SENSITIVITY TO TAX REVENUES AND OPTIMAL ANTI-PIRACY POLICY INSTRUMENTS

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ABSTRACT

We examine the effects of a government's sensitivity to its tax revenues, earned from the software industry, on its anti-piracy policies that consists of monitoring and penalizing a commercial software pirate. We consider a strategic entry-deterrence framework where the original producer chooses a pricing strategy that either allows or deters the pirate's entry. Sensitivity to tax revenues is a necessary but not a sufficient condition to prevent piracy. Welfare maximization may or may not result in monitoring as the socially optimal outcome. If monitoring is socially optimal then the pirate's entry is deterred. The equilibrium entry-deterring price may be less than the equilibrium monopoly price. Only in the extreme case the monopoly outcome is restored.

Keywords: Accommodating strategy, Aggressive strategy, Commercial piracy, Sensitivity factor.

JEL Classification: K42, L11.

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1. INTRODUCTION

Software piracy has emerged as a leading issue and a growing concern for software developers and governments due to its high social and economic costs. The Seventh Annual BSA (Business Software Alliance) Global Software Piracy Study published in June 2002 reports that the world software piracy rate has increased from 37 percent in 2000 to 40 percent in 2001. The consequence of software piracy is not only losses in retail software revenue, but also job, wage, and tax revenue losses. Tax revenue losses imply loss in meaningful public programs. For example the estimated total tax loss in U.S. for the year 2000 due to software piracy is $1,593,204,483.[1] Software piracy deprives the EU Member States of more than 9 billion euro in tax revenues.[2]

In this paper we focus on commercial piracy and consider a situation in which the government is responsible for exercising anti-piracy policies which consists of monitoring and penalizing the pirate within a strategic entry-deterrence framework. We analyze the impact of government's sensitivity to tax revenue from the software industry on its anti-piracy policy instruments, and consequently, its effectiveness in deterring commercial piracy.

Commercial piracy refers to piracy through the retail channel and BSA defines it in its "Recommendations for Resellers" as follows.[3 4]

> *"Unscrupulous businesses and organized crime rings engage in the illegal duplication and sale of copyrighted material with the intent of directly imitating the copyrighted product. Sometimes the product looks very much like the real product; in other cases, the quality is obviously suspect, with poor print quality, homemade labels and the like."*

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[1] See U.S. Software State Piracy Study by BSA, November 2001.
[2] See http://global.bsa.org/eupolicy/enforcement/.
[3] See http://www.bsa.org/usa/antipiracy/tools/resellers.phtml.
[4] See http://www.bsa.org/usa/antipiracy/types/ for a detailed discussion on the types of piracy.

The need to address piracy from the commercial front and hence, this paper's focus on commercial software piracy can be justified on the basis of the following two reasons. First it is difficult to implement enforcement policies towards end-user piracy. Second, focusing on commercial piracy and attempting to prevent it may not eliminate overall piracy but may reduce it, the impact of which is discussed later in this section.

The general focus of the literature on piracy has been on one by end-users and the effects of network externalities.[5] Harbough and Khemka (2000) address the issue of enforcement targeted towards only high-value end-users versus extensive enforcement. They discuss some of the difficulties in implementing extensive enforcement though it is superior to the targeted one. The main difficulty lies in raising the cost of piracy to consumers by disrupting easy access to pirated copies. This arises due to the advent of peer-to-peer technologies for sharing software and other files without a central server that makes the restriction to access pirated software prohibitively costly.

The high cost of monitoring households makes it very difficult, if not impossible, to prevent end-user piracy. Alternatively, it may be the case that due to lack of proper technical knowledge in making counterfeits of original software, many households depend on the availability of pirated soft ware in the retail market.

Therefore, we need to address the issue of commercial software piracy separately from end-user piracy. Even if piracy cannot be eliminated fully, government's anti-piracy efforts directed towards sellers of pirated software rather than end-users may restrict overall piracy.

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[5] Chen et al (1999) show that pricing rather than monitoring is a better strategy to deal with end-user piracy. Cheng et al (1997) and Noyelle (1990) shows that high software prices are the dominant reason for piracy. Oz and Thisse (1999) shows that no protection against is an equilibrium in the presence of network externalities. Takeyama (1994), Conner and Rumelt (1991), and Nascimento and Vanhonacker (1988) also discusses the issue of copyright protection in the presence of network externalities.

IDC Economic Impact Study reports the effect of a 10 percent reduction in piracy rate across different regions of the world over a four year period from 2002 to 2006.[6] The IDC study shows that such a reduction in the piracy rate will add: 1.1 million new jobs, and more than $15 billion in tax revenues in the Asia-Pacific region; 145000 new jobs and more than $24 billion in tax revenues in North America; 50000 new jobs and more than $800 million in tax revenues in Eastern Europe; 200000 new jobs and more than $22.5 billion in tax revenues in Western Europe.

In our model there is a producer of legitimate software (hereafter, referred to as the monopolist) and a pirate who illegally reproduces and sells copies of legitimate software which is an inferior substitute of the legitimate software. This follows the definition of commercial piracy according to BSA. There is also a government who is responsible for monitoring and penalizing the pirate. The government also taxes the monopolist's profit at an exogenously given proportional tax rate. We consider an entry-deterrence framework, in which the monopolist after observing the government's anti-piracy policy chooses a pricing strategy that either allows (*accommodating strategy*) or deters (*aggressive strategy*) the pirate's entry. The pirate then chooses a price if it decides to enter. The consumers can either buy the original, the pirated product, or nothing.

The government chooses its anti-piracy instruments that maximize social welfare. Social welfare consists of the monopolist's after-tax profit, the pirate's profit, consumer surplus, and the government's tax revenue from the monopolist and its net expected revenue from antipiracy policies. The government attaches a weight to the tax revenue in its social welfare function. The value of the weight, which we call the "*sensitivity factor*", indicates the government's sensitivity to its tax revenues and

[6] See http://global.bsa.org/idcstudy/.

hence, towards its public works program. Indirectly, this weight can also be interpreted as government's sensitivity towards copyright protection. The optimal policy variables endogenously determine the monopolist's subgame perfect equilibrium pricing strategy.

