24. Impact of Piracy on Innovation at Software Firms and Implications for Piracy Policy

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Abstract

A Business software alliance (BSA) commissioned study in 2006, found that $34 billion was lost due to piracy of software in 2005. The BSA and its members invest significant resources in educating users about copyright, its value, and enforcing copyright laws. However, does effort spent in educating users about the harmful aspects of piracy, and taking action against end-users using pirated software always result in higher quality software? In this paper, we look at how innovation in the presence of piracy is affected by the policy choice of alliances such as the BSA. Surprisingly, we find that a stricter piracy policy, that increases the perceived cost to using pirated software for end-users, may in some cases lead to an increase in piracy (demand for pirated products), and a decrease in product quality. Thus an active BSA that tries to educate consumers and takes legal action against consumers, may actually be promoting piracy and hurting innovation in some cases. An intuitive rationale for this is that, in some regions, quality choice by the firm and the policy choice by the BSA are strategic substitutes in the fight against piracy. Thus an increase in the policy variable by the BSA, makes the firm choose a lower quality. Depending on the likelihood that the pirated product is functional, the BSA would choose a piracy policy ranging from an inactive to a very active policy.

Keywords: Software piracy, Policy, Quality, Innovation

Introduction

A Business software alliance (BSA) commissioned study (BSA 2006) found that $34 billion was lost due to piracy of software in 2005. In its fight against piracy, the software industry has combined forces through alliances such as the BSA, and the software publishers alliance (SPA). These alliances educate consumers on software management and copyright protection, cyber security, trade, e-commerce, and other Internet-related issues. They also work with law enforcement agencies in several countries to take action against pirates. The main advantage of these alliances is the tremendous economies of scale in fighting piracy. The BSA study found that countries varied in their piracy rate, ranging from Vietnam at 90%, to the United States at 21% (BSA 2006). The large variance in piracy rates could possibly be attributed to cultural differences, and the actions taken by alliances such as the BSA and the SPA in the specific countries.

An often cited reason by software firms for building up their case against piracy, is the detrimental impact of piracy on innovation.

> *"Strong intellectual property protection spurs creativity, which opens new opportunities..."* - CEO, BSA (Gross 2003).

We look at how innovation (quality) is affected by the policy choice of alliances such as the BSA when piracy is prevalent. The BSA and its members invest significant resources in educating users about copyright, its value, and enforcing copyright laws (BSA Enforcement). Does effort spent in educating users about the harmful aspects of piracy, and taking action against end-users using pirated software always result in higher quality software? These are the issues we address in this paper. These issues are of interest not just to alliances such as the BSA, and software firms, but also to a social planner such as the government in deciding public policy regarding piracy. Empirical studies on the impact of piracy on the quality choice of firms, are understandably hard because of the inherent difficulty in operationalizing a measure for quality. The analytical approach would provide intuition on the long term impact of piracy policies on welfare, quality choices, and price competition.

The two most common forms of piracy are end-user piracy (friends sharing copyrighted software) and counterfeiting (large scale duplication of illegal software). This paper is about the latter. Software companies estimate they lost $12 billion in revenue in 2000 because of counterfeiting. That is 15% of the industry's $80 billion in worldwide sales (Iwata, 2001). Counterfeit versions of popular software are available at a much lower price on the Internet and from street peddlers. Microsoft's Office XP for example (original retail price $479) was available at auction sites in 2001 for $200. According to Microsoft, there's a 90 percent chance the discs are counterfeit (Wood 2001). Organized piracy or counterfeiting is thus a major cause of concern to software firms. Surprisingly, counterfeiting has received little attention in the piracy literature. The impact of piracy policies on innovation, and pricing strategies of the firm in the presence of a counterfeit supplier, is the focus of this paper.

The environment that we study consists of a firm that develops a software, a pirate that creates an illegal copy of the software, and an alliance such as the BSA which implements piracy policies (legal action, educating users about the detrimental effects of piracy etc.). The market for the software is shared between the firm and the pirate. Consumers differ in their ethical cost to pirate. The ethical cost to pirate is a function of the level of the policy choice variable. A stricter piracy policy increases the ethical cost for consumers to pirate, thus affecting the demand for pirated products. We develop a game theoretic model in which the BSA chooses the piracy policy first. After observing the policy choice by the BSA, the firm chooses the quality of software. In the final stage, after quality has been chosen, the firm and the pirate choose prices simultaneously, knowing how prices are going to affect demand. We use backward induction to solve the game: we first determine the optimal prices for both firm and pirate, given that they choose prices simultaneously, and that they observe the quality choice by the firm and the policy choice of the BSA. Then based on these optimal prices, we calculate the optimal quality chosen by the firm, given that the firm observes the policy choice of the BSA. Finally based on the optimal quality choice of the firm, and the optimal prices charged by both the firm and the pirate, we calculate the optimal policy choice by the BSA.

