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Product Quality in the presence of Network Externality and Commercial Piracy

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Abstract

Our paper develops a two-stage sequential game between an incumbent and a pirate to find the optimal quality level of the firm in the presence of network externality. The results show that the incumbent in the presence of piracy chooses minimum quality for its product and undertakes an anti-copying investment that adversely affects the effective quality level of the pirated good. Further, under SPNE the incumbent becomes a price leader and the pirate chooses to be a follower.

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1. Introduction

The technological revolution of the present century has opened up a world of opportunities. However, easy and affordable availability of technology has resulted in unauthorized copying of intellectual property[1]. The study addresses the problem of commercial piracy in the presence of network externality where the quality level of the original as well as that of pirated product is endogenously determined.

There exists a wide array of studies to gauge the impact of piracy. The paper by *Lu and Poddar (2011)* analyses the impact of IPR protection and costly entry deterrence by the original product developer on a commercial pirate. The paper by *Martinez Sanchez (2010)* analyzes the role of the government and an incumbent in preventing the entry of the pirate. *Shy and Thisse (1999)* showed how in the presence of network effect software firm can reduce protection and thereby increase sales and when network effect is sufficiently strong choose non protection. *Silve and Bernhardt* (1998) explain why a software manufacturer may allow limited piracy in the presence of significant network externality for home consumers who have lower willingness to pay than business consumers. *Takeyama (1994)* has shown how the presence of network effect creates positive externality allowing firms to price discriminate between different classes of consumers. *Banerjee* (2010) shows that for a single producer facing technological uncertainty incentive to innovate increases when the network effect is stronger than the piracy effect. However, with R&D competition, if the piracy effect dominates the network effect, then the less efficient firm increases investment and that of the more efficient firm's decreases. The papers that have studied the role of network externality effect have not shed any light on the optimal quality choice of the original producer and that of the pirate. The paper by *Lahiri and Dey (2012)* shows that in the presence of "competition" from the end user pirate, a manufacturer may find it optimal to produce a higher-quality good to motivate consumers to give up the pirated version in favor of the legal one. However, their study has not considered the case of network externality effect and the possibility of the incumbent firm incurring copy-protection investment.

The present study tries to develop a model with network externality where the qualities of original and pirated products are endogenously determined. The results show that the legal producer endogenously chooses the lowest possible quality level for his product with network externality and undertakes an anti-copying investment that reduces the effective quality of the pirated product. If the lowest possible quality level increases exogenously, then the anti-copying investment as well as the pirate's profit falls.

2. The Model

The model considers an MNC selling software in an LDC with the possibility that a pirate can copy the product without any per unit cost, and there is network externality as developed by Shy and Thisse (1999). The quality of the original product is q where $q \in [\overline{q}, \underline{q}]$ and there is no cost of developing the original software (Wauthy (1996), Banerjee (2003)). The MNC and the pirate play a sequential game. Following Banerjee (2010), the model assumes that the pirated product will be operational with a positive probability[2]. The model further assumes that in the first stage of the sequential game, the MNC determines the quality of the original

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[1]Business Software Alliance (BSA) study shows in 2010 the piracy rate of software is 64% worldwide (as compared to 21% in North America) with a commercial value of $2,739 billion, as seen on 28.8.2012

[2]Lahiri and Dey (2012) and Sundararajan (2004) have assumed that the quality of pirated good is always lower than that of the original product.

product and undertakes an investment that adversely affects the operational effectiveness (or the quality) of the pirated product.[3,4]. In the next stage the prices are determined. The paper presents the case where the incumbent announces the price of the product. The pirate observes and if it decides to enter then it acts as a price follower. We denote this as the f-case.[5,6]

It is assumed that there exists a continuum of consumers indexed by θ where $\theta \in [\theta_h, \theta_l]$. θ is assumed to follow a uniform distribution and represents income level of a representative consumer. Each consumer is assumed to purchase only one unit of the software and there is no resale market for used software. Following Gabsweicz (1979), Shaked and Sutton (1983), it is assumed that the net utility from consuming one unit of product with quality q is $q(\theta - p)$ where p be the price of the product and θ be the consumer's income level. Equation 1 defines the Utility levels:

$$U = \begin{cases} q(\theta - P_o) + \mu(D_o + \alpha D_p) & \text{if he buys the original product} \\ \alpha[q(\theta - P_p)] + \alpha\mu(D_o + \alpha D_p) & \text{if he buys the pirated product} \\ 0 & \text{if he buys none} \end{cases} \quad (1).$$

Here μ be the parameter signifying the network effect, $\mu \in (0,1)$. The model assumes that α is the probability that the pirated product works, 0<α<1. Thus $D_0 + \alpha D_P$. is the total demand for original and pirated good P_o and P_p are prices of the original and pirated product respectively.

