

# OPTIMAL ENFORCEMENT AND ANTI-COPYING STRATEGIES TO COUNTER COPYRIGHT INFRINGEMENT

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## **ABSTRACT**

This paper uses an entry-deterrence framework to study the mix of enforcement policies and anti-copying investment strategies to counter copyright infringement. The incumbent firm chooses a quantity and an anti-copying investment that may prohibit copying, and a fake-producer who is the possible entrant competes with the incumbent firm by illegally selling identical copies of his product. The government is responsible for monitoring and penalizing the fake-producer. We show that if monitoring is socially optimal then the subgame perfect equilibrium anti-copying investment does not guarantee the prevention of copying. If not monitoring is socially optimal then the subgame perfect equilibrium anti-copying investment may guarantee the prevention of copying.

**KEYWORDS:** Accommodating Strategy, Aggressive Strategy,  
Anti-copying Investment, No-copying Strategy

**JEL CLASSIFICATION:** K42, L11.

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## 1. INTRODUCTION

An interesting news article made headlines in The Statesman, an English daily published from Kolkata, India, on December 9, 2004. It reads as follows. “Perhaps for the first time, film makers are getting an upper hand over pirates. Interestingly the film in question is 44 years old – Mughal-E-Azam.<sup>1</sup> Video pirates are having a tough time making pirated CDs of the color version of the classic.” The film is completely in a digital format and the digital standards are such that piracy will not be easy, says the project director. The story assumes significance since it suggests that producers have successfully taken anti-piracy measures. This is unique because producers in developing countries generally depend on government enforcement rather than undertaking anti-copying investments to prevent piracy.<sup>2</sup>

In developing countries, like India, copyright infringement at the commercial level can take two forms.<sup>3</sup> The copied product is either an imperfect or a perfect substitute of the original one. The first situation, which is the general assumption in the literature on piracy, implies that a consumer makes a choice regarding whether to buy the original or the copied product.<sup>4</sup> In the second case identical copies of products like audio and visual

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<sup>1</sup> Mughal-E-Azam is a classic Indian blockbuster movie.

<sup>2</sup> D. Malhotra mentions that technocrats in India are developing methodologies that can check copyright infringement. However, this is still at a nascent stage. See [www2.accu.or.jp](http://www2.accu.or.jp), vol.31, no.2. BBC (January 20, 2003) reports that the music industry has been trying out different technologies to stop the unauthorized copying of CDs.

<sup>3</sup> “Copyright infringement is the unauthorized use of copyrighted material in a manner that violates one of the copyright owner’s exclusive rights, such as the right to reproduce or perform the copyrighted work, or to make derivative works that build upon it. For electronic and audio-visual media, unauthorized reproduction and distribution is often referred to as piracy. This may occur through organized black market reproduction and distribution channels, sometimes with blatantly open commercial sale, or through purely private copying or downloading to avoid paying a purchase price. With digital technology, most modern piracy involves an exact and perfect copy of the original made from a hard copy or downloaded over the Internet.” Adopted from Wikipedia, the free encyclopedia. See [http://en.wikipedia.org/wiki/Copyright\\_infringement](http://en.wikipedia.org/wiki/Copyright_infringement).

<sup>4</sup> See Banerjee (2003, 2004), Besen and Kirby (1989), Takeyama (1994) for explanations of the assumption that the copied product is an imperfect substitute of the legitimate one.

CDs, and videocassettes of movies that include packaging and warranty are sold along with the legitimate ones in retail stores and at the same price to avoid detection.

Therefore, the consumers cannot distinguish the original from the copied product. The purpose of this paper is to focus on the mix of government's enforcement policy and a producer's anti-copying investment using a strategic entry-deterrence framework to counter the second form of commercial copyright infringement.<sup>5</sup>

We consider a market where there is an incumbent firm, hereafter referred to as the monopolist, and a possible entrant, hereafter referred to as the fake-producer, who commercially competes with the monopolist by selling identical copies of his product.<sup>6</sup> The government is responsible for monitoring and penalizing the fake-producer. The penalty is given institutionally. The monopolist's choice variable consists of output and an anti-copying investment. The higher the anti-copying investment the lower is the probability of copying and above a certain critical level of investment copying is prevented with certainty.

