ECONOMIC ANNALS, Volume LXIII, No. 219 / October – December 2018
UDC: 3.33 ISSN: 0013-3264

https://doi.org/10.2298/EKA1819115B

*Paulomi Basu**
*Tanmoyee Banerjee***

A THEORETICAL ANALYSIS OF PRODUCT VERSIONING IN THE CONTEXT OF COMMERCIAL PIRACY

ABSTRACT: *The study develops a vertically differentiated duopoly model in the presence of commercial piracy with two groups of consumers, a business group and a home group, with the former having higher willingness to pay for the product. A firm producing an original information good sells it with endogenously chosen product quality and acts as a price leader, and the commercial pirate becomes the price follower. There exists a stringent government policy of monitoring commercial piracy, which increases the marginal cost of the pirate. We study and compare the two regimes of no-versioning (selling a single quality product) and product versioning (selling products with different price and quality combinations to different consumer groups). In the versioning regime, depending upon demand and government monitoring parameters, two equilibria are observed. Comparing the original firm's profit in each of these versioning cases suggests that versioning may or may not be the original firm's optimal strategy in the presence of commercial piracy. This result is counterintuitive to existing literature on product versioning in the context of end-user piracy.*

KEY WORDS: *Intellectual Property Right; Product-versioning; Commercial Piracy; Heterogeneity; Quality.*

JEL CLASSIFICATION: L13; L15

* Research Scholar, Department of Economics, Jadavpur University
** Professor, Department of Economics, Jadavpur University

1. INTRODUCTION

Intellectual property rights (IPR) ensure legal justice for innovations. They are particularly important in incentivizing producers to innovate new products and invest in R&D. However, firms face serious threats to their profit and market share due to the problem of product piracy. Product piracy in any form is a violation of IPR, and despite the legal backing the original producer suffers from the activity of pirates. This problem is specifically relevant in the case of the information goods industry because of its vulnerability to the threat of piracy. Piracy is generally of two types: end-user piracy and commercial piracy. End-user piracy refers to piracy by private individuals for their personal use, whereas commercial piracy is when a firm makes illegal copies of the original information good and sells them commercially. As the economy has become digitalized the rate of piracy has increased exponentially. Books, journals, and music and video cds are equally or even more susceptible to digital piracy than software. The incidence of piracy is more severe in developing economies that are characterised by low per capita income and a large income gap between rich and poor. Here it is easier to practice piracy because IPR protections and enforcement are weak. The logic behind this is that piracy instils competition in the market and thereby enhances the consumer surplus. In developing economies with low per capita income, consumers are usually less willing to pay, and consequently cannot keep up with the dynamic global digitalisation. This constricts their exposure and knowledge, further aggravating the problem of underdevelopment, and can encourage governments to relax the IPR regime and tolerate a level of piracy. In such situations the welfare-maximising target supersedes the protection of the interests of the original information good producer, which is generally a large multinational corporation. Thus, in an environment where commercial piracy prevails, the original good producer seeks alternative strategies to maximise profit.

The producers of the original product adopt various strategies to combat piracy. Sometimes they invest in installing anti-piracy measures in their product, or they adopt a policy of limit pricing to restrict the entry of the pirate. In this paper we try to discover whether the practise of product versioning is an effective measure for original good producers to maximise profit and combat piracy. In an economy with a relaxed IPR regime and a large proportion of consumers with low willingness to pay for the product (as in a developing economy), the original good producers find it optimal to design different versions for different spectrums of consumers with varying willingness to pay. This ensures that some or most of the lower fringes of consumers buy a lesser version of the original information good at a lower price. Since this policy does not interfere with the welfare-maximizing objective of the government (by keeping the consumer surplus unchanged), versioning is becoming an important tool to fight piracy.

In the literature on commercial piracy and related government policy, Banerjee (2003) addresses the trade-off between government monitoring of piracy and aspects of anti-piracy investment by incumbent firms. Banerjee (2005) discusses the effect of lobbying in the context of commercial piracy. These papers provide a broad outline of commercial piracy and the functioning of pirates.

There is a gamut of literature that discusses various issues related to product versioning under end-user piracy (Alvisi et al. 2002; Wu et al. 2003; Cremer et al. 2008; Cho et al. 2010). Alvisi et al. (2002) assert that end-user piracy incentivises the original good producer to produce different qualities of the same product to deter piracy. Wu et al. (2003) assert that product versioning in a much more effective tool to deter end-user piracy than technological anti-piracy tools or penalising the pirates. They show that the strategy of product versioning is also a welfare-maximising strategy. Cremer and Pestieau (2008) discuss the pricing policy of product versions produced by a monopolist in the presence of end-user piracy and identify three different equilibria of piracy control based on the nature of the original good-producing monopolist. The profit-maximising monopolist charges the highest for piracy control, followed by the welfare-maximising monopolist and then the public authority. Cho and Ahn (2010) discuss the quality choices of an original good producer practicing product versioning in a vertically differentiated market in the presence of end-user piracy. The paper addresses the issue of a vertically differentiated market based on the parameter of the consumers' willingness to pay, which we adopt in our study. The paper concludes that product versioning is optimal in the presence of end-user piracy and that the producer will choose a relatively lower-quality product for high-end consumers and a higher-quality product for low-end consumers in comparison to a situation without piracy.