Social welfare maximization may or may not result in monitoring as the socially optimal policy depending on the strength of the sensitivity factor. If it is socially optimal to monitor, then piracy is always deterred and the aggressive strategy is the subgame perfect equilibrium. The equilibrium price may be less than the equilibrium monopoly price. The threat of the pirate's entry generates competition that causes the equilibrium price to be less than the monopoly price. Only in the extreme case, piracy is deterred and the monopoly outcome is restored.[7] We show that the sensitivity factor is a necessary but not a sufficient condition to deter piracy. If not monitoring is the socially optimal policy then the market is shared between the monopolist and the pirate.

The paper is arranged as follows. In section 2 we present the model. Section 3 contains the equilibrium analysis of the accommodating and the aggressive subgames. In section 4 we discuss the welfare analysis and in section 5 we provide the concluding remarks.

2. THE MODEL

We consider four types of agents: the consumers, the monopolist, a pirate who illegally reproduces and sells licensed software, and the government which is responsible for monitoring and penalizing the pirate. We begin our analysis by describing the monopoly situation in the absence of piracy.

[7] Banerjee (2003) shows that monitoring may or may not be the socially optimal policy in addressing the issue of commercial piracy. However, he shows that, if monitoring is the socially optimal policy, then the monopoly outcome is always restored. In the present paper, the strategic entry-deterrence framework generates more general results and the monopoly outcome is only a special case.

There is a continuum of consumers indexed by $\theta, \theta \in [\theta_l, \theta_h]$. θ is assumed to follow a uniform distribution. We assume there is no resale market for used software. Each consumer is assumed to purchase only one unit of the software. Following Tirole (1988), the utility of a type θ consumer is,

$$U(\theta) = \begin{cases} \theta - p_m & \text{if the consumer buys the software,} \\ 0 & \text{if the consumer does not buy.} \end{cases} \tag{1}$$

θ is the valuation of the consumer and p_m is the price of one unit of the software charged by the monopolist. Thus, in the model, consumers differ from one another on the basis of their valuation of the software.

θ_m is the marginal consumer who is indifferent between buying and not buying:

$$U(\theta_m) = \theta_m - p_m = 0 \Rightarrow \theta_m = p_m. \tag{2}$$

In the absence of piracy, the monopolist faces the demand function,

$$D_m(p_m) = \int_{\theta_m}^{\theta_h} \frac{1}{\theta_h - \theta_l} d\theta. \tag{3}$$

We treat the cost incurred by the monopolist to develop the software as a sunk cost. The cost of replicating the software after it has been developed is assumed to be zero. Hence, the monopolist's profit is the total revenue; $\pi_m = p_m D_m$. The consumer surplus is $CS = \int_{\theta_m}^{\theta_h} (\theta - p_m) d\theta$. The equilibrium monopoly results are,

$$p_m^* = \frac{\theta_h}{2},\ \theta_m^* = \frac{\theta_h}{2},\ \pi_m^* = \frac{\theta_h^{\ 2}}{4(\theta_h - \theta_l)},\ \text{and } CS^* = \frac{\theta_h^{\ 2}}{8}. \tag{4}$$

Now, suppose that a commercial pirate exists in the market. The government only works through the supply side in controlling piracy. Users do not face the risk of prosecution from the use of pirated software. The government is responsible for monitoring and penalizing the pirate. Let α and G be the monitoring rate and the penalty. The pirate pays the penalty G if his illegal operation is detected. Let $c(\alpha)$ be the cost of monitoring. We assume $c(0) = 0, c'(\alpha) > 0, c'(0) = 0, c''(\alpha) > 0.$

The government chooses α and G to maximize domestic social-welfare subject to a balanced budget constraint. We assume this to avoid issues of redistribution that are associated with maximization of net revenue. Let R be the net expected revenue of the government from its anti-piracy policy.

$$R = \alpha G - c(\alpha). \tag{5}$$

The balanced budget constraint means $R = 0$. This implies that the penalty equals the average cost of monitoring:

$$G = \frac{c(\alpha)}{\alpha}, \text{ for } \alpha > 0. \tag{6}$$

In the absence of monitoring, the penalty is irrelevant. So we assume $G = 0$ if $\alpha = 0$. G is an increasing function of α. By assumption, the marginal cost of monitoring increases with monitoring. So the average cost of monitoring also increases with monitoring. The government also taxes the monopolist's profit proportionately at a given rate 't'.

The pirated software is an inferior substitute of the original software. Let q be the quality of the pirated software, $q \in (0,1)$, and q is given exogenously.[8] The quality of the original software is normalized to 1. The qualitative difference between the original and the pirated software arises because the support benefits and the full warranty that are included with the purchase of the original software does not come with the purchase of the pirated software. We also assume that the pirate's marginal cost of duplicating is zero.

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[8] We set this bound to ensure that the profits are not indeterminate.

The game played between the government, the monopolist, the pirate, and the consumers is specified in extensive form as follows.

Stage 1: The government chooses a penalty G and a monitoring rate α.

Stage 2: The monopolist chooses a price p_m.

Stage 3: The pirate observes the monopolist's strategy, and decides to enter or not. If it enters then it chooses a price p_c.

Stage 4: The consumers decide either to buy the original software or the pirated one or nothing.

We now analyze the behavior of the different agents in our model. The The utility of a type θ consumer if the pirate enters the market is,

$$U(\theta) = \begin{cases} \theta - p_m & \text{if the consumer buys the original software,} \\ q\theta - p_c & \text{if the consumer buys the pirated software,} \\ 0 & \text{if the consumer does not buy.} \end{cases} \tag{7a}$$

p_c and $q\theta$ is the price and effective valuation of the pirated copy. If the pirate does not enter the market then a consumer's utility is,

$$U(\theta) = \begin{cases} \theta - p_m & \text{if the consumer buys the software,} \\ 0 & \text{if the consumer does not buy.} \end{cases} \tag{7b}$$

If the pirate exists in the market then there are two marginal consumers, θ_1^a and θ_2. The marginal buyer θ_1^a is indifferent between buying the original and the pirated software:

$$\theta_1^a - p_m = q\theta_1^a - p_c \Rightarrow \theta_1^a = \frac{p_m - p_c}{(1-q)}. \tag{8}$$