The monopolist may behave as a Stackelberg leader and choose the profit maximizing output and anti-copying investment assuming that the fake-producer copies his product and is competing with him. We call this the *accommodating* strategy. Alternatively, he may deter the fake-producer's entry either by choosing an entry deterring limit output, which we call the *aggressive* strategy or by choosing the critical

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<sup>5</sup> Indian Music Industry (IMI) in its web site [www.indianmi.org](http://www.indianmi.org) lists three or four shops in each major cities of India that have been raided and their owners arrested for the sale of pirated music CDs. This highlights the importance that IMI attaches to commercial copyright infringement and provides a justification for considering an oligopolistic market structure in our paper.

<sup>6</sup> Unlike this paper Banerjee (2003) considers an anti-copying investment, which is like a fixed cost that prevents copying with certainty.

level of investment that guarantees no copying with certainty, which we call the *no-copying* strategy.

The government's social welfare maximizing monitoring rate endogenously determines the monopolist's equilibrium output and anti-copying investment strategy. We show that monitoring may be the socially optimal outcome. In this case the accommodating strategy is the subgame perfect equilibrium and the equilibrium anti-copying investment does not prevent copying with certainty. If not monitoring is socially optimal then either the no-copying or the accommodating strategy is the subgame perfect equilibrium. In the former case copying is prevented with certainty, which does not happen in the latter case.

These results imply that the equilibrium anti-copying investment is always positive. It also implies that even in developing countries like India where enforcement policies against copyright infringement are rather weak it is possible to prevent piracy through anti-copying investment and this result supports the Mugal-E-Azam story.

The findings of this paper differ from those in the existing literature on commercial piracy, (Banerjee 2003, 2004), where the pirated product is assumed to be an imperfect substitute of the original one. Banerjee (2003) shows that if monitoring is the socially optimal outcome then piracy is prevented and the monopoly outcome is restored. Banerjee (2004), considers a strategic entry-deterrence framework and show that lobbying by the monopolist is a necessary but not a sufficient condition that may result in monitoring as the socially optimal outcome in which case piracy may be prevented with certainty. Unlike this paper that considers a mix of anti-copying investment and

enforcement policies to prevent copyright infringement, the literature on piracy focuses only on enforcement policies targeted towards piracy.<sup>7</sup>

This paper is arranged as follows. In Section 2 we present the model and in section 3 we analyze the equilibrium no-copying, accommodating, and aggressive strategies. Section 4 sets out the social welfare analysis and in Section 5 we provide the concluding remarks.

## 2. THE MODEL

We begin our analysis by describing the monopoly situation. For simplicity we assume a linear demand function of the form,  $p(Q) = 1 - Q$ , where  $Q$  and  $p$  denote the quantity and the price. We assume an installed monopolist. This allows us to avoid the fixed cost of developing the product, and the marginal cost of production is assumed to be zero. The monopoly results are  $p_m^* = \frac{1}{2}$ ,  $Q_m^* = \frac{1}{2}$ , and  $\pi_m^* = \frac{1}{4}$ .

Let us now introduce the fake-producer in our model who is the possible entrant and the monopolist is the incumbent firm. The fake-producer tries to counterfeit and sell unauthorized identical reproductions of the monopolist's product. The government's role is to monitor the illegal activities of the fake-producer. If detected the fake-producer pays

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<sup>7</sup> Software piracy can be either in the form of end-user or commercial piracy. End-user piracy refers to the situation where users make copies of legitimate software for personal consumption. Chen and Png (1999) show that pricing rather than monitoring is a better strategy for a firm to deal with piracy by end-users. Cheng, Sims, and Teege (1997) and Noyelle (1990) mention that the high price of software products is the dominant reason for piracy. Harbough and Khemka (2000) compares targeted enforcement to extensive enforcement and show that the latter is better than the former. Oz and Thisse (1999) show that in the presence of network externalities non-protection against piracy is an equilibrium. Takeyama (1994), Conner and Rumelt (1991), and Nascimento and Vanhonacker (1988) also discuss the role of network externalities on the marketing of software. Banerjee (2003, 2004), explores the impact of government action on commercial software piracy where the government is solely responsible for identifying and punishing software pirates. Commercial software piracy refers to a situation where a firm illegally reproduces and sells copies of legitimate software, thereby, competing with the original producer.

a penalty at an institutionally given level  $G$ . The game played between the government, the monopolist and, the fake-producer is specified in an extensive form as follows.