The existing literature either addresses the issue of product versioning by the original good producer in the context of end-user piracy as a tool to deter it, or the monitoring of technological instruments to fight commercial piracy. Amalgamating these two ideas, our paper tries to gauge the issue of product versioning in the presence of commercial piracy, to decide the quality level of the original producer, and to optimise the strategy by comparing the profit of the original good producer in the context of product versioning or no-versioning.

The rest of the paper is arranged as follows. Section 2 illustrates the model, explaining the product-versioning regime and no-product-versioning regime. Section 3 compares the versioning and no-versioning regimes in order to optimise the strategy of the original firm. Section 4 concludes.

2. THE MODEL

The theoretical model studies the profitability of a firm producing an original good (hereafter referred to as the original firm) while practicing product versioning in a duopoly market with heterogeneous consumers in the presence of commercial piracy. The consumers' heterogeneity is based on their willingness to pay for the good. The first group is the business group with relatively higher willingness to pay for quality and is indexed by $\beta \in [\underline{\beta}, \overline{\beta}]$, where β denotes the valuation of the product for a representative consumer in the group. This group is assumed to never purchase a pirated product. For example, consumers such as academic institutions and corporations are unlikely to purchase pirated products. The second group is that of the group of home consumers with a lower willingness to pay for the product and is indexed by $\theta \in [0, \overline{\theta}]$, where θ denotes the valuation of the product by a representative consumer. This group represents individual consumers who might be inclined to buy a pirated product at a lower price. It is further assumed that the business group will not buy the product designed for the home group because it lacks certain technical facilities, such as LAN in the case of software. The original firm serves a linear consumer spectrum such that $\overline{\theta} \gtrless \underline{\beta}$, with the assumption that the business consumers will neither buy the home product nor get involved in the act of piracy. The original firm produces an information good in two distinct versions of different quality to cater to the two groups of consumers.

For simplicity, we assume that the original firm is an established business; hence the development cost can be avoided. The quality cost of both versions of the original good is assumed to be quadratic, with the business version being more costly. The commercial pirate competes with the original firm by making unauthorized copies of the information good and selling them on the market. The quality of the pirated product is inferior to that of the home version of the original good; in fact it is an imperfect substitute for the home version. The quality loss may be the result of the pirate's regressive copying technique, the loss of support services that come with the original product, or the probability that the copy is defective. The pirate's cost associated with copying from the original good is negligible and hence is assumed to be zero. Thus, in this model the commercial pirate competes with the original firm to capture the home group market. The quality of the original product is denoted by $q_i, i = h, l$, and the quality of the pirated product is denoted by α. For simplicity of analysis we assume that $\alpha = \mu q_l \left[\mu \in (0,1) \right]$. The model assumes that the government stringently monitors commercial piracy and that this monitoring activity raises the pirate's unit cost of production. The original firm takes into account the monitoring rate g and acts as the price leader and the pirate acts as the price follower. The game is solved using the backward induction method.

2.1 The Product Versioning Regime

This section discusses the versioning strategy of the original firm. The firm first chooses the price and quality for both its versions. The pirate observes them and imitates the home version of the product, where government monitoring imposes a unit cost on the pirate. The pirate thus acts as a price follower. After this the consumers make their purchasing decision. The price–quality for two versions of the original good are assumed to be (p_h, q_h) for the business group and (p_l, q_l) for the home group. We further assume $q_h > q_l$ and $p_h > p_l$. The commercial pirate reproduces the good with quality α [$\alpha = \mu q_l$; $0 < \mu < 1$] and sells at price p_c. The utility function of the business consumer purchasing one unit of the product is :

$$U(\beta) = \begin{cases} \beta q_h - p_h, \text{when buys the original product} \\ 0, \text{ otherwise.} \end{cases} \tag{1}$$

The utility function of the home consumer purchasing one unit of the product is:

$$U(\theta)=\begin{cases}\theta q_l - p_l, \text{ when buys the original product}\\ \theta\mu q_l - p_c, \text{ when buys the pirated product}\\ 0, \text{ otherwise.}\end{cases} \tag{2}$$

We suppose β_1 to be the marginal business consumer who is indifferent between purchasing the good and not purchasing, θ_1 to be the marginal home consumer who is indifferent between purchasing the original good and the pirated good, and θ_2 to be the marginal home consumer who is indifferent between purchasing the pirated good and nothing.[1]

The original firm faces demand from both the business group of consumers and the home group. The demand from the business market faced by the original firm is given in (3).

$$D_m^{\beta}(p_h)=\int_{\beta_1}^{\bar{\beta}} dq=\left[\bar{\beta}-\frac{p_h}{q_h}\right] \tag{3}$$

The demand from the home market faced by the original firm is given in (4).