We find that when the firm knows it has a superior product, and that the policy choice by the BSA is low, then it should price aggressively to make it unprofitable for the pirate to exist in the market. Also, when the firm knows it doesn't have a high quality product, but the BSA has chosen a high policy choice, it does not engage in an aggressive pricing strategy, and leaves a small segment of the market for the pirate. Surprisingly, we find that a stricter piracy policy that increases the perceived cost to using pirated software for end-users, may in some cases lead to an *increase* in piracy (demand for pirated products), and a *decrease* in product quality. Thus an active BSA, that tries to educate consumers, and takes legal action against consumers, may actually be promoting piracy and hurting innovation in some cases. An intuitive rationale for this is that, in some regions, quality choice by the firm, and the policy

choice by the BSA are strategic substitutes in the fight against piracy. Thus an increase in the policy variable, makes the firm choose a lower quality. Regarding the optimal policy choice by the BSA, we find that, when the likelihood that the pirated software will be functional is low, then it is non-optimal for the BSA to expend any cost to reduce piracy. When it is medium, then a high level of policy choice is optimal only for high values of technology cost and low values of policy cost. When the likelihood that the pirated software will be functional is high, then, the BSA should almost always choose a high level of policy choice.

The rest of the paper is organized as follows: in Section 2 we cover the relevant literature. The basic model is set up in Section 3. Finally we discuss the managerial implication of the results and directions for future research in Section 4. All proofs have been kept out of the paper for brevity.

Background

Novos and Waldman (1984) distinguish between two types of effects of piracy on social welfare: the first effect is the loss due to underproduction, and the second is the positive welfare effect due to decrease in loss due to under-utilization. The underproduction loss comes from the decreased incentive for firms to innovate in the presence of piracy, which leads to reduced variety, or reduced quality in the long term. Decrease in loss due to under-utilization results from more consumers getting to use the software as a result of piracy. In this paper our focus is on the loss due to underproduction. One of the key differences between our paper and Novos and Waldman (1984) is that our results don't depend on the specification of the consumer distribution function (more detail explained later). In Novos and Waldman (1984) however, the key result is obtained with a restricted consumer distribution function.

Specifically, we look at how innovation (quality) is affected by the policy choice of alliances such as the BSA, when piracy is prevalent. Most of the software piracy literature (Conner and Rumelt 1991; Chen and Png 2003; Shy and Thisse 1999) addresses end-user piracy as opposed to organized pirating by a firm (counterfeiting) (Banerjee 2003). Previous papers that have looked at end-user piracy have studied the impact of protection strategies on prices and profits in a monopoly setting (Conner and Rumelt 1991), and in a duopoly setting (Shy and Thisse 1994). They find that, when network externalities are high enough, then non-protection is optimal. Chen and Png (2003) study the problem of a social planner, who has three policy choices: to tax the copying medium, to subsidize legal sales and to fine offenders. They find that, from a welfare perspective, providing subsidies to users is optimal compared to taxing the copying medium, or penalizing copiers.

Banerjee (2003) studies the optimal monitoring rate and fine to charge a pirate in a setting where the market is shared between the firm and the pirate. The paper finds that welfare maximization may or may not result as the socially optimal outcome. The impact of the reliability of the pirated software, and the impact of network externality on the policy variable are also studied. Chen and Png (2003) mention that the long term impact of policy choice on innovation has received little attention. Novos and Waldman (1984) look at the impact on quality choices by a firm in an end user piracy setting. They find that quality choices are below the socially optimal level in the presence of piracy.

The setting in our paper is perhaps closest to Banerjee (2003). Both papers look at counterfeiting. We look at the impact of policy on quality and price choices of firms, Banerjee studies the impact on prices. Policy affects the supply of pirated software in (Banerjee 2003), while it affects the demand side of the market in our paper. From a research question perspective, this paper is in the same vein as Novos and Waldman (1984). However, they look

at an end user piracy setting, and the impact of policy on the quality choices of firms is not studied. A recent working paper (Bae and Choi 2003) studies the impact of intellectual property right protection on innovation. They operationalize the intellectual property right protection through a 'reproduction cost' and a 'degradation cost'. Both are exogenous parameters that allow comparative statics on optimal quality choice. Unlike this paper (Bae and Choi 2003), our policy variable is endogenous and we study the impact of competition.

Gopal and Sanders (1997) distinguish between preventive and deterrent measures to fight software piracy and show in a setting with club formation, that using deterrent measures is optimal. Another paper by the same authors (Gopal and Sanders 1998) develops an economic model that provides the rationale for the reluctance of a number of governments to aggressively enact and enforce intellectual property rights. The model incorporates the incentive structures for governments, software publishers, and individual consumers.

