine product of  $q_1$ , the price of the product is  $p_1$ . On the one hand, the purchase of genuine goods by consumers can obtain the effect brought by the use of the products, on the other hand, the utility brought by the externality of the product network. In addition to the purchase of genuine products, consumers can also buy pirated products or not buy any products. When consumers buy pirated products, consumers get lower quality and network external utility than when purchasing genuine products. When consumers are not selling enough products, the consumer utility is zero. It should be noted that here, the concept of product quality does not refer to the reliability and stability of the product manufacturer, but to the function, convenience and service level relative to the original level of improvement and improvement, such as product upgrades and service upgrades, etc., which is the concept of product quality relative to its own level. The main parameters in the paper are summarized in **Table 1**.

#### 3.1. Model Hypothesis

Reference to related literature [16] [17] [18], we will make relevant hypothesis:

1)  $\beta$  portrays the influence of network externalities on consumer utility, which reflects the degree of influence of network externality on consumer effect, and  $0 \leq \beta \leq 1$ . The greater the value, the more consumers value the utility of the product network's externalities; on the contrary, the smaller the value, the less the consumer is concerned about the externality of the network during the purchase

**Table 1.** Main model variables and parameter meanings.

$q$	Genuine manufacturers provide product quality and other secondary levels, which is the decision variables of genuine manufacturers
$p_i$	$i = 1, 2$ , Genuine (pirated) product price, that is, genuine (pirated) vendor decision variables;
$d_i$	$i = 1, 2$ , Genuine (pirated) vendor demand, and assumed market capacity is 1
$v$	Consumers' valuation of the quality of genuine products
$\beta$	The consumer's preference for product network externality, the increase of unit demand to consumer utility
$\alpha$	The discount rate, that is, the consumer's evaluation of pirated products is a discount on the value evaluation of genuine products, $0 < \alpha < 1$

of the product.

2) Consumers' valuation of genuine product quality is evenly distributed on  $[0, 1]$ ;

3) The quality control cost of genuine manufacturers is  $\frac{1}{2}cq^2$ , and the marginal cost is 0, where  $c$  is the cost coefficient of quality control of genuine manufacturers. Some studies use this assumption, such as Lahiri [1], Pang *et al.* [6];

4) The quality of genuine products is  $q$ , the quality of pirated products is  $\alpha q$ ,  $\alpha \in (0, 1)$ , correspondingly, the utility increase from the pirated products due to the network effect is also  $\alpha$  times of the genuine product. For information products, pirated products generally refer to cracking products, and cracking products are obtained by illegally modifying genuine products. Quality is not independent, there is a relationship, and the quality of pirated products is generally less than genuine products, because: a) pirated products do not have follow-up services of genuine manufacturers, such as product updates and product patch; b) pirated products may have imperfect or missing functions; c) There are unsafe factors in pirated products, such as being injected into Trojans; d) other factors, such as pirated products being unstable or slow to download [16] [19].

5) Pirated products also have network externalities, which are determined by two conditions. First, consumers can purchase pirated products to obtain network externalities brought by other consumers, for example Doc documents edited by the software Word 2007 widespread in the market [8] [12] [20]. Secondly, consumers use pirated Office software to edit documents, so that the user base of Office software increases, and the value of the product to the original users increases. This shows that pirated products can create network externalities of products together with genuine products. Because pirated products can enjoy and create network externalities, therefore the paper assumes that pirated products have network externalities.

### 3.2. Demand Function

According to the definition of consumer utility function by Deng [9] [15] and Zhao [7], the consumer utility function can be expressed as:

$$u = \begin{cases} vq - p_1 + \beta d_1, & \text{when buying genuine products} \\ 0, & \text{when not buying} \end{cases} \quad (1)$$

Suppose  $v_1$  indicates the critical consumer valuation when there is no difference between the utility of the purchased product and the utility of not purchasing the product, according to (1),  $vq - p_1 + \beta d_1 = 0$ , we can get  $v_1 = \frac{p_1 - \beta d_1}{q}$ . Because

the market capacity is 1, that is, consumers who are at  $(v_1, 1)$  purchase genuine products, consumers at  $(0, v_1)$  do not buy products. At this time, the market coverage of genuine manufacturers is greater. Because  $v$  obeys  $[0, 1]$  distribution, the demand function of monopoly genuine manufacturers can be expressed as demand function  $D_1 = \int_{v_1}^1 1dv = \frac{q - p_1}{q - \beta}$ , then  $v_1 = \frac{p_1 - \beta(q - p_1)}{q(q - \beta)}$ .