$$D_m^{\theta}(p_l,p_c)=\int_{\theta_1}^{\bar{\theta}} dq=\left[\bar{\theta}-\frac{p_l-p_c}{q_l(1-\mu)}\right] \tag{4}$$

The pirate faces demand from only the home group of consumers:

$$D_c^{\theta}(p_l,p_c)=\int_{\theta_2}^{\theta_1} dq=\frac{p_l-p_c}{q_l(1-\mu)}-\frac{p_c}{\mu q_l} \tag{5}$$

1 $\beta_1=\frac{p_h}{q_h};\theta_1=\frac{p_l-p_c}{q_l(1-\mu)};\theta_2=\frac{p_c}{\mu q_l}$

The profit of the pirate is :

$$\pi_c = (p_c - g)\left[\frac{p_l - p_c}{q_l(1-\mu)} - \frac{p_c}{\mu q_l}\right] \tag{6}$$

The pirate is assumed to incur zero marginal cost, but the government's monitoring rate g constitutes a kind of unit cost. The price game is solved first, using the backward induction method. The original firm decides to play the pricing game sequentially and acts as a price leader. The reaction function of the pirate is derived to be :

$$p_c = \frac{\mu p_l + g}{2} \tag{7}$$

The joint-profit function of the firm from the two consumer spectrums, assuming the lump sum quadratic quality cost for both versions of the original good and incorporating the reaction function of the pirate, is :

$$\pi_v = p_h\left[\bar{\beta} - \frac{p_h}{q_h}\right] - \frac{q_h^2}{2} + p_l\left[\left(\bar{\theta} + \frac{g}{2q_l(1-\mu)}\right) - \frac{p_l(2-\mu)}{2q_l(1-\mu)}\right] - \frac{\tau q_l^2}{2} \tag{8}$$

where $\tau < 1$ implies that the quality of the home product is cheaper to produce than the quality of the business product.

2.2 Perfect discrimination of consumers

Assuming that the firm can perfectly discriminate between the home group and the business group, the equilibrium prices are:

$$p_h^* = \frac{\bar{\beta} q_h}{2} \tag{9}$$

$$p_l^* = \frac{\bar{\theta} q_l(1-\mu)}{(2-\mu)} + \frac{g}{2(2-\mu)} \tag{10}$$

Since the business consumers have no incentive to buy the pirated product, a stricter IPR regime will have no effect on them, and the price of the business version is unaffected by a rise in *g*. As *g* rises the price of the pirated product rises and consequently the price of its substitute home version rises too. The increase of the demand parameters $\overline{\beta}$ and $\overline{\theta}$ will increase the equilibrium prices.

The profit of the firm is :

$$\pi_v^* = \left[\frac{\overline{\beta}^2 q_h}{4} - \frac{q_h^2}{2}\right] + \left[\frac{\overline{\theta}^2 q_l(1-\mu)}{2(2-\mu)} + \frac{\overline{\theta} g}{2(2-\mu)} + \frac{g^2}{8q_l(1-\mu)(2-\mu)} - \frac{\tau q_l^2}{2}\right] \qquad (11)$$

We observe that the profit of the original firm is increasing in *g*, as a stricter monitoring regime allows it to charge a higher price for its home-version product, which is a close substitute for the pirated product. This enhances the profit. An increase in the demand parameters $\overline{\beta}$ and $\overline{\theta}$ also enhances the profit of the original firm by increasing the prices for both versions.

The pirate is the price follower in the game and chooses its equilibrium price:

$$p_c^* = \frac{\overline{\theta}\,\mu q_l(1-\mu)}{2(2-\mu)} + \frac{g(4-\mu)}{4(2-\mu)} \qquad (12)$$

The price of the pirated good increases with *g*. A rise in *g* induces the pirate to raise its price for profitable production.

Quality choice: Next we consider the firm's choice of quality. Under a versioning regime the original firm chooses $q_h \in \left[\underline{q_h}, \overline{q_h}\right]$ and $q_l = \left[\underline{q_l}, \overline{q_l}\right]$, where $\overline{q_l} < \underline{q_h}$. The endogenised quality of the business version at equilibrium is $q_h = \frac{\overline{\beta}^2}{4}$, since the individual profit of the business version is the maximum for this level of quality. We checked the second order condition (S.O.C.) of the profit maximisation problem and derived $\frac{\partial^2 \pi_v}{\partial {q_h}^2} < 0$. But for the home version, the first order condition for profit maximisation with respect to q_l is given as:

$$\frac{\partial \pi_v}{\partial q_l} = 0 \left[\frac{\bar{\theta}^2 (1-\mu)}{2(2-\mu)} - \frac{g^2}{8{q_l}^2 (1-\mu)(2-\mu)} \right] = \tau q_l \tag{13}$$

The S.O.C. for profit maximisation in the case of the home version requires:

$$\frac{\partial^2 \pi_v}{\partial {q_l}^2} \langle 0 = \rangle \frac{g^2}{4{q_l}^3 (1-\mu)(2-\mu)} < \tau \tag{14}$$