Model

There is a firm that produces a product (software) of quality, q, at price, p. Quality of the software means two things: first software that has fewer bugs is of a higher quality. Second, software with more features (e.g. graphical analysis, regression analysis etc. in a mathematical analysis software) is of a higher quality. All consumers value the software equally at its quality. There exists a pirate who sells a pirated version of this product at price, p_c. The quality of the pirated software is, ϕq ($0 \le \phi \le 1$). ϕ is the likelihood that the pirated software is functional. An article in *PC Magazine* (Wood 2001) notes that consumers could face a variety of problems with counterfeit software: it could contain a virus, or it may not be functional; after all counterfeiters are not known for their quality control. Alternately, ϕ captures the degradation in the quality of the product, due to lack of customer support, documentation etc. Alliances such as the BSA implement policies, or take actions to prevent piracy. These policies/actions may be in the form of legal action against users, or educating users about the harms of piracy. The BSA benefits from tremendous economies of scale in fighting piracy. Although the firm is a monopolist in its market, there are other software firms which also rely on the BSA to prevent piracy. These policies of the BSA increase the perceived cost to the user of using pirated software. We denote this policy/action measure by, η, ($0 \le \eta \le \bar{\eta}$). A higher η (stricter policy), corresponds to a more active role by the BSA to prevent piracy. Consumers (denoted by z) differ in the ethical propensity to use pirated software. z is assumed to be uniformly distributed on [0,1]. Given a consumer, z, the ethical cost to a consumer of using pirated software is, $z\eta$. This formulation of cost ensures that the greater the policy measure, the greater the cost to pirate for a consumer of type z, and for a given policy measure, individual consumers may differ in their ethical cost to pirate. A consumer with a higher z, has a higher ethical cost to pirate. We summarize our notation in Table 1.

The utility of a consumer of type z:

$$U(q,z) = \begin{cases} q - p & \text{if consumer buys from firm} \\ \phi q - p_c - z\eta & \text{if consumer buys from pirate} \\ 0 & \text{if consumer does not buy} \end{cases} \tag{1}$$

Let $\hat{z}$ be the consumer type indifferent between buying from the firm and buying from the pirate. So $q - p = \phi q - p_c - \hat{z}\eta$.

$$\hat{z} = \frac{p - p_c + \phi q - q}{\eta} \tag{2}$$

The firm's demand:

$$d = 1 - \hat{z} = 1 - \left(\frac{p - p_c + \phi q - q}{\eta} \right) \tag{3}$$

The pirate's market share is $\hat{z}$.

Table 1: Notation

Notation	Description
q	Quality of software.
p	Price charged by firm.
ϕ	Likelihood that the pirated version is functional.
p_c	Price charged by pirate.
η	Policy choice by BSA.
z	Ethical propensity not to pirate - consumer's type.
d_f, d_c	Firm and pirate's demand.
π_f, π_c	Profit of firm and pirate.
k	Quality cost coefficient.
c	Policy cost coefficient.
i, j	Indexes for firms in duopoly.
x	Location based preference cost.

The firm pays a membership fees to the BSA for fighting piracy. The membership fees is exogenous and for simplicity assume that it is zero. Considering a positive membership fees will only reduce the profit function of the firm by this fixed amount and will not qualitatively affect the nature of the results. Assuming a convex cost function ($\frac{1}{2}kq^2$; $k > 0$) for the firm to develop a product of quality q, the corresponding profit functions for the firm and the pirate are:

$$\pi_f = p \left[1 - \left(\frac{p - p_c + \phi q - q}{\eta} \right) \right] - \frac{1}{2}kq^2 \tag{4}$$

$$\pi_c = p_c \left(\frac{p - p_c + \phi q - q}{\eta} \right) \tag{5}$$

The BSA chooses η to maximize overall surplus. The game played between the firm, the pirate, and the BSA is specified in extensive form as follows:

Stage 1: The BSA chooses the policy measure η.

Stage 2: Having observed η, firm chooses quality q.

Stage 3: Firm and the pirate choose prices simultaneously (Bertrand Competition).

We work backwards, first determining the optimal prices for both firm and pirate, given that they choose prices simultaneously, and that they observe the quality choice by firm (1). Then based on these optimal prices, we calculate the optimal quality chosen by the firm (2), and then the optimal choice of η by the BSA (3).

Pricing subgame

The pirate and the firm can observe the quality choice made by the firm in the previous stage, and the policy choice made by the BSA in stage 1. Both choose prices to maximize profits.

Proposition 1. *Given a policy choice,* η, *by the BSA, and a quality choice,* q, *by the firm, the optimal price for the firm, and for the pirate, and the demand for the firm are:*

$$
\begin{cases}
p^* = q, \; p_c^* = \dfrac{\phi q}{2}, \; d^* = 1 - \dfrac{\phi q}{2\eta} \text{ if } \dfrac{q}{\eta} < \dfrac{2}{2+\phi} \\[3mm]
p^* = \dfrac{q(1-\phi)+2\eta}{3}, \; p_c^* = \dfrac{\eta - q(1-\phi)}{3}, \; d^* = \dfrac{2\eta + q(1-\phi)}{3\eta} \text{ if } \dfrac{2}{2+\phi} \leq \dfrac{q}{\eta} \leq \dfrac{1}{1-\phi}. \\[3mm]
p^* = q(1-\phi), \; p_c^* = 0, \; d^* = 1 \text{ if } \dfrac{q}{\eta} > \dfrac{1}{1-\phi}
\end{cases}
$$