The marginal buyer θ_2 is indifferent between buying from the pirate and not buying at all:

$$q\theta_2 - p_c = 0 \Rightarrow \theta_2 = \frac{p_c}{q}. \tag{9}$$

If the pirate does not enter the market then there is only one marginal consumer, θ_1^b, who is indifferent between buying the original software or not. So,

$$\theta_1^b = p_m \tag{10}$$

We derive the demand faced by the monopolist and the pirate from (8), (9), and (10) and is shown in (11).

$$D_m(p_m, p_c) = \begin{cases} \dfrac{\theta_h - \theta_1^a}{\theta_h - \theta_l} = \dfrac{\theta_h}{\theta_h - \theta_l} - \dfrac{p_m - p_c}{(1-q)(\theta_h - \theta_l)}, & \text{if the pirate enters,} \\ \dfrac{\theta_h - \theta_1^b}{\theta_h - \theta_l} = \dfrac{\theta_h - p_m}{\theta_h - \theta_l}, & \text{if the pirate does not enter.} \end{cases}$$
$$D_c(p_m, p_c) = \begin{cases} \dfrac{\theta_1^a - \theta_2}{\theta_h - \theta_l} = \dfrac{(qp_m - p_c)}{q(1-q)(\theta_h - \theta_l)}, & \text{if the pirate enters,} \\ 0 & \text{if the pirate does not enter.} \end{cases} \tag{11}$$

Correspondingly, the consumer surplus is, [9]

$$CS = \begin{cases} \displaystyle\int_{\theta_1^a}^{\theta_h} (\theta - p_m)d\theta + (1-\alpha)\int_{\theta_2}^{\theta_1^a} (q\theta - p_c)d\theta, & \text{if the pirate enters,} \\ \displaystyle\int_{\theta_1^b}^{\theta_h} (\theta - p_m)d\theta & \text{if the pirate does not enter.} \end{cases} \tag{12}$$

We assume that a firm remains in the market only if it is making nonzero profit. The pre-tax profit of the monopolist and the expected profit of the pirate are,

$$\pi_m(p_m, p_c) = \begin{cases} \dfrac{\theta_h p_m}{\theta_h - \theta_l} - \dfrac{p_m{}^2 - p_c p_m}{(1-q)(\theta_h - \theta_l)}, & \text{if the pirate enters,} \\ \dfrac{\theta_h p_m - p_m{}^2}{\theta_h - \theta_l}, & \text{if the pirate does not enter.} \end{cases}$$
$$\pi_c(p_m, p_c, \alpha) = \begin{cases} \dfrac{(1-\alpha)(qp_m p_c - p_c{}^2)}{q(1-q)(\theta_h - \theta_l)} - \alpha G, & \text{if the pirate enters,} \\ 0 & \text{if the pirate does not enter.} \end{cases} \tag{13}$$

The monopolist chooses a pricing strategy that either allows or deters the

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[9] If the pirate enters and his operations are not detected, which occurs with probability $(1-\alpha)$, then the consumer surplus is the sum of the consumer surpluses of the buyers of the original and the pirated software. Alternatively, if the pirate enters and his operations are detected, which occurs with probability α, only the original software is available. In this case the consumer surplus consists of the surplus of the buyers of the original product. This justifies the formulation of the consumer surplus in (12).

pirate's entry. The pricing strategy that allows the pirate's entry is called the *accommodating strategy* (which is denoted by the superscript *ac*). The entry-deterring pricing strategy is called the *aggressive strategy* (which is denoted by the superscript *ag*). Figure 1 provides a diagrammatic representation of the entire game showing the payoffs.

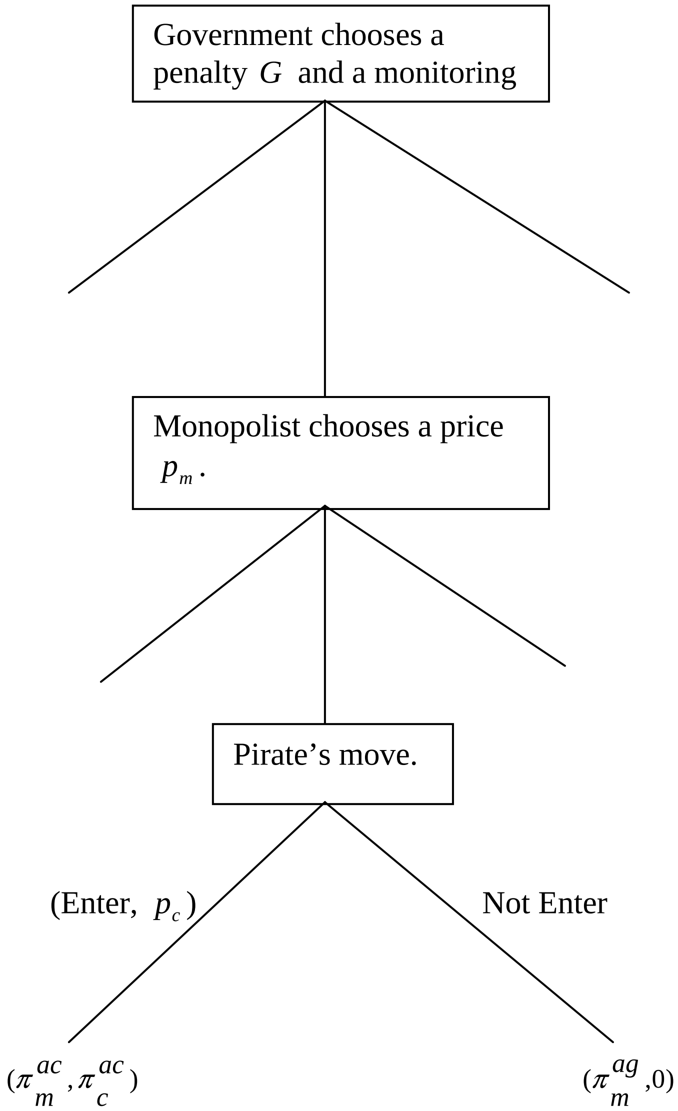

Figure 1

The government chooses a monitoring rate and a penalty that maximizes social welfare subject to the balanced budget constraint. The social welfare (*SW*) function without any weight attached to the tax revenue is, $SW = (1-t)\pi_m + \pi_c + CS + t\pi_m = \pi_m + \pi_c + CS$. The term $t\pi_m$ is the government's revenue, which it earns from taxing the monopolist's profit. The net revenue from monitoring the pirate does not appear in the social welfare function because of the balanced budget constraint.