**Stage 1:** The government chooses a monitoring rate,  $\alpha$ .

**Stage 2:** The monopolist chooses a quantity  $q_m$  and an anti-copying investment  $x$ .

**Stage 3:** The fake producer makes his entry decision and chooses a quantity  $q_f$ .

Let us now discuss the behavior of each of the agents in our model. In many developing countries like India, identical copies of audio and visual CDs, or videocassettes of the original product, that includes packaging and warranty are sold through small retail channels. For example, a seller of audio and video, or even software CDs, reproduces copies of licensed products and sells them along with the original products. To prevent detection and given that the products are identical, the fake products are sold at the same price as the original ones. The consumers cannot distinguish the fake product from the legitimate one. Only specially trained experts can distinguish the original product from the fake one. Such experts may be hired by the government to monitor the illegal activities.

So in our model we assume that the government is responsible for monitoring the illegal activities of a fake-producer. Let  $\alpha$  denote the monitoring rate, which is the probability that the government can detect the illegal activities of the fake-producer, and  $G$  be the institutionally given penalty that the fake producer has to pay if his illegal activities are unearthed.<sup>8</sup> It may be partly redistributed to the monopolist to cover for the

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<sup>8</sup> It is possible that the government monitors but cannot detect the fake-producer. This means that the government knows that fake products are sold in the market but cannot detect the seller. One explanation can be that the fake-producer may get some prior information of a possible police raid and may decide to remove the fake products from the store. As Becker and Stigler (1974) mention, detection with certainty is difficult because malfeasant agents try to prevent detection.

damages that he incurs due to the sell of fake products. Let  $c(\alpha)$  be the monitoring cost with the properties,  $c'(\alpha) > 0$  and  $c''(\alpha) > 0$ .

The monopolist's strategy consists of choosing a quantity  $q_m$  and a level of investment,  $x$ , that may prevent copying of the legitimate product. Let  $h(x)$  be the probability that the fake-producer can copy when the anti-copying investment is  $x$ . We assume that copying is completely prevented if  $x \geq \bar{x}$ , i.e.,  $h(x) = 0$ , for  $x \geq \bar{x}$ . We further assume that  $h'(x) < 0$  and  $0 \leq h(x) < 1$  for  $0 \leq x < \bar{x}$ .  $h'(x) = 0$ , for  $x \geq \bar{x}$ . For  $x < \bar{x}$  we get the following events and the probability of their occurrences.

$$\begin{aligned}
 \text{Probability that the fake producer can copy and is detected} &= \alpha h(x), \\
 \text{Probability that the fake producer can copy and is not detected} &= (1 - \alpha)h(x), \\
 \text{Probability that the fake producer cannot copy} &= (1 - h(x)).
 \end{aligned} \tag{1}$$

The fake-producer's output is zero if he cannot copy or if he copies and is detected when trying to sell his product. This occurs with probability,  $(1 - h(x)) + \alpha h(x)$ . Table 1 summarizes the market demand, the monopolist's and the fake-producer's profits, and the consumer surplus for each of the events described in equation (1).

**TABLE 1**

<b>Events</b>	<b>Market Demand</b>	<b>Monopolist's Profit</b>	<b>Fake-producer's Profit</b>
Fake-producer copies and is detected.	$p = 1 - q_m$ because $q_f = 0$ .	$q_m - q_m^2 - x$	$-G$
Fake-producer cannot copy.	$p = 1 - q_m$ because $q_f = 0$ .	$q_m - q_m^2 - x$	0
Fake-producer copies and is not detected.	$p = 1 - q_m - q_f$	$q_m - q_m^2 - q_m q_f$	$q_f - q_f^2 - q_m q_f$

Using Table 1 and the probability of the occurrences of the different events described in equation (1) we get the monopolist's profit function  $\pi_m$  as follows.

$$\pi_m(q_m, q_f, x, \alpha) = (1 - \alpha)h(x)(q_m - q_m^2 - q_m q_f - x) + (1 - (1 - \alpha)h(x))(q_m - q_m^2 - x) \quad (2)$$

The monopolist chooses from the following three strategies. He may decide to deter the fake-producer's entry by choosing,  $x = \bar{x}$ . We call this the *no-copying strategy* (*nc-strategy*). Alternatively, he may choose to deter the fake-producer's entry through a limit output strategy, which we call the *aggressive strategy* (*ag-strategy*). The monopolist may choose to behave as a Stackelberg leader and choose the profit maximizing output and anti-copying investment assuming that the fake-producer copies his product and is competing with him. We call this the *accommodating strategy* (*ac-strategy*). Let  $\pi_m^i$  and  $\pi_f^i$  denote the monopolist's and the fake producer's profit for the monopolist's strategy,  $i \in \{nc, ac, ag\}$ . We assume that the fake-producer enters only if he makes positive profit.