Define $\frac{q}{\eta}$ as the 'quality to policy' ratio. When the ratio is small ($\frac{q}{\eta} < \frac{2}{2+\phi}$), the share of the market taken up by the pirate ($\frac{\phi q}{2\eta}$) is small, hence it is optimal for the firm to extract all the surplus from its consumers. It charges a price equal to quality, while the pirate charges half its expected quality. Optimal price set by the firm and the pirate increase in quality, while the demand decreases with quality. A change in policy has no effect on the prices but decreases piracy (demand for pirate). When the quality to policy ratio is high ($\frac{q}{\eta} > \frac{1}{1-\phi}$), a big chunk of the market can potentially be lost to the pirate, hence it becomes optimal for the firm to lower its price to a level ($q(1-\phi)$), where the pirate is forced to leave the market. In this region, an increase in η has no effect on prices or piracy. An implication from the pricing in the two regions is that, when the firm knows it has a superior product and the policy choice by the BSA is low, then it should price aggressively to make it unprofitable for the pirate to exist in the market. Also, when the firm knows it doesn't have a high quality product, but the BSA has chosen a high policy choice, it does not engage in an aggressive pricing strategy and leaves a small segment of the market for the pirate. For the range $\frac{2}{2+\phi} \leq \frac{q}{\eta} \leq \frac{1}{1-\phi}$ the following observations can be made: the price set by the firm (pirate) is an increasing (decreasing) function of quality choice. Similarly the demand for the firm is an increasing function of quality, which means that the demand for the pirated software (henceforth called piracy), is a decreasing function of quality. The impact of policy choice η on prices is less certain, since it depends on how the quality choice changes with η. There is a direct effect (+ve) on the price of the firm, due to an increase in η, and an indirect effect because of the effect of η on q. Similarly, there is a positive effect of an increase in η on the price of the pirate. This effect is because of the increase in the price of the firm with η, and hence is smaller. The price set by the pirate is also affected by the indirect effect of η on q. An increase in η has a negative effect on the demand of the firm through an increase in price, and an indirect effect because of the effect of η on q.

Quality choice

As found in the previous section, the optimal pricing strategy is different for the three regions specified. The quality choice problem for the firm is: $\max \; p^* d^* - \dfrac{1}{2}kq^2$, subject to the boundary conditions of each of the three regions. For a given value of η, the firm chooses quality to

maximize profits in each of the three regions.

Denoting $\eta_1 = \frac{2(1-\phi)^2}{3k}$, $\eta_2 = \frac{0.82(1-\phi)^2}{k}$, $\eta_3 = \frac{(1-\phi)^2}{k}$, $\eta_4 = \frac{2(1-\phi)}{3k}$, $\eta_5 = \frac{2-\phi}{2k}$, and assuming that $\phi > \frac{1}{3}$, the following is true $0 < \eta_1 < \eta_2 < \eta_3 < \eta_4 < \eta_5 < \eta_6 < \overline{\eta}$.

Proposition 2. *(a) Given a policy choice, η, by the BSA, the optimal quality choice by the firm, optimal price set by firm and pirate, optimal profit, and demand for firm are:*

Range of η	q^{**}	p^{**}	p_c^{**}	π_f^{**}	d^{**}
$0 \le \eta \le \eta_2$	$\frac{1-\phi}{k}$	$\frac{(1-\phi)^2}{k}$	0	$\frac{(1-\phi)^2}{2k}$	1
$\eta_2 < \eta \le \eta_4$	$\frac{4(1-\phi)\eta}{[9k\eta - 2(1-\phi)^2]}$	$\frac{6\eta^2 k}{[9k\eta - 2(1-\phi)^2]}$	$\frac{\eta[3k\eta - 2(1-\phi)^2]}{[9k\eta - 2(1-\phi)^2]}$	$\frac{4\eta^2 k}{[9k\eta - 2(1-\phi)^2]}$	$\frac{6\eta k}{[9k\eta - 2(1-\phi)^2]}$
$\eta_4 < \eta \le \eta_5$	$\frac{2\eta}{2+\phi}$	$\frac{2\eta}{2+\phi}$	$\frac{\eta\phi}{2+\phi}$	$\frac{2\eta[2-k\eta]}{(2+\phi)^2}$	$\frac{2}{2+\phi}$
$\eta_5 < \eta < \overline{\eta}$	$\frac{\eta}{\phi+k\eta}$	$\frac{\eta}{\phi+k\eta}$	$\frac{\phi\eta}{2(\phi+k\eta)}$	$\frac{\eta}{2(\phi+k\eta)}$	$\frac{\phi+2k\eta}{2(\phi+k\eta)}$

respectively.