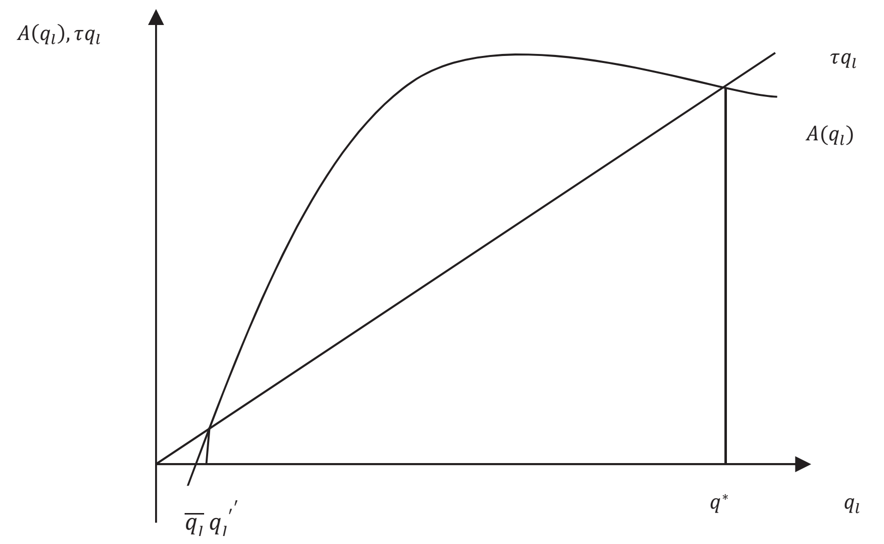
(13) can be simplified as $A(q_l) = \tau q_l$, where

$$A(q_l) = \left[\frac{\bar{\theta}^2 (1-\mu)}{2(2-\mu)} - \frac{g^2}{8{q_l}^2 (1-\mu)(2-\mu)} \right] \tag{15}$$

Here, $A'(q_l) > 0$ and $A''(q_l) < 0$. $A(q_l) = 0$ for $q_l = \overline{q_l} = \frac{g}{2\bar{\theta}(1-\mu)}$

Thus, $A(q_l)$ can be represented by a concave upward sloping curve. Figure 1 diagrammatically determines the equilibrium value for q_l.

Figure 1: Determination of Quality of Home Group Product under Perfect Discrimination



In Figure 1 τq_l is represented by the linear curve passing through the origin. $A(q_l)$ and τq_l intersect at $q_l^{'}$ and q_l^{*}. But the sufficient condition for profit maximisation is satisfied at $q = q_l^{*}$, where $\tau > A'(q_l) = \left[\frac{g^2}{4q_l^3(1-\mu)(2-\mu)}\right]$.

Hence, the endogenised quality is determined at $q_l = q_l^{*}$

2.3 Imperfect discrimination of consumers

In this section we consider the situation where the original good producer cannot perfectly discriminate between the business group and the home group, and it is possible for the home group to imitate the business group and purchase the product designed for the business group. However, we have already assumed that the business group will strictly not buy the version of the product designed for the home group. Therefore, to prevent the home group of consumers from purchasing the business version of the product, the original firm chooses its price for the business version so that even the consumer with highest willingness to pay in the home group cannot afford to purchase it, i.e., $\overline{\theta} q_h \leq p_h$. Hence, we get the following constraint:

$$p_h \geq \overline{\theta} q_h \tag{16}$$

The firm will thus maximise its profit given in (8) subject to the above constraints and the pirate will maximise the profit given in (6). Depending upon the parameter values, two different equilibrium configurations can be identified.

Case 1: This particular case happens for parametric condition $\overline{\beta} > 2\overline{\theta}$. Under this condition the original firm will chose the unconstrained optimum solution as shown in (9) and (10). The joint profit of the firm in this case is identical to the profit of the perfect discrimination as given in (11).[2]

Under the condition $\overline{\beta} > 2\overline{\theta}$ it is observed that when the highest-willingness-to-pay parameter of the business group is sufficiently higher than that of the home group, the firm earns the unconstrained monopoly profit even under imperfect discrimination. Since this case coincides with the perfect discrimination regime, the quality provided by the original firm for both the business group and the home group will be the same as shown in the last subsection.

Case 2: For parametric restriction $\overline{\beta} < 2\overline{\theta}$, the firm reaches its equilibrium prices at: [3]

$$p_{h2} = \overline{\theta} q_h \tag{17}$$

$$p_l^* = \frac{\overline{\theta} q_l (1-\mu)}{(2-\mu)} + \frac{g}{2(2-\mu)} \tag{10}$$

In this case, the highest willingness-to-pay parameter value for the business consumer is relatively small with respect to that of the home group. Therefore,

2 Proof in Appendix.
3 Proof in Appendix.

though the firm charges an unconstrained maximising price for the home group market, it cannot do the same for the business group. Basically, when $\bar{\theta} > \frac{\bar{\beta}}{2}$, the consumer at the upper end of the home spectrum may deviate to the business group product. To restrict such deviation the firm charges $p_{h2} > p_h^*$.