The fake-producer's expected profit if he copies the monopolist's product, which occurs with probability  $h(x)$ , is

$$\pi_c(q_m, q_f, x, \alpha) = (1 - \alpha)(q_f - q_f^2 - q_m q_f) - \alpha G. \quad (3)$$

### 3. EQUILIBRIUM NO-COPYING, AGGRESSIVE, AND ACCOMMODATING STRATEGIES

In this section we discuss the equilibrium *nc*-, *ag*-, and *ac*-strategies. We solve for the equilibrium accommodating and the aggressive strategies by using the method of backward induction. In view of equation (3), the fake-producer's reaction function is,

$$q_f = \frac{1 - q_m}{2}.$$

### 3.1 NO-COPYING STRATEGY (NC)

In this subgame the monopolist chooses  $x = \bar{x}$  which, by assumption, is sufficient to prevent copying. The equilibrium results are,  $p_m^{nc*} = \frac{1}{2}$ ,  $q_m^{nc*} = \frac{1}{2}$ , and  $\pi_m^{nc*} = \frac{1}{4} - \bar{x}$ . The monopolist may choose the *nc-strategy* only if  $\pi_m^{nc*} = \frac{1}{4} - \bar{x} > 0$ . For the rest of the analysis we assume that  $\bar{x} < \frac{1}{4}$ .

### 3.2 AGGRESSIVE STRATEGY (AG)

In this case the monopolist strategically deters the fake producer's entry by choosing a limit output such that it is not profitable for the fake-producer to enter the market given that he can copy the monopolist's product. Substituting the fake producer's reaction

function in his expected profit function yields,  $\pi_f(q_m, q_f, x, \alpha) = (1 - \alpha) \left( \frac{1 - q_m}{2} \right)^2 - \alpha G$ .

The fake producer's entry is deterred if,  $\pi_f(q_m, q_f, x, \alpha) \leq 0$ . So the entry-deterrence

condition is,  $1 - 2\sqrt{\frac{\alpha G}{1 - \alpha}} \leq q_m$ .

Suppose the entry-deterrence condition holds with strict inequality. Then the monopolist can reduce the quantity and increase his profit without disturbing the entry-deterrence condition as long as the output is less than the monopoly level. Since the fake producer's entry is deterred if his profit is zero, the entry-deterrence condition holds with

strict equality. At  $\alpha = \alpha_{\max}$ , where  $\frac{\alpha_{\max} G}{1 - \alpha_{\max}} = \frac{1}{16}$ ,  $q_m = \frac{1}{2}$ . For monitoring rates above

$\alpha_{\max}$ , the monopolist will continue producing  $q_m = \frac{1}{2}$  and not reduce his output any

more because that will reduce his profit. Therefore, for the rest of the paper we will consider the monitoring rate range that satisfies,  $\alpha \in [0, \alpha_{\max}]$ .

Since the fake producer's entry is deterred, the issue of detecting him do not arise. Also the issue of the fake-producer copying the monopolist's product do not arise because it is only the monopolist's product that exists in the market. So the market demand is  $p = 1 - q_m$ . The monopolist's profit if he does not make the anti-copying investment is  $\pi_m = q_m - q_m^2$ . If he makes the anti-copying investment then his profit is  $\pi_m = q_m - q_m^2 - x$ . Clearly, not making the anti-copying investment is the dominant strategy. The results for the equilibrium *ag-strategy* are summarized in Proposition 1 and the proof is given in the Appendix.