We solve the equilibrium of the game depicted in Figure 1 by using the method of backward induction. In view of (13), the reaction function of the pirate is,

$$p_c = \frac{qp_m}{2}. \tag{14}$$

3. EQUILIBRIUM ACCOMMODATING AND AGGRESSIVE STRATEGIES

In this section we discuss the equilibrium accommodating and aggressive strategies.

3.1 THE ACCOMMODATING SUBGAME

In the *ac-subgame* the monopolist's pricing strategy allows the pirate's entry. If the government uncovers the pirate's illegal operations, which occurs with probability α, he pays a penalty *G* to the government. Substituting the pirate's reaction function, (14) into the monopolist's profit function, $\pi_m(p_m, p_c) = \frac{\theta_h p_m}{\theta_h - \theta_l} - \frac{p_m{}^2 - p_c p_m}{(1-q)(\theta_h - \theta_l)}$, and equating its first derivative with respect to p_m to zero gives us the equilibrium *ac-strategy*. The results are summarized in Proposition 1.

<u>Proposition 1</u>

(i) The monopolist's equilibrium ac-strategy and the pirate's equilibrium price is $p_m^{ac*} = \frac{(1-q)\theta_h}{(2-q)}$ *and* $p_c^{*} = \frac{(1-q)q\theta_h}{2(2-q)}$.

(ii) $\theta_1^{a*} = \dfrac{\theta_h}{2}$, *and* $\theta_2^* = \dfrac{(1-q)\theta_h}{2(2-q)}$ *characterizes the size of the monopolist's and pirate's markets in equilibrium.*

(iii) *The profits of the monopolist and the pirate are:* $\pi_m^{ac*} = \dfrac{(1-q)\theta_h{}^2}{2(2-q)(\theta_h - \theta_l)}$ *and* $\pi_c^{ac*}(\alpha) = \dfrac{(1-\alpha)(1-q)q\theta_h^2}{4(2-q)^2(\theta_h - \theta_l)} - \alpha G$.

Proposition 1 shows that in the presence of piracy the monopolist retains its original monopoly market by lowering the price of its product. This occurs because of the competition generated by the pirate's entry. So the pirate only captures the lower-end of the market without disturbing the monopolist's market. Proposition 1 also shows that the pirate's equilibrium profit is a decreasing function of the monitoring rate, α. However, the monopolist's equilibrium profit is unaffected by the monitoring rate because it is independent of it.

The consumer surplus and the social welfare, without any weight attached to the tax revenue, for the equilibrium *ac-strategy* are,

$$CS^{ac*}(\alpha) = \frac{(4+q-q^2)\theta_h{}^2}{8(2-q)^2} - \alpha \int_{\theta_2^*}^{\theta_1^{a*}} (q\theta - p_c^{ac*})d\theta\,, \tag{15}$$

and, $SW^{ac*}(\alpha) = \pi_m^{ac*} + \pi_c^{ac*}(\alpha) + CS^{ac*}(\alpha) + R$. (16a)

Rearranging (16a) we get the social welfare function as,

$$SW^{ac*}(\alpha) = \pi_m^{ac*} + CS^{ac*}(\alpha) + \frac{(1-\alpha)(1-q)q\theta_h^2}{4(2-q)^2(\theta_h - \theta_l)} - \alpha G + \alpha G - c(\alpha)$$

$$= \pi_m^{ac*} + CS^{ac*}(\alpha) + \frac{(1-\alpha)(1-q)q\theta_h^2}{4(2-q)^2(\theta_h - \theta_l)} - c(\alpha)\,. \tag{16b}$$

<u>Proposition 2</u>

$SW^{ac*}(\alpha)$ *is a decreasing function of* α.

The proof of Proposition 2 follows from the fact that the pirate's profit and the consumer surplus, in equilibrium, are decreasing functions of the monitoring rate. Also, the monopolist's profit is independent of the monitoring rate and the monitoring cost increases with an increase in the monitoring rate.

3.2. *THE AGGRESSIVE SUBGAME*

In this section we discuss the monopolist's equilibrium entry-deterring *aggressive-strategy*. By substituting the pirate's reaction function (14) in its profit function, we get,

$$\pi_c(p_m,\alpha) = \frac{(1-\alpha)qp_m{}^2}{4(1-q)(\theta_h-\theta_l)} - c(\alpha) . \qquad (17)$$

[10]

The pirate's entry is deterred if $\pi_c(p_m,\alpha) = \frac{(1-\alpha)qp_m{}^2}{4(1-q)(\theta_h-\theta_l)} - c(\alpha) \le 0$. By rearranging the terms we get the entry-deterrence condition as,

$$p_m{}^2 \le \frac{4(1-q)(\theta_h-\theta_l)c(\alpha)}{q(1-\alpha)} . \qquad (18)$$

The monopolist chooses a price and a monitoring rate that maximizes its profit subject to the entry-deterrence condition. Formally, this can be stated as

$$\underset{p_m}{\max imize}\, \pi_m(p_m,\alpha) = \frac{\theta_h p_m - p_m{}^2}{\theta_h - \theta_l} \qquad (19)$$

subject to $p_m{}^2 \le \frac{4(1-q)(\theta_h-\theta_l)c(\alpha)}{q(1-\alpha)}$.

Suppose the entry deterrence condition holds with strict inequality, that is, $p_m{}^2 < \frac{4(1-q)(\theta_h-\theta_l)c(\alpha)}{q(1-\alpha)}$. In this case the monopolist can increase its price for any given monitoring rate such that the inequality still holds. This increases the

[10] From the balanced budget constraint we know that $\alpha G = c(\alpha)$.

monopolist's profit as long as the price is less than the equilibrium monopoly price, which is, $p_m^* = \frac{\theta_h}{2}$. We continue this till the entry-deterrence condition holds with equality. So the monopolist's profit-maximization problem can be restated as,

$$\max_{p_m} imize\, \pi_m(p_m, \alpha) = \frac{\theta_h p_m - p_m{}^2}{\theta_h - \theta_l} \tag{20}$$

subject to $p_m{}^2 = \frac{4(1-q)(\theta_h - \theta_l)c(\alpha)}{q(1-\alpha)}$.