The profit of monopolizing genuine manufacturers is

$$\pi_1 = p_1 d_1 - \frac{1}{2} c q^2 \quad (2)$$

Solving the first derivative of  $p_1$ ,  $q$  for the profit function  $\pi_1$ , and solving the simultaneous equations

$$\begin{cases} \frac{\partial \pi_1}{\partial p_1} = \frac{q - 2p_1}{q - \beta} = 0 \\ \frac{\partial \pi_1}{\partial q} = \frac{p(p - \beta)}{(\beta - q)^2} - cq = 0 \end{cases} \quad (3)$$

Then we will get

$$\begin{cases} q^* = \frac{1 + 8c\beta \pm \sqrt{1 - 16c\beta}}{8c} \\ p_1^* = \frac{1 + 8c\beta \pm \sqrt{1 - 16c\beta}}{16c} \end{cases} \quad \text{that's } p_1 = \frac{q}{2} \quad (4)$$

To make the results meaningful, assuming  $c\beta \leq \frac{1}{16}$ , the above results are back to the demand function and the profit function, so the equilibrium result of the market is:

$$\begin{aligned} \pi^* &= \frac{(1 - \sqrt{1 - 16c\beta} + 8c\beta)^2}{32c(1 - \sqrt{1 - 16c\beta})} - \frac{(1 + 8c\beta \pm \sqrt{1 - 16c\beta})^2}{128} \\ D^* &= \frac{1 - \sqrt{1 - 16c\beta} + 8c\beta}{2(1 \pm \sqrt{1 - 16c\beta})} \end{aligned} \quad (5)$$

After analysis, we get a proposition:

**Proposition 1**  $\frac{dq^*}{d\beta} > 0$ ;  $\frac{dp^*}{d\beta} > 0$ ;  $\frac{dD^*}{d\beta} < 0$

Proposition 1 shows that in the monopolistic market without piracy, there are only genuine products in the market. Consumers can form network externalities when purchasing genuine products. The stronger the externality of the network, the more powerful the manufacturers are to improve product quality and develop new products to the market. Providing products of higher quality and higher quality, the improvement of product quality will increase the cost, and the market equilibrium price will also increase with the externality of the network, and the increase in price will lead to a decrease in market demand.

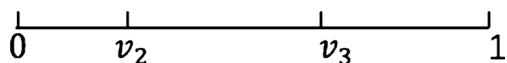
#### 4. Quality Selection Model in the Presence of Piracy

The above consideration is an oligopolistic market, and there is no competition from pirate vendors. Now assume that pirated software appears on the market, and that genuine manufacturers will crack down on and prevent piracy, that is, the market consists of three parties: the genuine manufacturer (recorded as 1), the pirated manufacturer (recorded as 2), and the consumer. Genuine manufac-

turers provide consumers with a genuine product, product quality  $q_1$  and product price  $p_1$ . After the genuine products enter the market, pirate manufacturers quickly produce and market pirated products similar to genuine products, The quality and price are  $q_2$  and  $p_2$  respectively. At this time, consumers can choose to buy genuine products or pirated products. However, due to the gap between product quality, reliability and service, consumers' evaluation of pirated products is the value of genuine products. A discount for evaluation, assuming a discount rate of  $\alpha$ , that is, the consumer's evaluation of the pirated product is a discount on the value evaluation,  $0 < \alpha < 1$ . Correspondingly, the consumer's obtained from the pirated product due to the network effect. The utility increment is also  $\alpha$  times of the genuine product. To this end, referring to the consumer utility function of Deng [9] and Zhao [7], this paper constructs the utility function of consumers in the presence of network externalities:

$$u = \begin{cases} v - p_1 + (\beta d_1 + \alpha \beta d_2), & \text{when buying genuine products} \\ \alpha v q_1 - p_2 + \alpha (\beta d_1 + \beta d_2), & \text{when buying pirated products} \\ 0, & \text{when not buying} \end{cases} \quad (6)$$

We use  $v_2$  to indicate the critical point when consumers buy pirated products and do not buy them,  $v_3$  indicates the critical point when consumers buy genuine products and pirated products.