Demand functions for the original and pirated products are as follows[7,8]:

$$D_o = \int_{\theta^*}^{\theta_h} d\theta / (\theta_h - \theta_l) = \theta_h q / (qk - \mu) - qP_o / (1-\alpha)(qk - \mu) + q\alpha P_P / (1-\alpha)(qk - \mu) + \mu\alpha D_P / (qk - \mu) \quad (2).$$

Where $k = \theta_h - \theta_l$. Here k gives the size of market as well as a measure of income dispersion. Further $qk > \mu$ must hold for positive demand. For $\theta_* \geq \theta_l$

[3]Lahiri (2012) and Jain (2008) also considered examples and strategy choices of incumbent firm to reduce the functional quality level of the illegal software.

[4]Software publishers (especially in the case of video games) use various methods for crippling the software in case it is illegally copied. These games will initially show that the copy is successful, but eventually render themselves unplayable via subtle methods. https://en.wikipedia.org/wiki/Copy_protection. Accessed on 8.7.2013.

[5] We have also considered the case where both the incumbent and the pirate simultaneously announce their prices, which we denote as the s-case. The numerical analysis done in the subsequent section shows that the f-case emerges as the equilibrium choice as the pirate always benefits from being a follower.

[6] Following (Martínez-Sánchez (2010)) we have also considered the case where after observing the level of anti-coping investment and quality of the original product the pirate announces its price first. We denote this by l-case where the pirate becomes the price leader and in the incumbent becomes price follower. However in this case the profit of the incumbent becomes strictly dominated compared to that of the f-case and s-case. Thus in the subsequent analysis we have not mentioned it.

[7]The marginal consumer indifferent between purchasing the original product and the pirated product satisfies, $\theta^* = q(P_0 - \alpha P_P) - (1-\alpha)\mu(D_0 + \alpha D_P) / q(1-\alpha)$. The marginal consumer indifferent between purchasing the pirated product and not buying anything satisfies, $\theta_* = P_P - \mu(D_0 + \alpha D_P) / q$

[8]For $\theta_* < \theta_l$ $D_p = (P_o - \alpha P_P) q / (1-\alpha)(qk + \mu\alpha) - \mu D_o / (qk + \mu\alpha) - \theta_l q (qk + \mu\alpha)$

$$D_P = \int_{\max(\theta_*,\theta_l)}^{\theta^*} d\theta/(\theta_h - \theta_l) = P_o - P_P / k(1-\alpha) \quad (3).$$

Let F be a onetime fixed set up cost undertaken by the pirate. The profits of the pirate and incumbent are as follows:

$$\Pi_P = P_P D_P - F = P_P.((P_O - P_P)/k(1-\alpha)) - F \quad (4).$$

$$\prod_0 = D_0 P_0 - C(\alpha) \quad (5).$$

Here $C(\alpha)$ is the level of anti-copying investment incurred by the MNC to reduce the operational effectiveness or the quality of the pirated good such that $C'(\alpha) < 0, C''(\alpha) > 0$. For simplicity of analysis we assume

$$C(\alpha) = 1/\alpha^2 \quad (6).$$

We solve the f-case, and corresponding values of quality, anti-copying investment and profits using backward induction method. The profits of the pirate and the incumbent for f-case are presented in Table 1.

Table 1: Price, Demand and Profit under the f-case[9]

MNC	Pirate[10]
$P_0^f = \frac{(1-\alpha)\theta_h qk}{qk(2-\alpha)-\mu\alpha}, D_0^f = \frac{\theta_h q}{2(qk-\mu)}$ $\Pi_0^f = \frac{(1-\alpha)k(\theta_h q)^2}{2(qk-\mu)[qk(2-\alpha)-\mu\alpha]} - \frac{1}{\alpha^2}$	$P_P^f = \frac{(1-\alpha)\theta_h q k}{2[qk(2-\alpha)-\mu\alpha]}, D_P^f = \frac{\theta_h q}{2[qk(2-\alpha)-\mu\alpha]}$ $\Pi_P^f = \frac{(1-\alpha)k(\theta_h q)^2}{4[qk(2-\alpha)-\mu\alpha]^2}$

3: Quality and anti-copying investment for the f-case

The quality and anti-copying investment of the incumbent MNC for the f-case can be found by maximizing the expected profit of the MNC as defined in Table 1 with respect to q and α. The first order conditions are defined in equations (7), (8)[11].

$$\partial\Pi_0^f / \delta q = -q\mu k(1-\alpha)\theta_h^2\{qk-\mu\alpha\}/((qk-\mu)^2[qk(2-\alpha)-\mu\alpha]^2) < 0 \quad (7).$$

$$\partial\Pi_0^f / \delta\alpha = -\theta_h^2 q^2 k / 2[qk(2-\alpha)-\mu\alpha]^2 + 2/\alpha^3 = 0. \quad (8).$$