$p_m^{ag}(\alpha) = \sqrt{\frac{4(1-q)(\theta_h - \theta_l)c(\alpha)}{q(1-\alpha)}}$ is the solution to (20) and the monopolist's profit is $\pi_m^{ag}(\alpha) = p_m^{ag}(\alpha)(1 - p_m^{ag}(\alpha))$. Let $p_m^{ag*}(\alpha)$ be the solution to this aggressive entry-deterrence strategy. The results are summarized in Proposition 3 the proof of which requires Lemma 1. We include the proof of Proposition 3, which also contains the comparative static analysis of the monopolist's profit with respect to the monitoring rate, in the Appendix.

Lemma 1

$\frac{c(\alpha)}{1-\alpha}$ *is increasing in* α.

The proof of Lemma 1 follows from the fact that $c(\alpha)$ is increasing in α and $(1-\alpha)$ is decreasing in α.

Proposition 3

The equilibrium ag-strategy and the monopolist's equilibrium profit are,

$p_m^{ag*}(\alpha) = \min\left(\sqrt{\frac{4(1-q)(\theta_h - \theta_l)c(\alpha)}{q(1-\alpha)}}, \frac{\theta_h}{2}\right)$, *and*

$$\pi_m^{ag*}(\alpha) = \begin{cases} \dfrac{p_m^{ag*}(\alpha)(\theta_h - p_m^{ag*}(\alpha))}{\theta_h - \theta_l}, \text{ for } 0 \le \alpha \le \alpha_{\max}^{\text{ag}}, \\ \dfrac{\theta_{\text{h}}{}^2}{4(\theta_h - \theta_l)}, \qquad \text{for } \alpha_{\max}^{ag} \le \alpha \le 1. \end{cases}$$

$\alpha_{\max}^{ag}$ *satisfies* $\dfrac{c(\alpha_{\max}^{ag})}{1-\alpha_{\max}^{ag}} = \dfrac{q\theta_h{}^2}{16(1-q)(\theta_h - \theta_l)}$.

$p_m^{ag}(\alpha) = \sqrt{\dfrac{4(1-q)(\theta_h - \theta_l)c(\alpha)}{q(1-\alpha)}}$ is an increasing function of the monitoring rate. As the monitoring rate reaches the critical value $\alpha_{\max}^{ag}$ the price becomes the same as the equilibrium monopoly price, $\dfrac{\theta_h}{2}$. For further increases in the monitoring rate there is no reason to choose a price more than $\dfrac{\theta_h}{2}$, since that lowers profit and has no effect on entry. So up to $\alpha_{\max}^{ag}$ the monopolist's profit is an increasing function of the monitoring rate and beyond $\alpha_{\max}^{ag}$ it is the same as in the monopoly case.

Figure 2 provides a diagrammatic representation of the comparative static analysis of the monopolist's profit for the equilibrium *ac*- and *ag-strategies* with respect to α. We draw Figure 2 using Lemma 2.

<u>Lemma 2</u>

Let $\overline{\alpha}$ *be the monitoring rate such that* $\pi_m^{ac*}(\overline{\alpha}) = \pi_m^{ag*}(\overline{\alpha})$. $\alpha_{\max}^{ag} > \overline{\alpha}$.

This is because $\pi_m^{ag*}(\alpha_{\max}^{ag}) > \pi_m^{ac*}(\overline{\alpha}) = \pi_m^{ag*}(\overline{\alpha})$ and $\pi_m^{ag*}(\alpha)$ is increasing in α in the range $\alpha \in [0, \alpha_{\max}^{ag}]$.

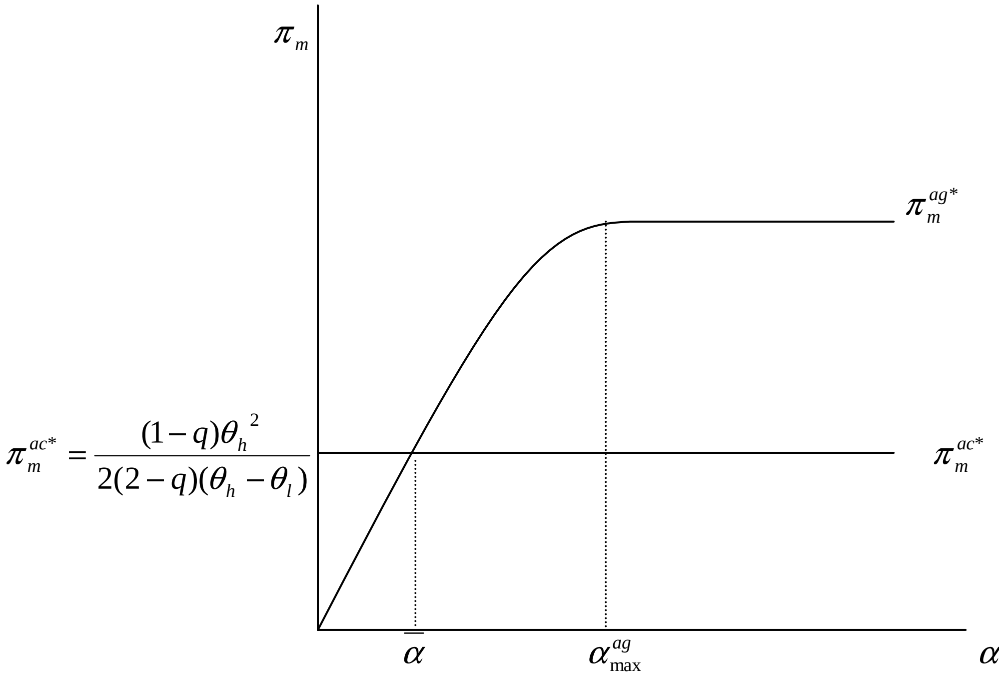

Figure 2

Proposition 4

$\alpha \in [0, \alpha_{\max}^{ag}]$ is the Pareto-efficient range of monitoring rate.