(b) Changes in optimal values with an increase in the policy variable are summarized below:

Range of η	$\frac{\partial q^{**}}{\partial \eta}$	$\frac{\partial p^{**}}{\partial \eta}$	$\frac{\partial p_c^{**}}{\partial \eta}$	$\frac{\partial \pi_f^{**}}{\partial \eta}$	$\frac{\partial d^{**}}{\partial \eta}$
$0 \le \eta \le \eta_2$	0	0	0	0	0
$\eta_2 < \eta \le \eta_4$	$-$	$+$	$+$	$+$	$-$
$\eta_4 < \eta \le \eta_5$	$+$	$+$	$+$	$+$	0
$\eta_5 < \eta < \overline{\eta}$	$+$	$+$	$+$	$+$	$+$

The above result shows the optimal choices in stage 2 given a policy choice in stage 1. We find that for a range of the policy variable ($\eta_2 < \eta \le \eta_4$), quality choice by the firm and the demand for the product actually decrease with a stricter policy η. Also, in the range ($0 \le \eta \le \eta_2$), the policy variable has no impact on quality, prices, profit or demand. Software firms often cite the detrimental impact of piracy on the incentive to innovate as a reason for increased action/policy against piracy. Indeed we find that for an $\eta > \eta_4$, that is the case. However, we find that in the range ($\eta_2 < \eta \le \eta_4$), a firm chooses a higher quality, and the piracy is actually lower, when the piracy policy is relaxed. Thus an active BSA that tries to educate consumers and takes legal action against consumers is actually promoting piracy and hurting innovation in this range. Novos and Waldman (1984) find a similar result with respect to the impact of copyright protection. Their result shows that for that for a certain type of consumer distribution, with increased protection, the quality of software might be lower. In our paper however, with the same distribution, in certain ranges, a higher policy variable could have a negative effect on quality. Hence our results don't depend on the specification of the distribution function of consumers.

Graphically the above result is represented in Figure 1. When the policy variable is below the

threshold $\eta_2 = \frac{0.82(1-\phi)^2}{k}$, it is optimal for the firm to price low enough to force the pirate out of the market. Understandably, the policy variable cannot affect the price, profit, or demand in this range, and hence flat curves in this region. Beyond this threshold level, the firm has a higher profit if it shares the market with the pirate. It raises its price which results in the pirate finding it profitable to enter the market. Note that the profit and price charged by the firm are increasing in η beyond η_2.
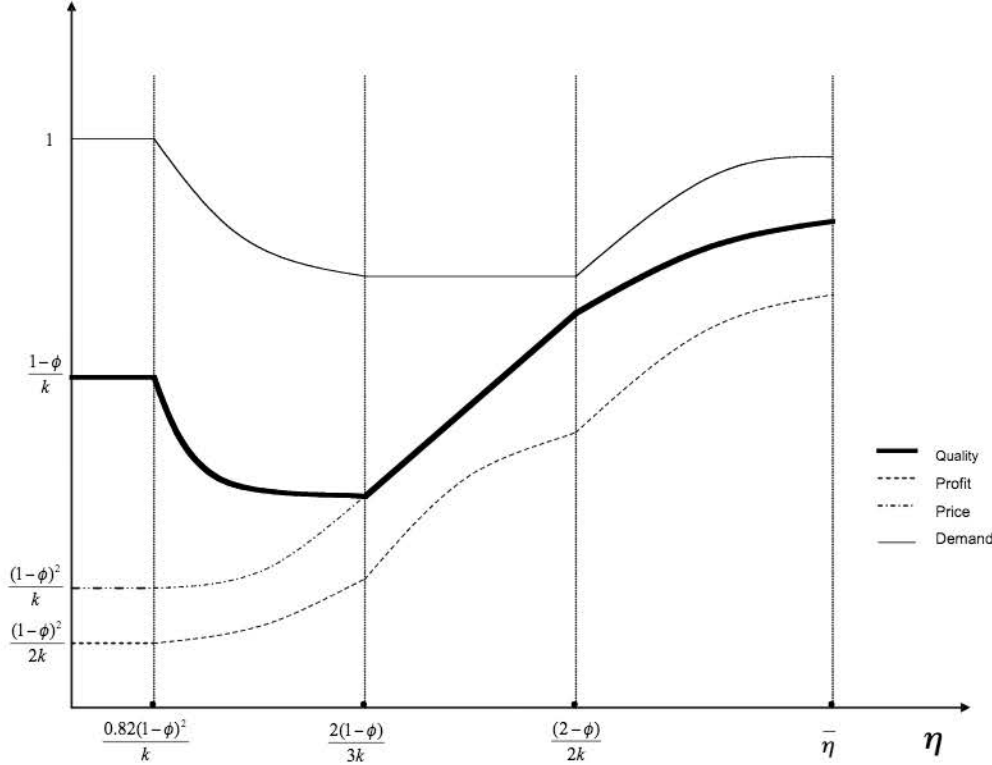

Figure 1: Plots of change in optimal quality, prices, demand and profits with η

Lemma 1. In the regions $(\eta_2 < \eta \leq \eta_4)$ and $(\eta_5 < \eta < \bar{\eta})$, the sign of $\frac{\partial q^{**}}{\partial \eta}$ is the same as the sign of $\frac{\partial^2 d^*}{\partial \eta \partial q}$. For $(\eta_2 < \eta \leq \eta_4)$ $\frac{\partial^2 d^*}{\partial \eta \partial q} < 0$ and for $(\eta_5 < \eta < \bar{\eta})$ $\frac{\partial^2 d^*}{\partial \eta \partial q} > 0$.