It is observed again that only the price of the home version increases with *g*. The price of the business version is not affected. For this reason the corresponding price of the pirate is the same as (12). It is also observed that the prices for both versions of the original good are increasing in the demand parameter θ. Finally, the profit of the original firm is:

$$\pi_{v2} = \left[\bar{\beta}\bar{\theta} q_h - \bar{\theta}^2 q_h - \frac{q_h^2}{2} \right] + \left[\frac{\bar{\theta}^2 q_l (1-\mu)}{2(2-\mu)} + \frac{\bar{\theta} g}{2(2-\mu)} + \frac{g^2}{8 q_l (1-\mu)(2-\mu)} - \frac{q_l^2}{2} \right] \quad (18)$$

Quality choice: The optimum quality provided by the original firm for the business version of the product is $q_h = (\bar{\beta} - \bar{\theta})\bar{\theta}$. However, the optimum quality of the home version remains the same as that in case 1, which in turn is the same as in the case of perfect discrimination. The S.O.C. of profit maximisation is also checked and found to be to be satisfactory. Thus, in the case where $\bar{\theta} > \frac{\bar{\beta}}{2}$, implying that the home group consumer is willing to pay a sufficiently high price for the product, the original good producer deteriorates the quality of the business group product in order to deter the home group consumers from purchasing the business group product.

In both Case I and Case 2 the pirate's price increases with the monitoring rate *g*, since with an increase in *g* the pirate's unit cost increases, thereby raising the price.

2.4 No-Versioning of Product Regime

The following section discusses the 'no-versioning' regime of the model. The original firm produces a single version of the good with quality *q* and sells at price p_{nv}, incurring a quality cost of $\frac{\tau q^2}{2}$. The commercial pirate reproduces the good with quality α $[\alpha = \mu q \,; 0 < \mu < 1]$ and sells at price p_c. When $p_h = p_l = pp_{nv}$ and $q_h = q_l = q$, the profit of the original firm as given in (8) is reduced to:

$$\pi_{nv} = p_{nv}\left[\bar{\beta} - \frac{p_{nv}}{q}\right] + p_{nv}\left[\bar{\theta} - \frac{p_{nv}(2-\mu) - g}{2q(1-\mu)}\right] - \frac{\tau q^2}{2} \tag{19}$$

The original firm chooses its equilibrium price: [4]

$$p_{nv} = \frac{2q\left(\bar{\beta} + \bar{\theta}\right)(1-\mu) + g}{2(4-3\mu)} \tag{20}$$

The firm's price increases with stringent monitoring. It is further observed that $\frac{\partial p_{nv}}{\partial \bar{\beta}} > 0$ and $\frac{\partial p_{nv}}{\partial \bar{\theta}} > 0$, i.e., an increase in either $\bar{\beta}$ or $\bar{\theta}$ also increases the equilibrium price.

The profit of the original firm is :

$$\pi_{nv} = \frac{\left[2q\left(\bar{\beta} + \bar{\theta}\right)(1-\mu) + g\right]^2}{8q(1-\mu)(4-3\mu)} - \frac{\tau q^2}{2} \tag{21}$$

In this regime too, $\frac{\partial \pi_{nv}}{\partial \bar{\beta}} > 0$ and $\frac{\partial \pi_{nv}}{\partial \bar{\theta}} > 0$, i.e., the profit of the original firm is increasing in demand parameters $\bar{\beta}$ and $\bar{\theta}$. An increase in either of the demand parameters $\bar{\beta}$ or $\bar{\theta}$ increases the demand base and the average willingness to pay for the product for both consumer spectrums of the original firm, resulting in an enhancement of profit.

Given the price of the original firm, the pirate's price is :

$$p_{cnv} = \frac{\left(\bar{\beta} + \bar{\theta}\right)\mu q(1-\mu)}{2(4-3\mu)} + \frac{g(8-5\mu)}{4(4-3\mu)} \tag{22}$$

---

[4] Proof in Appendix.

The price of the pirated good increases with *g*. A rise in *g* induces the pirate to raise its price for profitable production.

Quality choice : The first order condition for profit maximisation is given as:

$$\frac{\partial \pi_{nv}}{\partial q} = 0 => \left[\frac{4\left(\overline{\beta}+\overline{\theta}\right)^2 (1-\mu)^2}{8(1-\mu)(4-3\mu)} - \frac{g^2}{8q^2(1-\mu)(4-3\mu)} \right] = \tau q \tag{23}$$

The S.O.C. for profit maximisation in the case of the single version (the no-versioning case) is given by:

$$\frac{\partial^2 \pi_{nv}}{\partial q^2} = \frac{g^2}{8q^3(1-\mu)(4-3\mu)} - \tau < 0 \tag{24}$$

It can be simplified as $V(q) = \tau q$, where

$$V(q) = \left[\frac{4\left(\overline{\beta}+\overline{\theta}\right)^2 (1-\mu)^2}{8(1-\mu)(4-3\mu)} - \frac{g^2}{8q^2(1-\mu)(4-3\mu)} \right] \text{ with } V(q)' > 0 \text{ and } V''(q) < 0 \tag{25}$$

The quality of the no-versioning regime can be determined diagrammatically in a similar manner to the home version in the versioning regime.