Proposition 4 can be explained using Figure 2. Raising the monitoring rate α beyond $\alpha_{\max}^{ag}$ does not change profit or consumer surplus, but it increases the cost of monitoring which is a deadweight loss. So for the rest of our analysis we will only consider the range $\alpha \in [0, \alpha_{\max}^{ag}]$.

The consumer surplus and the social welfare without any weight attached to the tax revenue for the equilibrium *ag-strategy* are,

$$CS^{ag*}(\alpha) = \int_{\theta_2^*}^{\theta_h} (\theta - p_m^{ag*}(\alpha))d\theta = \frac{\theta_h^{\ 2}}{2} - \theta_h p_m^{ag*}(\alpha) + \frac{(p_m^{ag*}(\alpha))^2}{2}, \text{ and}$$
$$SW^{ag*}(\alpha) = \frac{\theta_h^{\ 2} - (p_m^{ag*}(\alpha))^2}{2} - c(\alpha). \tag{21}$$

Proposition 5 summarizes the comparative static analysis of the social welfare function with respect to α.

Proposition 5

$SW^{ag*}(\alpha)$ *is monotonically decreasing in* α.

The proof of Proposition 5 follows from the fact that $\frac{dp_m^{ag*}(\alpha)}{d\alpha} > 0$ for the range $0 \le \alpha < \alpha_{\max}^{ag}$, $\frac{dp_m^{ag*}(\alpha)}{d\alpha} = 0$ at $\alpha = \alpha_{\max}^{ag}$, and $c'(\alpha) > 0$. Intuitively, an increase in α raises the monopolist's profit up to $\alpha_{\max}^{ag}$ where it reaches a maximum. However, an increase in α increases the equilibrium price that results in a reduction in the consumer surplus. Further, the cost of monitoring, which is a deadweight loss, increases with an increase in α. So the overall effect of an increase in α is a fall in the social welfare.

4. SOCIAL WELFARE ANALYSIS

The government seeks the monitoring rate and penalty that maximizes social welfare. These optimal policy variables affect the monopolist's profits in the equilibrium *ac*- and *ag-strategies*. We compare the profits to determine the monopolist's optimal strategy.

The monopolist chooses the *ag-strategy* if $\pi_m^{ag*}(\alpha) \ge \pi_m^{ac*}(\alpha)$. For simplicity we assume that if the monopolist's equilibrium profits under the two strategies are equal then it chooses the entry-deterrent *ag-strategy*.

Let us introduce the sensitivity factor and redefine the social welfare function. The sensitivity factor is a weight, $\gamma = 1 + \beta$, which the government attaches to its tax revenue which it earns by taxing the monopolist's profit. This weight measures the government's sensitivity to the tax revenue, which it earns from the software market. It also signifies the importance, which the government attaches to its public works program in terms of the positive externalities that it generates to the society. The social welfare function can be redefined as,

$$SW_s^x(\alpha) = (1-t)\pi_m^x(\alpha) + \pi_c^x(\alpha) + CS^x(\alpha) + (1+\beta)t\pi_m^x(\alpha), x \in \{ac, ag\}. \qquad (22)$$

The subscript, '*s*', stands for the social welfare function with the sensitivity factor.

Rearranging the terms, the social welfare function for the *ac*- and *ag-subgames* can be rewritten as,

$$\begin{aligned} SW_s^{ac*}(\alpha) &= t\beta\pi_m^{ac*} + SW^{ac*}(\alpha), \text{ and,} \\ SW_s^{ag*}(\alpha) &= t\beta\pi_m^{ag*}(\alpha) + SW^{ag*}(\alpha) \end{aligned} \qquad (23)$$

Let α_s^{ac*} and α_s^{ag*} be the social welfare-maximizing monitoring rates for the *ac*- and *ag-strategies*.

<u>Proposition 6</u>

The social welfare maximizing monitoring rate for the equilibrium ac-strategy is zero; $\alpha_s^{ac*} = 0$.

Proposition 6 follows from the fact that $\pi_m^{ac*} = \dfrac{(1-q)\theta_h{}^2}{2(2-q)(\theta_h - \theta_l)}$ is independent of the monitoring rate. So the sensitivity factor has no effect on π_m^{ac*}. Also $SW^{ac*}(\alpha)$ is a decreasing function of the monitoring rate, (Proposition 2).

Let us now consider the social welfare function for the equilibrium *ag-strategy*. The derivative of $SW_s^{ag*}(\alpha)$ with respect to α is,

$SW_s^{ag*\prime}(\alpha) = t\beta\pi_m^{ag*\prime}(\alpha) + SW^{ag*\prime}(\alpha) \underset{>}{\overset{<}{=}} 0$. This is because $SW_s^{ag*\prime}(\alpha) < 0$, and $t\beta\pi_m^{ag*\prime}(\alpha) > 0$ in the range $\alpha \in [0, \alpha_{\max}^{ag}]$. For β sufficiently low, that is, $0 < \beta \le \underline{\beta}$, $SW_s^{ag*\prime}(\alpha) < 0$ and for β sufficiently high, that is, $\beta \ge \overline{\beta}$, $SW_s^{ag*\prime}(\alpha) > 0$. In the intermittent range, $\overline{\beta} \ge \beta > \underline{\beta}$, $SW_s^{ag*\prime}(\alpha) = 0$. We assume that in this range,

$SW_s^{ag*''}(\alpha) < 0$. Proposition 7 summarizes the social welfare maximizing monitoring rates for the equilibrium *ag-strategy*, denoted as α_s^{ag*}. The proof of Proposition 7 is provided in the Appendix.

Proposition 7

(i) *For* $0 < \beta \le \underline{\beta}$, $\alpha_s^{ag*} = 0$.

(ii) *For* $\beta \ge \overline{\beta}$, $\alpha_s^{ag*} = \alpha_{\max}^{ag}$.