**Proposition 1.** *The equilibrium entry-detering limit output and the anti-copying*

*investment are  $(q_m^{ag*}, x^{ag*}) = \left(1 - 2\sqrt{\frac{\alpha G}{1 - \alpha}}, 0\right)$ , for  $0 \leq \alpha \leq \alpha_{\max}$  where,  $\frac{\alpha_{\max} G}{1 - \alpha_{\max}} = \frac{1}{16}$ .*

*$q_m^{ag*}$  is nonincreasing in  $\alpha$  for  $0 \leq \alpha \leq \alpha_{\max}$ .*

The monopolist's profit for the equilibrium aggressive strategy is,

$$\pi_m^{ag*} = q_m^{ag*} - q_m^{ag*2}. \quad (4)$$

At  $\alpha = 0$ ,  $q_m^{ag*} = 1$  and  $\pi_m^{ag*}(\alpha) = 0$ . This means that in the absence of monitoring the market becomes contestable in the sense that the equilibrium entry-detering limit output equals the perfectly competitive outcome, which is 1, since the marginal cost is assumed to be zero. At  $\alpha = \alpha_{\max}$ , the monopolist's equilibrium profit is the same as that in the

monopoly case, that is,  $\pi_m^{ag*}(\alpha_{\max}) = \frac{1}{4}$ .

### 3.3 ACCOMMODATING STRATEGY (AC)

In this case the monopolist behaves like a leader in a Stackelberg game and chooses the profit maximizing quantity and anti-copying investment assuming that the fake-producer copies his product. Let  $q_m^{ac*}$ ,  $x^{ac*}$ , and  $q_f^{ac*}$  be the monopolist's output and anti-copying investment, and the fake-producer's output for the equilibrium *ac-strategy* and the results are summarized in Proposition 2. The proof is given in the Appendix.

**Proposition 2.** (i) *The fake-producer cannot enter if  $\alpha \in [\alpha_{\max}, 1]$ .*

(ii) *The monopolist's equilibrium output and anti-copying investment and the fake-*

*producer's equilibrium output are,  $(q_m^{ac*}, x^{ac*}) = \left(\frac{1}{2}, x^{ac*}\right)$ ,  $q_f^{ac*} = \frac{1}{4}$  for  $0 \leq \alpha < \alpha_{\max}$ .*

*$x^{ac*}$  is the solution to  $h'(x) = -\frac{\delta}{1-\alpha}$  and  $\frac{\alpha_{\max} G}{1-\alpha_{\max}} = \frac{1}{16}$ . At  $\alpha = \alpha_{\max}$ ,  $(q_m^{ac*}, x^{ac*}) = \left(\frac{1}{2}, 0\right)$*

*and  $q_f^{ac*} = 0$ .*

(iii) *The equilibrium anti-copying investment  $x^{ac*}$  is strictly less than  $\bar{x}$  and decreasing in  $\alpha$  for  $0 \leq \alpha < \alpha_{\max}$ .*

From Proposition 2 we see that in case of the *ac-strategy* the monopolist retains its market share as in the monopoly case, that is  $q_m^{ac*} = \frac{1}{2}$  and therefore, is unaffected by the monitoring rate. The equilibrium anti-copying investment level  $x^{ac*}$  cannot guarantee the prevention of copying with certainty because  $x^{ac*} < \bar{x}$  and is decreasing in the monitoring rate. This means that as the monitoring rate increases the monopolist free rides and decreases the equilibrium level of anti-copying investment. Since  $x^{ac*}$  satisfies

$h'(x) = -\frac{8}{1-\alpha}$ , an increase in the monitoring rate increases the absolute value of  $h'(x)$ .

This means that an increase in the monitoring rate decreases the equilibrium level of anti-copying investment but at the same time decreases the probability of copying. This is

because  $\frac{dh(x^{ac*})}{d\alpha} = h'(x^{ac*})x^{ac*}'(\alpha) > 0$  since  $h'(x^{ac*}) < 0$  and  $x^{ac*}'(\alpha) < 0$ .

At  $\alpha = \alpha_{\max}$  the issue of detecting the fake-producer and whether he can copy or not does not arise because he cannot enter the market. Therefore, at  $\alpha = \alpha_{\max}$ , there is no anti-copying investment in equilibrium and the monopolist's profit is

$\pi_m^{ac*}(\alpha_{\max}) = q_m^{ac*} - q_m^{ac*2}$  which on substituting  $q_m^{ac*} = \frac{1}{2}$  yields,  $\pi_m^{ac*}(\alpha_{\max}) = \frac{1}{4}$ . So at