Proposition 1

i. *In the f-case when the incumbent MNC endogenously determine quality of its product along with the level of copy protection investment, the optimum quality level chosen is $q^* = \max(\mu/k+\varepsilon, \underline{q})$ where $\underline{q}$ is the lowest possible quality level and ε is a very small positive quantity*

ii. *In the f-case as network effect (μ) increases, the incumbent raises the anti-copying investment, thereby reducing the operational effectiveness of the pirated product (α).*

iii. *Profit of the incumbent always increases with network effect and profit of the pirate increases with μ if $(\alpha(qk+\mu)-2\mu)>0$ holds in f-case.*

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9 As long as $qk>\mu$ we always have $[qk(2-\alpha)-\mu\alpha]>0$ as $\alpha/(2-\alpha)<1$. The prices and demand are always positive.

10 A sufficient condition that both pirate and the MNC will operate is the market is $\theta_h > 2(\theta_l + \mu/q)$

11 It can be shown that second order condition holds.

Proof: i) The proof follows from (7). As the quality is bounded from below by the positive demand condition, the equilibrium quality is given by $q^* = max(\mu / k + \varepsilon , \underline{q})$.

ii) Differentiating (8) with respect to μ gives the result.

iii) It can be shown that profit of the MNC always unambiguously increases with the network effect. However the sufficient condition that the profit of the pirate will increase with μ in the f-case is $(\alpha (qk + \mu) - 2\mu) > 0$.

Thus in the presence of network externality, when the MNC endogenously chooses the quality of its final product along with the level of copy protection investment, it deteriorates the quality of the original product. This result is in contrast to that obtained by Lahiri and Dey (2012). However, Sundarajan (2003) had noted that implementing technology-based protection may necessitate degrading the value of a legal product or lowering the quality for legal users. [12] Basically, in our model the profit of the MNC increases with the degree of quality differences (1-α) for a given value of q but not with his own quality level. Thus, the MNC incurs a heavy anti-copying investment to reduce the effective quality of fake product (αq) for a given value of q, when it actually chooses the lowest quality for its own product.

Further, Proposition 1 shows that the network externality effect increases the profit of the incumbent and the pirate at the unchanged level of α. A possible explanation for this is that the network effect raises demand for the original product thus improving the profit of the incumbent. However, a strong network effect also increases demand for the pirated product. To reduce the demand as well as profitability of the pirate, the incumbent increases anti-copying investment and hence reduces α. Alternatively, an increase in network effect improves the profit of the pirate. But the increase in anti-copying investment by the incumbent lowers the quality of the pirated good and thus reduces the profit of the pirate. Hence, the ultimate effect depends on the strength of the network effect and value of the parameter corresponding to market size (k).

Proposition 2

Under f-case for an increase in $\underline{q}$ *the incumbent chooses a lower level of anti-copying investment and the profit of the pirate is also reduced*

Proof: Differentiating (8) with respect to q gives the first result. Differentiating pirate's profit with respect to q gives the second result. The results depicted in proposition 2 have very interesting implications. When the incumbent is endogenously choosing its quality and anti-copying investment level in the presence of network externality effect, it chooses lowest quality level $\underline{q}$ for its product when $\underline{q} > \mu / k + \varepsilon$. If this lowest quality $\underline{q}$ increases exogenously, the MNC reduces the anti-copying investment level to maximizes its profit where $\delta \pi_o^f / \delta q < 0$. Under the circumstances it is observed that the incumbent is also reducing its price to compete with the pirate. This effect is in turn reducing the profit of the pirate[13].

[12] There is a large number of examples where the firm undertaking copy protection strategies or implementing DRM actually hurt legal consumers. The Sony-BMG root kit scandal of 2005-2006 is a classic example where the legal buyers were hurt due to copy-protection measures. (http://en.wikipedia.org/wiki/Sony_BMG_copy_protection_rootkit_scandal, accessed on 20.7.2013)

[13] Proposition 1 and 2 will be true for the s-case as well, where the incumbent and the pirate chooses the price simultaneously.

4: Numerical Analysis

This subsection tries to find out equilibrium solution of the firms with the help of a numerical analysis. We compare the profits of the incumbent and the pirate for f-case and the case where the pirate and incumbent MNC simultaneously choose the price (s-case).

Table 2 presents the results of numerical analysis to compare the profits of the pirate and incumbent where $\theta_* \geq \theta_l$.