In the region $(\eta_2 < \eta \leq \eta_4)$ since $\frac{\partial^2 d^*}{\partial \eta \partial q} = -\frac{1-\phi}{3\eta^2} < 0$, quality choice and policy are strategic substitutes in the fight against piracy. Since quality and policy are strategic substitutes, increase in the policy variable η would lead to the firm choosing a lower quality i.e. $\frac{\partial q^{**}}{\partial \eta} < 0$. Other results regarding the impact of η on price, demand, and profits follow intuitively from the above result, and the discussion after proposition 1. The indirect effect of increase in η on quality is negative, and hence the demand decreases, and the price of the pirate increases, with η. The direct effect of increase in η, dominates the indirect negative effect of η on quality and so the price of the firm increases with η. The firm increases its price with a stricter piracy policy and extracts more surplus from its loyal customers.

For $\eta > \eta_4 = \frac{2(1-\phi)}{3k}$, the price follows the quality, and all consumers who buy legally earn a

surplus of zero. In the range $\eta_4 < \eta \leq \eta_5$ the policy variable is effective to the extent that a higher η leads to a higher quality choice. However, a higher policy variable does not lead to lower piracy as seen by the flat demand plot in this range.

For $\eta_5 < \eta \leq \overline{\eta}$, an increase in η leads to higher quality and lower piracy. Since $\frac{\partial^2 d^*}{\partial \eta \partial q} = \frac{\phi}{2\eta^2} > 0$ (from Lemma 1), quality choice and policy are strategic complements in the fight against piracy. Since quality and policy are strategic complements, increase in the policy variable η would lead to the firm choosing a higher quality i.e. $\frac{\partial q^{**}}{\partial \eta} > 0$. However even at $\eta = \overline{\eta}$, there is still a demand for the pirated product i.e. the demand for the firm < 1.

Policy choice

The BSA chooses the policy variable to maximize the total surplus. Left alone, the BSA would only care about the profit of the firm. However, given that the BSA depends on the government for support in implementing its policies, the government can have enough influence on the BSA, for it to consider maximizing the surplus of the legal consumers also. Depending on the bargaining power between the government and the BSA, η could be chosen to maximize the profit of just the firm, to also maximizing surplus of legal consumers. In this section we have done the analysis for the case where the BSA chooses to maximize the surplus of the firm and the consumers who buy legally. In the Appendix we also present the results for the case where the BSA only maximizes the surplus of the firm.

The BSA maximizes this surplus in each of the four regions and picks the strategy where the maximized total surplus is the greatest. Consumer surplus of the consumers who buy legally from the firm:

$$CS = (q^{**} - p^{**}) * d^{**} \tag{6}$$

Assuming that the BSA bears a cost ($\frac{1}{2}c\eta^2$ where $c > 0$) for implementing a policy η. The BSA's maximization problem is, maximize total surplus (TS) i.e. $\max \pi_f^{**} + CS - \frac{1}{2}c\eta^2$ subject to the boundary conditions of each of the four regions.

$$TS = \begin{cases} \dfrac{1-\phi^2}{2k} - \dfrac{1}{2}c\eta^2 & \text{if } 0 \leq \eta \leq \eta_2 \\[2mm] \dfrac{8\eta^2 k(1-\phi)(2+\phi)}{[9k\eta - 2(1-\phi)^2]^2} - \dfrac{1}{2}c\eta^2 & \text{if } \eta_2 < \eta \leq \eta_4 \\[2mm] \dfrac{2\eta[2-k\eta]}{(2+\phi)^2} - \dfrac{1}{2}c\eta^2 & \text{if } \eta_4 < \eta \leq \eta_5 \\[2mm] \dfrac{\eta}{2(\phi + k\eta)} - \dfrac{1}{2}c\eta^2 & \text{if } \eta_5 < \eta < \overline{\eta} \end{cases} \tag{7}$$

Proposition 3. *The optimal policy choice, for each of the four regions are: i) $\eta^I = 0$, ii) $\eta^{II} \approx \frac{0.82(1-\phi)^2}{k}$ iii) $\eta^{III} = \frac{2-\phi}{2k}$ if $\frac{c}{k} < \frac{4\phi}{(2-\phi)(\phi+2)^2}$ and $\eta^{III} = \frac{4}{4k+c(\phi+2)^2}$ if $\frac{4\phi}{(2-\phi)(\phi+2)^2} < \frac{c}{k} < \frac{2(1+2\phi)}{(1-\phi)(\phi+2)^2}$ iv) $\eta^{IV} = \frac{2^{\frac{1}{3}}(y - 2^{\frac{2}{3}}\phi c)^2}{6cky}$ where $y = \left[\phi c^2 (4c\phi^2 + 27k + 3\sqrt{3}\sqrt{\frac{8c\phi^2 + 27k}{k}}k)\right]^{\frac{1}{3}}$.*