(iii) *For* $\overline{\beta} \ge \beta \ge \underline{\beta}$, $\alpha_s^{ag*} \in [0, \alpha_{\max}^{ag}]$. *In this range* α_s^{ag*} *and* β *are positively related.*

Proposition 7 shows that depending on the degree of sensitivity which is indicated by the value of β, either $0 \le \alpha_s^{ag*} < \overline{\alpha}$ or $\alpha_{\max}^{ag} \ge \alpha_s^{ag*} \ge \overline{\alpha}$. This because the value of β determines the shape of $SW_s^{ag*}(\alpha)$.

Proposition 8 summarizes the social welfare-maximizing policies and the subgame perfect equilibrium strategies. The proof is provided in the Appendix. Let α_s^* denote the socially optimal monitoring rate and G_s^* be the corresponding penalty satisfying the balanced budget constraint.

Proposition 8

(i) *Commercial software piracy is deterred only if,* $\alpha_{\max}^{ag} \ge \alpha_s^{ag*} \ge \overline{\alpha}$, *and* $SW_s^{ag*}(\alpha_s^{ag*}) \ge SW_s^{ac*}(0)$. *In this case the optimal policy is,* $\left(\alpha_s^* = \alpha_s^{ag*}, G_s^* = \dfrac{c(\alpha_s^{ag*})}{\alpha_{sl}^{ag*}}\right)$ *and the ag-strategy,* $p_m^{ag*}(\alpha_s^{ag*})$, *is the subgame perfect equilibrium. If* $\alpha_s^{ag*} = \alpha_{\max}^{ag}$, *and the above conditions hold then the monopoly outcome is restored.*

(ii) *For all other cases,* $\alpha_s^* = 0$. *Consequently, the ac-strategy,*

$$p_m^{ac*} = \frac{(1-q)\theta_h}{(2-q)}$$ *, is the subgame perfect equilibrium.*

Proposition 8 shows that government's sensitivity to its revenue earned from the software market may or may not result in monitoring as the optimal policy. If it is optimal to monitor then piracy is deterred which means that government's sensitivity to its tax revenue is effective in preventing commercial software piracy. In the extreme case sensitivity to tax revenue is effective in deterring piracy and restoring the monopoly outcome.

Propositions 7 and 8 show that $\beta > \underline{\beta}$ is a necessary but not a sufficient condition for entry-deterrence. It means that higher the sensitivity factor the greater is the possibility for entry-deterrence. This is because an increase in the sensitivity factor has a greater effect on SW_s^{ag*} than on SW_s^{ac*}.

Let us consider the effect of an increase in β on SW_s^{ac*}. From Proposition 6 we know that irrespective of the value of β, SW_s^{ac*} is always a decreasing function of the monitoring rate. Hence, $\alpha_s^{ac*} = 0$. This because π_m^{ac*} is independent of the monitoring rate. Therefore, the tax revenue earned by taxing the monopolist's profit is also independent of the monitoring rate. So an increase in β has only direct effect in the sense that it only increases SW_s^{ac*} without having any impact on monopolist's profit and the tax revenue. It behaves like a shift factor by raising the social welfare but it is always the case that $\alpha_s^{ac*} = 0$.

An increase in β have direct and indirect effects on SW_s^{ag*}. The direct effect is that β behaves like a shift factor in the sense that an increase in β increases

SW_s^{ag*}. However, an increase in β has an indirect effect on SW_s^{ag*}. From Proposition 7 we know that in the range, $\overline{\beta} \geq \beta \geq \underline{\beta}$, $\alpha_s^{ag*} \in [0, \alpha_{\max}^{ag}]$ and α_s^{ag*} and β are positively related. So an increase in β raises the monitoring rate. We know that for $\alpha_s^{ag*} \in [0, \alpha_{\max}^{ag}]$ the monopolist's profit for the equilibrium *ag-strategy* is increasing in the monitoring rate. This means that in this range the government's tax revenue is also increasing in the monitoring rate. So an increase in the sensitivity factor raises the monopolist's profit and the tax revenue via the monitoring rate. For the range $\beta \geq \overline{\beta}$ an increase in β does not have any impact on the monopolist's profit and the tax revenue because in this range $\alpha_s^{ag*} = \alpha_{\max}^{ag}$. So in this case there is only direct effect but no indirect effect on SW_s^{ag*}.

5. CONCLUSION

In this paper we analyzed the effectiveness of government's sensitivity to tax revenue from the software industry in deterring commercial piracy through its anti-piracy policy, which consists of monitoring and penalizing the illegal operations of a commercial software pirate. We considered a strategic-entry deterrence framework where the monopolist chose a pricing strategy that either allowed (accommodating) or deterred (aggressive) the pirate's entry. The government's social welfare maximizing policy determined the subgame perfect pricing strategy and the pirate's entry.

We showed that government's sensitivity towards its tax revenue from the software industry is a necessary but not a sufficient condition to deter commercial software piracy. If the sensitivity is above a certain critical level then monitoring may be the socially optimal outcome in which case the monopolist's aggressive pricing strategy is the subgame perfect equilibrium and piracy is prevented. The greater the sensitivity factor the higher is the socially optimal monitoring rate and consequently the higher is the equilibrium entry-deterring price. In the extreme case the equilibrium monopoly price is restored.

Given the difficulty in implementing anti-piracy policies directed towards end-user piracy, addressing the commercial piracy issue may reduce the overall piracy rate. This paper showed that government's sensitivity towards its tax revenue from the software industry may be one necessary factor that may result in the prevention of commercial software piracy.

Reduction in the overall piracy rate will not only increase sales revenue, jobs, wages, and tax revenues but will also result in an increased growth. According to the IDC Economic Impact study, a 10 percent reduction in the piracy rate during the 2002- 2006 period will add: $170 billion in additional economic growth in the Asia-Pacific region, $11.2 billion in additional economic growth in Eastern Europe, $150 billion in additional economic growth in North America, and $91 billion in additional economic growth in Western Europe.