Table 2: Results of Numerical Analysis

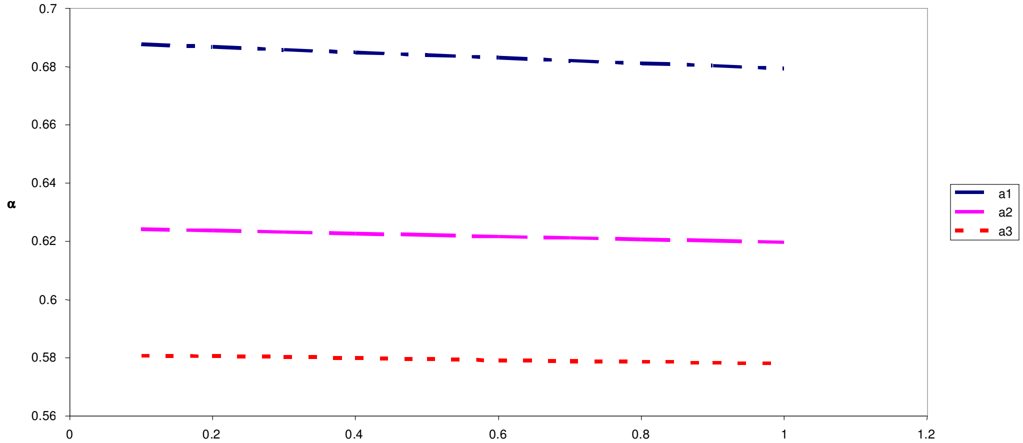
Parameter Values	Profit of Incumbent	Profit of pirate	SPNE
$\theta_h = 20, \theta_l = 1$, k=19 $0 < \mu < 1$, F=0	$\pi_o^f < \pi_o^s$	$\pi_p^s < \pi_p^f$	As profit of pirate in f-case dominates that of s-case, pirate chooses to be a follower and incumbent becomes leader
$\theta_h = 30, \theta_l = 1$, k=29 $0 < \mu < 1$ F=0	$\pi_o^f \approx \pi_o^s$	$\pi_p^s < \pi_p^f$	The profit of incumbent in f and s-case are more or less equal implying indifference between the two strategies. The profit of pirate in f-case dominates that of s-case, pirate chooses to follow and incumbent becomes leader
$\theta_h = 40, \theta_l = 1$, k=39 $0 < \mu < 1$ F=0	$\pi_o^f > \pi_o^s$	$\pi_p^s < \pi_p^f$	In this case the profit of incumbent firm is greater under f-case than under s-case. The profit of pirate in f-case dominates that of s-case, pirate chooses to follow and incumbent becomes leader
For $\theta_h < 2\theta_l$	Pirate does not enter the market.		

Thus, from the Table 2 we observe that $\pi_p^s < \pi_p^f$, for different values for k and θ_h. So we conclude that f-case will emerge as an equilibrium solution as the pirate always prefers to be a follower. It has been observed that price charged by the pirate as well as the incumbent is lower under simultaneous price-competition than the f-case irrespective of the size of the market. As a result, the pirate always receives a lower profit under s-case than the f-case and chooses to be a follower. Hence f-case endogenously emerges as the solution of the model.

Finally, we try to find the effect of the impact of distributional change and market size parameter on the anti-copying investment of the firm in equilibrium for the f-case. Figure 1 describes the result.

Figure 1

Movement of operational quality of pirated product across different income distributions for the f-case



In this figure we have plotted α for f –case for $\theta_h = 20, k = 19$ *and* $\theta_h = 30, k = 29$ *and* $\theta_h = 40, k = 39$

In the figure 'af1' and 'af2' 'af3' series correspond to values of α in f-case for $\theta_h = 20, k = 19$ *and* $\theta_h = 30, k = 29$ *and* $\theta_h = 40, k = 39$ respectively.

It is found that $\delta\alpha^f / \delta k > 0$ and $\delta\alpha^f / \delta\theta_h < 0$. Thus net effect for a change in k and θ_h is ambiguous. Figure 1 shows that anti-copying investment increases (alternatively α^f falls) with θ_h and k in the f-case. Basically, a lower value of α increases the quality differential between original and pirated products which in turn improves the profit of the original firm. Thus, when willingness to pay of the highest income class improves and market size widens the incumbent undertakes higher anti-copying investment in equilibrium.

5. Conclusion

Our paper develops a two stage sequential game between an incumbent MNC and a pirate to find the optimal quality level of the firm in the presence of network externality. The results show that the incumbent in the presence of piracy chooses minimum quality for its product. But it increases anti-copying investment as network externality effect becomes stronger. This in turn reduces the effective quality of the pirated product. Further, the results of numerical analysis show that in equilibrium, the incumbent emerges as price leader and the pirate follows as the pirate always prefers to be a price follower than to choose price simultaneously with the incumbent. Finally, an exogenous improvement in the minimum quality level which the incumbent provides, leads to a fall in anti-copying investment and profit of the pirate.

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