According to the formula (6) we solve

$$\begin{cases} v_3 = \frac{p_1 - p_2}{(1 - \alpha) q_1} - \frac{\beta d_1}{q_1} \\ v_2 = \frac{p_2}{\alpha q_1} - \frac{\beta (d_1 + d_2)}{q_1} \end{cases} \quad (7)$$

also because  $D_1 = \int_{v_3}^1 1dv$ ,  $D_2 = \int_{v_2}^{v_3} 1dv$ , then we get

$$\begin{cases} D_1 = \frac{(1 - \alpha) q_1 + p_2 - p_1}{\beta + q_1 (1 - \alpha)} \\ D_2 = \frac{\alpha p_1 - p_2}{\alpha (1 - \alpha) (q_1 - \beta)} \end{cases} \quad (8)$$

The game structure is as follows:

Stage 1: The genuine manufacturer chooses an appropriate quality level  $q_1$  and chooses a suitable price  $p_1$ ;

Stage 2: The pirate manufacturer determines the price  $p_2$  of the pirated product based on the observed anti-piracy supervision of the genuine manufacturer and the action information of the genuine manufacturer.

Genuine manufacturers supervised pirated manufacturers with a slap in the face and imposed penalties on the discovered piracy. Usually, according to a number of multiples of the value of pirated products to calculate the amount of

finer, this article assumes that when genuine manufacturers find piracy, according to the strength of the crackdown, the pirate manufacturer's fine is  $\phi f$ , at this time the pirate manufacturer's profit function is:

$$\pi_2 = (1 - \varnothing) p_2 d_2 - \varnothing f \quad (9)$$

Here, the pirate manufacturer's fine expenditure  $\varnothing p_1 d_2$  is regarded as the profit of the genuine manufacturer. At the same time, the supervision cost is also required. It is assumed that the cost function of the legitimate manufacturer to prevent piracy is  $C = g(\varnothing) + G$ , where  $g(\varnothing)$  is a variable regulatory cost that satisfies:

$$g'(\varnothing) > 0, \quad g''(\varnothing) > 0,$$

$G$  is the basic cost for the protection of intellectual property rights by genuine manufacturers. It usually has nothing to do with the size of the supervision. In particular, when  $\varnothing = 0, G = 0$ , otherwise  $G > 0$ , so the profit function of genuine manufacturers is:

$$\pi_1 = p_1 d_1 - \frac{1}{2} c q_1^2 + \varnothing f - (\varnothing) - G \quad (10)$$

It can be seen from the above game structure that the supervision of genuine manufacturers is the key to determining the structure of the game and the behavior of the manufacturers. In the case of the determination of the regulatory strength, according to the game structure, the quality selection and pricing of the manufacturer are determined, that is to say, when the change is made, the pricing and quality selection of the manufacturer will also change. Then, under the circumstances that the supervision of the genuine manufacturers is given, what is the equilibrium result of the market? How does the change in  $\varnothing$  affect the quality selection and pricing of the manufacturer? Let's discuss this issue first.

According to the inverse induction method, according to the second stage,  $\frac{\partial \pi_2}{\partial p_2} = 0$ , and get  $p_2 = \frac{\alpha p_1}{2}$ ,  $\beta \neq q_1$ , then according to the first stage,  $\frac{\partial \pi_1}{\partial p_1} = 0$ , we get  $p_1 = \frac{p_2 + (1 - \alpha) q_1}{2}$ . Linked cube program available, we get:

$$\begin{cases} p_1^* = \frac{4(1 - \alpha)\beta}{4 - \alpha} \\ p_2^* = \frac{2\alpha(1 - \alpha)\beta}{4 - \alpha} \\ q_1^* = 2\beta \end{cases} \quad (11)$$

Next, we substitute the equilibrium result into the profit function of the manufacturer, we can find:

$$\begin{cases} \pi_1^* = \frac{16\beta(1 - \alpha)}{(4 - \alpha)^2} - 2c\beta^2 + \varnothing f - g(\varnothing) - G \\ \pi_2^* = (1 - \varnothing) \frac{4(1 - \alpha)\alpha\beta}{3(4 - \alpha)^2} - \varnothing f \end{cases} \quad (12)$$



Analysis of the above equilibrium results, we can get following proposition:

**Proposition 2**  $\frac{dp_1^*}{d\beta} > 0; \frac{dp_2^*}{d\beta} > 0; \frac{dq_1^*}{d\beta} > 0$

Proposition 2 indicates that the balanced quality of genuine manufacturers is an increasing function of the strength of network externalities; under the supervision of genuine manufacturers, the increase of network externalities will make the balanced quality and price of genuine manufacturers increase; the equilibrium price of pirated manufacturers also increases. When there are pirated products in the market, with the increase of network externalities, genuine manufacturers should improve product quality. When there is piracy in the market, genuine manufacturers will improve the quality of products and maximize the separation of their products from pirated products to prevent the entry of pirated products and bring more utility to consumers. When genuine manufacturers improve product quality, products R&D will increase costs, and manufacturers will make up for the cost of improving quality by increasing prices. The stronger the externality of the network, the more pirated manufacturers can increase their prices.

**Proposition 3** 1)  $\frac{dp_1^*}{d\alpha} < 0; \frac{d\pi_1^*}{d\alpha} < 0$

2) when  $0 < \alpha < 22 - \sqrt{3}$ ,  $\frac{dp_2^*}{d\alpha} < 0$ ; when  $22 - \sqrt{3} < \alpha < 1$ ,  $\frac{dp_2^*}{d\alpha} > 0$ .

Proposition 3 indicates that the profit and demand of genuine manufacturers are decreasing with the increase of piracy rate; the increase of counterfeiting level of pirate manufacturers means that the difference in quality or service between pirated products and genuine products is reduced, and pirated products are consumed. At this time, genuine manufacturers are trying to attract consumers by lowering the price to differentiate products from piracy. For example, Microsoft is under pressure from piracy, and on July 1, 2008, Microsoft Office Home and Student Edition. 2007 retail full packaging software reduced from the previous 1451 yuan to 699 hospitals, a decline of more than 50%, Microsoft responded to market changes by lowering prices; and for pirated manufacturers, in the case of low counterfeiting. The difference is large between pirated products and genuine, then pirate manufacturers will attract consumers to expand the user base through low prices. After the user base is formed, pirate manufacturers will choose to raise prices and then gain more profits when raising the level of counterfeiting; but the increase in counterfeiting level will damage. The profits of genuine manufacturers are also damaging to the entire market.

In order to study the quality selection of manufacturers in the presence of pirated products, this part builds a supply chain model consisting of a single genuine manufacturer, a single pirate manufacturer and consumers. Through this part of the research, we find that when there is piracy in the market, it must be under the supervision of the network, with the enhancement of the externality of the network, genuine manufacturers will improve the quality of products and maximize the separation of their products from pirated products

to prevent the entry of pirated products, bring more utility to consumers, and then increase prices. Get more revenue. On the other hand, the increase in piracy rate in the market has damaged the profits and demand of genuine manufacturers. We also found that when the piracy rate in the market is higher, pirate manufacturers can use this opportunity to set high prices and obtain higher returns, while the piracy rate at a lower age, there are fewer consumers using pirated products on the market, and pirate manufacturers can obtain consumers by lowering prices.

## 5. Conclusions

In the presence of network externality, piracy will not only affect the pricing decisions and profit levels of genuine manufacturers, but also affect the quality selection of genuine manufacturers. This paper incorporates product quality into the analysis framework of corporate decision-making and anti-piracy strategies, and then analyzes the counterfeit level of pirated manufacturers and the influence of the supervision of genuine manufacturers on the pricing decisions of genuine manufacturers through the establishment of two-stage game model. Research shows that: 1) under the supervision of certain manufacturers, the increase of network externality will make the balanced quality and price of genuine manufacturers increase; the equilibrium price of pirated manufacturers will also increase; when there are pirated products in the market, with the increase of network externalities, genuine manufacturers should improve product quality to prevent the entry of pirated products and bring more utility to consumers. For pirate manufacturers, when the externality of the network is stronger, manufacturers can increase the price to obtain more income. 2) The profit demand of genuine manufacturers decreases with the increase of piracy rate; the piracy level of counterfeit goods rises, the attraction of pirated products to consumers increases, and at this time, genuine manufacturers attract consumers by lowering prices; but the increase of counterfeiting level will damage the profits of genuine manufacturers and damage the entire market.

This article assumes the pricing strategy and quality selection of genuine manufacturers under the externality of the network. However, in actual combat against piracy, there will be genuine manufacturers and the government to cooperate with the anti-piracy version. Later, the role of the government in the anti-piracy version can be studied.

## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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