APPENDIX

<u>Proof of Proposition 3</u>

$p_m^{ag}(\alpha) = \sqrt{\dfrac{4(1-q)(\theta_h - \theta_l)c(\alpha)}{q(1-\alpha)}}$ is an increasing function of α, because $\dfrac{c(\alpha)}{1-\alpha}$ is increasing in α. Now $\pi_m^{ag*}(\alpha) = \dfrac{p_m^{ag*}(\alpha)(\theta_h - p_m^{ag*}(\alpha))}{\theta_h - \theta_l} = 0$ when $\alpha = 0$ or $\alpha = \alpha_1$ where α_1 satisfies the condition $\dfrac{c(\alpha_1)}{1-\alpha_1} = \dfrac{q\theta_h^{\,2}}{4(1-q)(\theta_h - \theta_l)}$. So for the range $\alpha_1 \le \alpha \le 1$, $\pi_m^{ag*}(\alpha) = 0$. Taking the first derivative of

$\pi_m^{ag*}(\alpha) = \dfrac{p_m^{ag*}(\alpha)(\theta_h - p_m^{ag*}(\alpha))}{\theta_h - \theta_l}$ with respect to α and equating it to 0 yields

$\alpha = \alpha_{\max}^{ag}$ where $\alpha_{\max}^{ag}$ satisfies $\frac{c(\alpha_{\max}^{ag})}{1-\alpha_{\max}^{ag}} = \frac{q\theta_h^{\,2}}{16(1-q)(\theta_h - \theta_l)}$. Now, $p_m^{ag*}(\alpha_{\max}^{ag}) = \frac{\theta_h}{2}$

and $\pi_m^{ag*}(\alpha_{\max}^{ag}) = \frac{\theta_h^{\,2}}{4(\theta_h - \theta_l)}$ which are the same as the equilibrium monopoly

outcome. Now $\frac{c(\alpha_1)}{1-\alpha_1} = \frac{q\theta_h^{\,2}}{4(1-q)(\theta_h - \theta_l)} > \frac{c(\alpha_{\max}^{ag})}{1-\alpha_{\max}^{ag}} = \frac{q\theta_h^{\,2}}{16(1-q)(\theta_h - \theta_l)} \Rightarrow \alpha_1 > \alpha_{\max}^{ag}$

since $\frac{c(\alpha)}{1-\alpha}$ is increasing in α. So starting from $\alpha = 0$, $\pi_m^{ag*}(\alpha)$ increases as α

increases, reaches a maximum at $\alpha = \alpha_{\max}^{ag}$, decreases as α increases in the range

$\alpha_{\max}^{ag} < \alpha < \alpha_1$, and then $\pi_m^{ag*}(\alpha)$ becomes 0 in the range $\alpha_1 \le \alpha \le 1$. So in the range,

$1 \ge \alpha \ge \alpha_{\max}^{ag}$, the monopolist maximizes its profit by charging the monopoly price

$p_m^{ag*} = \frac{\theta_h}{2}$. There is no reason to choose a price more than $\frac{\theta_h}{2}$, since that lowers

profit and has no effect on entry. *Q.E.D.*

<u>Proof of Proposition 7</u>

In the range $0 < \beta \le \underline{\beta}$, $SW_s^{ag*\prime}(\alpha) < 0$. Therefore, $\alpha_s^{ag*} = 0$. For $\beta \ge \overline{\beta}$,

$SW_s^{ag*\prime}(\alpha) > 0$. Therefore, $\alpha_s^{ag*} = \alpha_{\max}^{ag}$. This is because $\alpha > \alpha_{\max}^{ag}$ is not Pareto

optimal as discussed in Proposition 4. For, $\overline{\beta} \ge \beta \ge \underline{\beta}$, $SW_s^{ag*\prime}(\alpha) = 0$ and there

exists an interior solution, $\alpha_s^{ag*} \in [0, \alpha_{\max}^{ag}]$. In this case if the interior solution exceeds

$\alpha_{\max}^{ag}$, then $\alpha_s^{ag*} = \alpha_{\max}^{ag}$ for reasons already discussed. Let us consider the range

$\overline{\beta} \ge \beta \ge \underline{\beta}$ for which $SW_s^{ag*\prime}(\alpha) = 0$. Let $\alpha_s^{ag*} \in [0, \alpha_{\max}^{ag}]$ be the solution to the

social welfare maximization problem. This means

$SW_s^{ag*\prime}(\alpha_s^{ag*}) = t\beta\pi_m^{ag*\prime}(\alpha_s^{ag*}) + SW^{ag*\prime}(\alpha_s^{ag*}) = 0$. Performing the total differential with respect to β and α_s^{ag*} yields, $\frac{d\alpha_s^{ag*}}{d\beta} = -\frac{SW_s^{ag*''}(\alpha_s^{ag*})}{t\pi_m^{ag*'}(\alpha_s^{ag*})} > 0$ because

$SW_s^{ag*''}(\alpha_s^{ag*}) < 0$ by assumption. *Q.E.D.*

<u>Proof of Proposition 8</u>

(a) Let us first consider the combination, $\alpha_s^{ac*} = 0$ and $0 \le \alpha_s^{ag*} < \overline{\alpha}$. In this case for any monitoring rate the equilibrium *ac-strategy* is the dominant one because for this combination $\pi_m^{ac*} > \pi_m^{ag*}$ as shown in Figure 2. Therefore, in this case, $\alpha_s^* = 0$.

(b) Now let us consider the combination, $\alpha_s^{ac*} = 0$ and $\alpha_{\max}^{ag} \ge \alpha_s^{ag*} \ge \overline{\alpha}$. In this case there are two possibilities.

(b.1) $SW_s^{ag*}(\alpha_s^{ag*}) \ge SW_s^{ac*}(\alpha_s^{ac*} = 0).$ Clearly, the government's optimal choice will be $\alpha_s^* = \alpha_s^{ag*}$. Correspondingly, the monopolist's subgame perfect equilibrium strategy will be $p_m^{ag*}(\alpha_s^{ag*})$ because in the range, $\alpha_{\max}^{ag} \ge \alpha_s^{ag*} \ge \overline{\alpha}$, the *ag-strategy* is the weakly dominant one as shown in figure 2.

(b.2) $SW_s^{ag*}(\alpha_s^{ag*}) < SW_s^{ac*}(\alpha_s^{ac*} = 0).$ In this case the government's optimal choice will be $\alpha_s^* = 0$ and p_m^{ac*} is the subgame perfect equilibrium strategy. *Q.E.D*

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