3. COMPARISON OF VERSIONING AND NO-VERSIONING

The original firm is a profit-maximising entity and will choose a strategy that will maximise its profit in the presence of commercial piracy. To analyse the situation, we compared the profit of the original firm under versioning and no-versioning regimes. The profit comparison between (11) and (21) (for $\overline{\beta} > 2\overline{\theta}$) and between (11) and (21) (for $\overline{\beta} < 2\overline{\theta}$) did not yield a conclusive result. Thus, we conclude that versioning may or may not be the optimal strategy of the original good producer in the presence of commercial piracy.

Therefore, we attempted to solve this problem by applying the simulation method.

In all existing literature concerning product versioning as a strategy to fight end-user piracy, the results unambiguously show that versioning enhances the profit of the original good firm. However, in our study we observed a counterintuitive result. Assuming the values of the demand parameters and the government monitoring rate, we numerically deduced the profit of the original firm for a set of values of μ (parameter measuring the degree of substitutability of the pirated good). It is observed that when the pirated version of the good is a close substitute for the home version of the original good it is feasible for the original firm to produce a single version of product, rather than two. Simultaneously, it is also observed that for all feasible cases the original firm's no-versioning profit always exceeds the versioning profit. The numerical tables below compare the profit of the versioning and no-versioning regimes for feasible ranges and both cases.

Table 1 (Case 1: $\bar{\beta} > 2\bar{\theta}$)[5] :

$\bar{\beta}$	$\bar{\theta}$	g	α	μ	q_h	q_l	q	π_m^{β}	π_m^{θ}	π_v	π_{nv}
4.5	2	0.5	0.5	0.1	5.0625	1.8844	10.2768	12.8144	1.1703	13.9847	26.8444
4.5	2	0.5	0.5	0.2	5.0625	1.7638	9.9409	12.8144	1.0801	13.8946	25.1858
4.5	2	0.5	0.5	0.3	5.0625	1.6272	9.54	12.8144	0.9883	13.8028	23.2801
4.5	2	0.5	0.5	0.4	5.0625	1.4698	9.0531	12.8144	0.8969	13.7113	21.0742
4.5	2	0.5	0.5	0.5	5.0625	1.2826	8.4492	12.8144	0.8096	13.6240	18.5035
4.5	2	0.5	0.5	0.6	5.0625	1.0395	7.6806	12.8144	0.7346	13.5491	15.4958

Table 2 (Case 2 : $\bar{\beta} < 2\bar{\theta}$)[6]

$\bar{\beta}$	$\bar{\theta}$	g	α	μ	q_h	q_l	q	π_m^{β}	π_m^{θ}	π_v	π_{nv}
3.75	2	0.5	0.5	0.1	3.5	1.8844	8.0419	6.125	1.1703	7.2953	16.5590
3.75	2	0.5	0.5	0.2	3.5	1.7638	7.7790	6.125	1.0801	7.2051	15.5540
3.75	2	0.5	0.5	0.3	3.5	1.6272	7.9652	6.125	0.9883	7.1133	14.3374
3.75	2	0.5	0.5	0.4	3.5	1.4698	7.0840	6.125	0.8969	7.0219	13.0646
3.75	2	0.5	0.5	0.5	3.5	1.2826	6.6113	6.125	0.8096	6.9346	11.5100
3.75	2	0.5	0.5	0.6	3.5	1.0395	6.0093	6.125	0.7346	6.8596	9.6934

5 Assuming $\tau = 1$.

6 Assuming $\tau = 1$.

Thus, our model shows that in a market with commercial piracy, with a lump sum cost of quality development the original good producer cannot choose a product-versioning strategy. This result is attributable to the fact that quality provision is costly and endogenous. Since the production of the business version of the product entails a higher quality cost, the firm may not find it profitable to diversify the product spectrum when it is competing with a profit-maximising commercial pirate.

6. CONCLUSION

In a duopoly structure where a firm produces an original information good which a commercial pirate illegally imitates, with quality costs for two groups of consumers with heterogenous valuation of the product, we analysed the efficacy of the original firm's product-versioning strategy to combat commercial piracy in a developing economy. We assumed the existence of a government that monitors piracy with a stringent monitoring activity that raises the pirate's unit cost of production. We studied two regimes, 'versioning' and 'no-versioning', and compared the reults. Depending on the demand parameters, in this structure there are two possible equilibria for the original firm in the versioning regime. However, in our study the mathematical comparison between the original firm's profit in the versioning and no-versioning regimes was found to be ambiguous. By applying simulation it was observed that, firstly, as the pirated product's degree of substitutability increases it becomes unfeasible for the original firm to adopt product versioning. It was further observed that when a commercial pirate is catering to the spectrum of consumers with a relatively low ability to pay for the product, no-versioning can be the original firm's optimal strategy. The quality cost of the original product diminishes the profit of the original producer. The fact that producing the business version of the good is costly puts downward pressure on the original producer's profit margin, irrespective of the size of the business consumer spectrum. Hence, when facing competition from a profit-maximising commercial pirate, the original producer will find it more profitable to produce a single version of the product with a relatively lower quality cost (the same as that of the home version) for the entire consumer spectrum rather than diversifying production. The findings of our paper counter the results of Alvisi, Argentesi and Carbonara's (2002) study, which assumes costless quality provision under end-user piracy. Cremer and