Here η^i denotes the optimal policy choice in region $i = I, II, III, IV$. In region I ($0 \le \eta \le \eta_2$), the profit of the firm and the consumer surplus don't depend on the policy choice. The BSA thus chooses the minimum policy choice $\eta^I = 0$. In region II ($\eta_2 < \eta \le \eta_4$), TS is a decreasing function of η. Again the BSA chooses the minimum level of policy choice in this range, $\eta^{II} \approx \frac{0.82(1-\phi)^2}{k} = \eta_2$. In region III ($\eta_4 < \eta \le \eta_5$), consumers who buy from the firm, get zero surplus since the firm charges a price equal to quality. The BSA maximizes the profit of the firm net its cost to implement the policy. The profit of the firm is a concave function (as seen from Figure 1), while the cost function of the BSA is convex. Thus if a maxima exists in this range, it is $\eta^{III} = \frac{4}{4k+c(\phi+2)^2}$. The constraints for this solution come from the restrictions that the maxima must be in the specified range of the policy variable. The other solution in region III is a corner solution, when the constraint $\eta \le \eta_5$ binds. In region IV ($\eta_5 < \eta < \overline{\eta}$), consumer surplus is again zero. The profit function of the firm is concave (as seen from Figure 1), while the cost function is convex. The maxima is at $\eta^{IV} = \frac{2^{\frac{1}{3}}(y-2^{\frac{2}{3}}\phi c)^2}{6cky}$. The maximized TS in each region can be obtained by substituting η^i in the corresponding TS given in (7).

Denoting the maximized TS in region i by TS^i_{max}, the global maxima can be obtained by comparing all four TS^i_{max}. It is a fairly involved algebraic problem to obtain the conditions under which each one of the solutions is the global maxima. Instead we evaluate TS^i_{max} for $i = I, II, III, IV$, varying the exogenous parameters c in the range $[0.001, 10]$ (increments 0.50), k in the range $[0.001, 10]$ (increments 0.50), and ϕ in the range $[0.34, 0.99]$ (increments 0.05). We find that in all cases, either TS^I_{max} or TS^{IV}_{max} dominates the other TS^i_{max}. We plot TS^I_{max} and TS^{IV}_{max} for three different parameter values of ϕ (0.60, 0.90 and 0.99), and different values of c and k (see Figure 2). When the likelihood that pirated software will be functional is low ($\phi = 0.60$), then the expected utility of consumers from pirating is low. In this case, TS^I_{max} dominates TS^{IV}_{max}, for all values of c and k (see Figure 2a). The BSA will choose a policy $\eta^{***} = 0$, i.e., it is non-optimal for the BSA to expend any cost to prevent piracy. When the likelihood that the pirated software will be functional, is medium ($\phi = 0.90$), then for high values of k and low values of c, TS^{IV}_{max} dominates TS^I_{max} (see Figure 2b). The BSA chooses a high level of policy choice $\eta^{***} = \eta^{IV}$ in this region. Consumers earn zero surplus for this choice since the firm does not price aggressively knowing that the pirate cannot take a big chunk of the market because of the high η. Thus, although the quality of the product is higher, consumers are left indifferent between buying and not buying. The consumers who buy from the firm are actually better off in terms of surplus when the BSA chooses a policy of $\eta^{***} = 0$. When the likelihood that the pirated software will be functional is high ($\phi = 0.99$), then the BSA will choose a high level of policy $\eta^{***} = \eta^{IV}$ for almost all values of c and k (see Figure 2c). A policy choice $\eta^{***} = 0$ is thus almost never optimal in this case. Any intermediate level of policy choice is non-optimal and for specific ranges of policy choice, an increase in policy may hurt innovation and promote piracy. For the case when the BSA maximizes the profit of the firm only, we still find that TS^I_{max} or TS^{IV}_{max} dominates the other TS^i_{max}. Since these two surpluses are the same as in the case where the