$\alpha = \alpha_{\max}$  the monopoly results hold. Therefore, the monopolist's equilibrium profit is,

$$\pi_m^{ac*}(\alpha) = \begin{cases} \frac{1}{4} - \frac{(1-\alpha)h(x^{ac*})}{8} - x^{ac*}, & \text{if } 0 \leq \alpha < \alpha_{\max}, \\ \frac{1}{4}, & \text{at } \alpha = \alpha_{\max}. \end{cases} \quad (5)$$

### 3.4 COMPARATIVE STATIC ANALYSIS

In this section we provide a comparative static analysis of the monopolist's equilibrium profits for the *ag*- and *ac*-strategies with respect to the monitoring rate. This allows us to compare the properties of the equilibrium profits with respect to the monitoring rate and is later used to determine the monopolist's subgame perfect equilibrium strategy for the socially optimal monitoring rate. The results are summarized in Proposition 3 and the proof is given in the Appendix.

**Proposition 3.** *There exists a monitoring rate  $\bar{\alpha}$ ,  $\bar{\alpha} \in [0, \alpha_{\max})$ , such that*

*$\pi_m^{ag^*}(\bar{\alpha}) = \pi_m^{ac^*}(\bar{\alpha})$ ,  $\pi_m^{ac^*}(\alpha) > \pi_m^{ag^*}(\alpha)$  for  $\alpha \in [0, \bar{\alpha})$ , and  $\pi_m^{ac^*}(\alpha) < \pi_m^{ag^*}(\alpha)$  for  $\alpha \in (\bar{\alpha}, \alpha_{\max})$ .*

Proposition 3 implies that  $\pi_m^{ag^*}(\alpha)$  is steeper than  $\pi_m^{ac^*}(\alpha)$  in the interval,  $\alpha \in [0, \alpha_{\max})$  and the single crossing property is satisfied in this interval. Let  $\bar{\alpha}$  be the monitoring rate at which,  $\pi_m^{ag^*}(\bar{\alpha}) = \pi_m^{nc^*}$ . We provide a diagrammatic representation of Proposition 3 in Figures 1 and 2. In Figure 1 we consider the case that  $\pi_m^{ac^*}(\alpha = 0) > \pi_m^{nc^*}$  and in Figure 2 we consider the opposite scenario.