Pestieau (2008) and Cho and Ahn (2010) conclude unambiguously that product versioning is the optimal strategy for the original producer in the presence of end-user piracy with a positive cost for quality provision. In the case of end-user piracy, the profit earned by the original producer is entirely monopoly profit, which is naturally more than the duopoly profit earned by the producer from the lower spectrum of consumers when it has to compete with a profit-maximising commercial pirate. Wu, Chen, and Anandalingam (2003) study a model of end-user piracy with heterogeneous consumers. They show that if the consumers face asymmetric piracy costs, under certain condition it is profitable to produce a single version of the good. This is in line with our study, which develops a model in the presence of commercial piracy and posits that the efficacy of a product-versioning strategy by the original firm in the presence of commercial piracy is ambiguous.

REFERENCES

Alvisi, M., Argentesi, E., and Carbonara, E. (2002). Piracy and Quality Choice in Monopolistic Markets. Preliminary draft.

Banerjee, D.S. (2003). Software piracy: a strategic analysis and policy instruments. *International Journal of Industrial Organization*, 21, 97–127.

Banerjee, D.S. (2005). Lobbying and commercial software piracy. *European Journal of Political Economy*, 22, 139–155.

Cho, W.Y., Ahn, B.H. (2010). Versioning of information goods under the threat of piracy. *Information Economics and Policy* 22, 332–340.

Cremer, H., Pestieau, P. (2009). Piracy prevention and the pricing of information goods. *Information Economics and Policy*, 21, 34–42.

Wu, S.Y., Chen, P.Y., Anandalingam, G. (2003). Fighting information goods piracy with versioning. *ICIS 2003 Proceedings*. Paper 51.

APPENDIX

Versioning with Imperfect Discrimination

Incorporating the reaction function of the pirate, the Lagrange expression associated with the joint profit of the original firm is given by :

$$L = p_h\left[\bar{\beta} - \frac{p_h}{q_h}\right] - \frac{q_h^2}{2} + p_l\left[\bar{\theta} - \frac{p_l(2-\mu)-g}{2q_l(1-\mu)}\right] - \frac{q_l^2}{2} + +\lambda\left[p_h - \bar{\theta}q_h\right] \quad \text{(A1)}$$

λ is the shadow price.

In view of the first order conditions FOCs the expression for equilibrium prices of the original firm are :

$$p_h = \frac{q_h\left(\bar{\beta}+\lambda\right)}{2} \quad \text{(A2)}$$

$$p_l = \frac{\bar{\theta}q_l(1-\mu)}{(2-\mu)} + \frac{g}{2(2-\mu)} \quad \text{(A3)}$$

Applying the Kuhn-Tucker theorem to the profit maximisation problem, the FOCs of the profit maximisation problem are :

$$\frac{\partial L}{\partial p_h} = \bar{\beta} - \frac{2p_h}{q_h} + \lambda = 0 \quad \text{(A4)}$$

$$\frac{\partial L}{\partial p_l} = \bar{\theta} - \frac{p_l(2-\mu)}{q_l(1-\mu)} + \frac{g}{2q_l(1-\mu)} \quad \text{(A5)}$$

$$\frac{\partial L}{\partial \lambda} = p_h - \bar{\theta}q_h \geq 0; \lambda > 0 \quad \text{(A6)}$$

Case 1 : $\bar{\beta} > 2\bar{\theta}$

Here, $\lambda = 0$. The constraint is non-binding, implying $p_h > \bar{\theta}q_h$

The equilibrium prices are the same as the unconstrained monopoly prices.

$$p_h = \frac{\bar{\beta} q_h}{2} \tag{7}$$

$$p_l = \frac{\bar{\theta} q_l (1-\mu)}{(2-\mu)} + \frac{g}{2(2-\mu)} \tag{8}$$

Putting the equilibrium prices in the constraint:

$$\frac{\bar{\beta} q_h}{2} > \bar{\theta} q_h \Rightarrow \bar{\beta} > 2\bar{\theta}$$

Thus, this case is feasible when $\bar{\beta} > 2\bar{\theta}$.