BSA also maximizes the profit of the legal consumers, the rest of the analysis is the same.
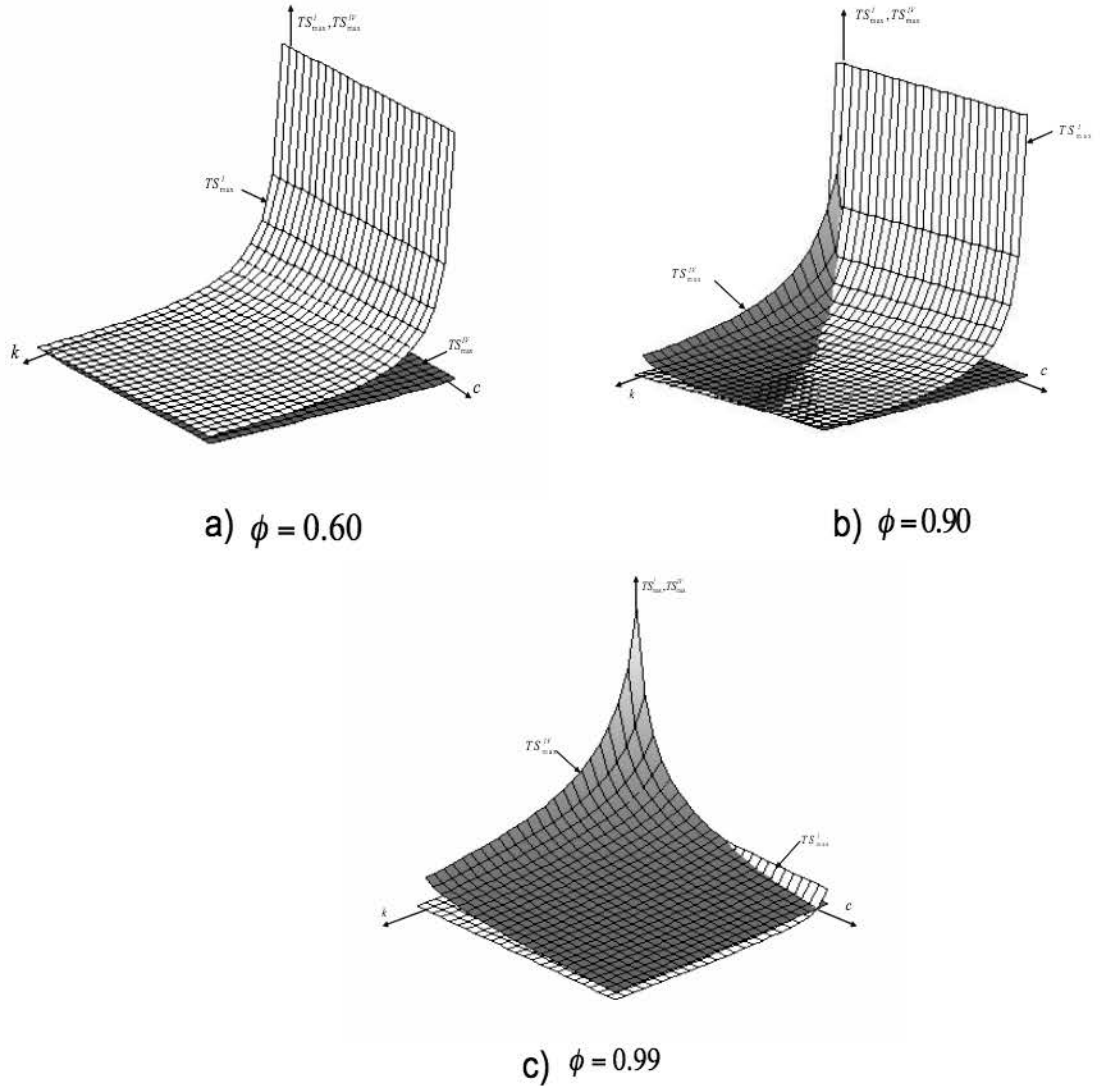

a) $\phi = 0.60$

b) $\phi = 0.90$

c) $\phi = 0.99$

Figure 2 $TS^{I}_{\max}$ and $TS^{IV}_{\max}$ for a) $\phi = 0.60$ b) $\phi = 0.90$ and c) $\phi = 0.99$

Discussion

In this paper our focus was on how innovation (quality) is affected by the policy choice of alliances such as the BSA when piracy is prevalent. We considered a market where the firm and the pirate share the demand for the product, and consumers differ in their ethical cost to pirate. Our results have the following implications:

Implications for the software firm:

- Given that the software firm can observe the policy choice by the BSA, and also the quality of its own software, then, when the firm knows it has a superior product and the policy choice by the BSA is low, then it should price aggressively to make it unprofitable for the pirate to exist in the market. Also, when the firm knows it doesn't have a high quality product, but the BSA has chosen a high policy choice, it should not engage in an aggressive pricing strategy and leave a small segment of the market for the pirate.

Implications for the BSA:

- In a monopoly market, an increase in the policy variable (in the form of legal action against pirating users, or educating users about the harms of piracy), could act as a disincentive for innovation. This happens because, in certain regions, the policy choice by the BSA, and the quality choice by the firm become strategic substitutes. Thus an increase in the policy variable leads to a decrease in the quality choice by the firm.

- If the likelihood that pirated software will be functional is low, then it is non-optimal for the BSA to expend any cost to reduce piracy. When the likelihood that the pirated software will be functional is medium, then a high level of policy choice is optimal, only for high values of technology cost, and low values of policy cost. When the likelihood that the pirated software will be functional is high, then, the BSA should almost always choose a high level of policy choice.

The results however, are subject to the limitations of the model. One limitation of the model is that, we assume that all consumers value software equally. One consequence of this assumption is that we find threshold type pricing policies. Another consequence of the above assumption is that the market is always covered. A direction for future research could be to model heterogeneity in valuations. To keep things tractable, one would have to sacrifice on heterogeneity in terms of ethical propensity to pirate, since otherwise the consumer's type, would be two dimensional. In this paper we don't consider the protection strategies by the firm. Future research could look at protection as a strategic choice by the firm. We assumed a functional form for the ethical cost to pirate. Our choice was motivated by keeping the model tractable, and using a functional form where the cost increases with the policy choice and increases more for the consumer who has a greater propensity not to pirate. The ethical cost function could also be a function of price i.e. the consumers could bear a higher cost for pirating more expensive software. Our framework could not be extended to this ethical cost function because it leads to corner solutions in the final stage. Future research could try out this alternate ethical cost function in an alternate framework. We assumed that the membership fees that the firm pays to the BSA to be zero. Given that the BSA enjoys economy of scale in fighting piracy, the membership fees would be a very small percentage of the total cost to fight piracy. Hence the results would not change qualitatively by assuming a positive membership fees.

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