Endogenised quality

The profit of the original firm from the business group is:

$$\pi_m^{\ \beta} = \left[\frac{\bar{\beta}^2 q_h}{4} - \frac{q_h^{\ 2}}{2} \right] \Rightarrow \frac{\partial \pi_m^{\ \beta}}{\partial q_h} = \frac{\bar{\beta}^2}{4} - q_h = 0 \Rightarrow q_h = \frac{\bar{\beta}^2}{4}$$

The profit of the original firm from the home group is:

$$\pi_m^{\ \theta} = \left[\frac{\bar{\theta}^2 q_l (1-\mu)}{2(2-\mu)} + \frac{\bar{\theta} g}{2(2-\mu)} + \frac{g^2}{8 q_l (1-\mu)(2-\mu)} - \frac{q_l^{\ 2}}{2} \right] \Rightarrow \frac{\partial \pi_m^{\ \theta}}{\partial q_l} = \frac{\bar{\theta}^2 (1-\mu)}{2(2-\mu)} - q_l - \frac{g^2}{8 q_l^{\ 2} (1-\mu)(2-\mu)} = 0$$

$$\Rightarrow 8 q_l^3 (2-\mu)(1-\mu) - 4\bar{\theta}^2 q_l^2 (1-\mu)^2 + g^2 = 0$$

Case 2 : $\bar{\beta} < 2\bar{\theta}$

In this case where $\lambda > 0$ (constraint non-binding), we observe
$\lambda = 2\bar{\theta} - \bar{\beta} > 0, i.e., \bar{\beta} < 2\bar{\theta}$

The equilibrium prices are :

$$p_{h2} = \bar{\theta} q_h \tag{20}$$

$$p_{l2} = p_l^* = \frac{\bar{\theta} q_l (1-\mu)}{(2-\mu)} + \frac{g}{2(2-\mu)} \tag{8}$$

Putting the equilibrium price of the business version, we observe that,

$$\lambda > 0 \Rightarrow p_{h3} = \bar{\theta} q_h \Rightarrow \frac{(\bar{\beta}+\lambda) q_h}{2} = \bar{\theta} q_h \Rightarrow (\bar{\beta}+\lambda) = 2\bar{\theta} \Rightarrow \bar{\beta} < 2\bar{\theta}$$

Thus, this case is feasible when $\bar{\beta} < 2\bar{\theta}$.

Endogenised Quality

The profit of the original firm from the business group is:

$$\pi_m^{\beta} = \left[\bar{\beta}\bar{\theta} q_h - \bar{\theta}^2 q_h - \frac{q_h^2}{2}\right] \Rightarrow \frac{\partial \pi_m^{\beta}}{\partial q_h} = \bar{\beta}\bar{\theta} - \bar{\theta}^2 - q_h = 0 \Rightarrow q_h = (\bar{\beta} - \bar{\theta}).\bar{\theta}$$

No-Versioning Case :

The profit of the original firm is:

$$\pi_m = p_m\left[\bar{\beta} - \frac{p_m}{q}\right] + p_m\left[\bar{\theta} - \frac{p_m(2-\mu)-g}{2q(1-\mu)}\right] - \frac{q^2}{2} \Rightarrow \frac{\partial \pi_m}{\partial p_m} = \bar{\beta} - \frac{2p_m}{q} + \bar{\theta} - \frac{p_m(2-\mu)}{q(1-\mu)} + \frac{g}{2q(1-\mu)} =$$

$$= (\bar{\beta}+\bar{\theta}) + \frac{g}{2q(1-\mu)} - \frac{p_m}{q}\frac{(4-3\mu)}{(1-\mu)}$$

$$\Rightarrow p_{nv} = \frac{2q(\bar{\beta}+\bar{\theta})(1-\mu)+g}{2(4-3\mu)}$$

The price of pirated goods is:

$$p_c = \frac{\mu p_m + g}{2} = \frac{\mu}{2}\left[\frac{q\left(\bar{\beta}+\bar{\theta}\right)(1-\mu)}{(4-3\mu)} + \frac{g}{2(4-3\mu)}\right] + \frac{g}{2} = \frac{\mu q\left(\bar{\beta}+\bar{\theta}\right)(1-\mu)}{2(4-3\mu)} + \frac{\mu g + 2g(4-3\mu)}{4(4-3\mu)} =$$

$$= \frac{\left(\bar{\beta}+\bar{\theta}\right)\mu q(1-\mu)}{2(4-3\mu)} + \frac{g(8-5\mu)}{4(4-3\mu)}$$

Endogenised quality

The profit of the original firm is:

$$\pi_{nv} = \frac{\left[2q\left(\bar{\beta}+\bar{\theta}\right)(1-\mu)+g\right]^2}{8q(1-\mu)(4-3\mu)} = \frac{4q^2\left(\bar{\beta}+\bar{\theta}\right)^2(1-\mu)^2}{8q(1-\mu)(4-3\mu)} + \frac{4qg\left(\bar{\beta}+\bar{\theta}\right)(1-\mu)}{8q(1-\mu)(4-3\mu)} + \frac{g^2}{8q(1-\mu)(4-3\mu)}$$

$$\Rightarrow \frac{\partial \pi_{nv}}{\partial q} = \frac{4\left(\bar{\beta}+\bar{\theta}\right)^2(1-\mu)^2}{8(4-3\mu)} - \frac{g^2}{8q^2(1-\mu)(4-3\mu)} = 0 \Rightarrow q = \frac{g}{2\left(\bar{\beta}+\bar{\theta}\right)(1-\mu)}$$