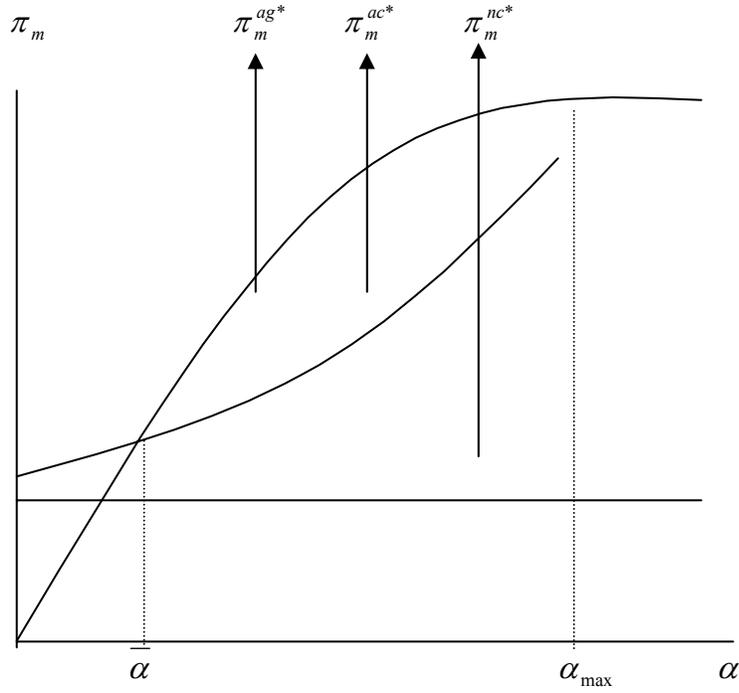


FIGURE 1

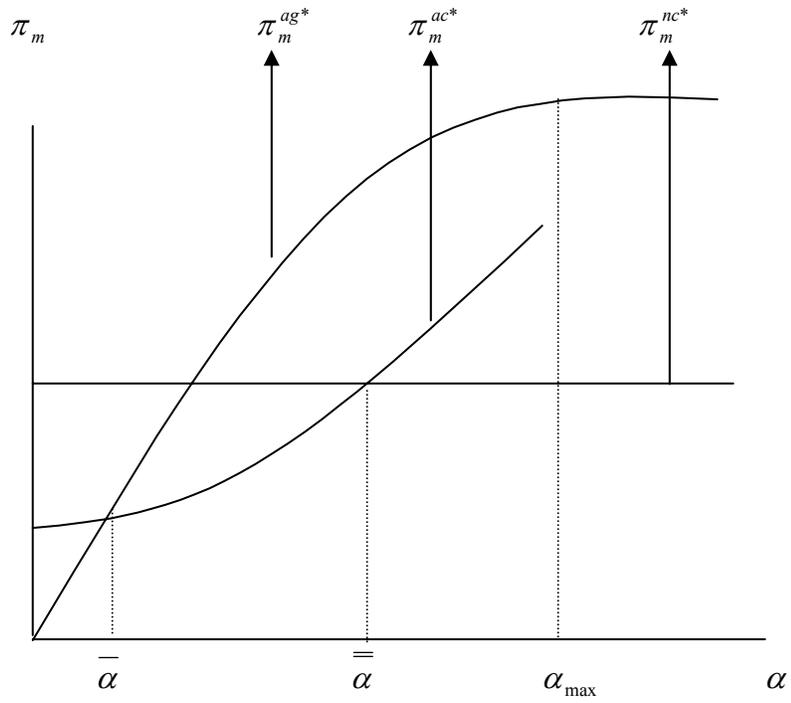


FIGURE 2

#### 4. SOCIAL WELFARE ANALYSIS

In this section we perform the welfare analysis and determine the socially optimal monitoring rate, which in turn determines the monopolist's subgame perfect equilibrium strategy. Social welfare ( $SW$ ), defined as the surplus of every agent in the model that is,

$$SW^i(\alpha) = CS^i(\alpha) + \pi_m^{i*}(\alpha) + \pi_f^{i*}(\alpha) + \alpha G - c(\alpha), i \in \{nc, ac, ag\}. \quad (6)$$

We begin by determining the consumer surplus for the monopolist's different strategies. Since the market demand curve is linear with unit slope, the consumer surplus

is,  $\frac{(1-p)q}{2} = \frac{q^2}{2}$ , where  $p$  and  $q$  are the market price and quantity. The consumer

surplus for the equilibrium  $nc$ - and  $ag$ -strategies are  $CS^{nc} = \frac{1}{8}$  and

$CS^{ag} = \frac{1}{2} \left( 1 - \sqrt{\frac{\alpha G}{1-\alpha}} \right)^2$ . So in these two cases the fake-producer's profit does not appear

in the social welfare function since there is no fake product in the market and therefore, the fake-producer's profit is zero. The social welfare functions in these two cases are,

$$SW^{nc} = \frac{3}{8} - \bar{x} - c(\alpha), \quad (7)$$

$$SW^{ag}(\alpha) = \frac{2q_m^{ag*} - q_m^{ag*2}}{2} - c(\alpha).$$

In case of the equilibrium  $ac$  strategy, in the interval  $\alpha \in [0, \alpha_{\max})$ , the fake-product exists in the market with probability  $(1-\alpha)h(x)$  in which case the consumer surplus is

$\frac{9}{32}$  and the monopolist's and the fake-producer's profits are  $\pi_m^{ac*} = \frac{1}{8} - x^{ac*}$  and

$\pi_c^{ac*} = \frac{1}{16}$ . With probability  $\alpha h(x)$  the fake-producer copies and is detected. So there is

no fake product in the market. In this case the consumer surplus, and the monopolist's

and fake-producer's profits are;  $CS = \frac{1}{8}$ ,  $\pi_m^{ac^*} = \frac{1}{4} - x^{ac^*}$ , and  $\pi_c^{ac^*} = -\alpha G$ . The fake-

producer cannot copy the product with probability  $(1 - h(x^{ac^*}))$  in which case the

consumer surplus, the monopolist's, and the fake-producer's profits are  $CS = \frac{1}{8}$ ,

$\pi_m^{ac^*} = \frac{1}{4} - x^{ac^*}$ , and  $\pi_c^{ac^*} = 0$ . So the ex ante expected social welfare for the equilibrium

*ac-strategy* is,

$$\begin{aligned}
 SW^{ac}(\alpha) &= (1 - \alpha)h(x^{ac^*})\left(\frac{1}{8} - x^{ac^*} + \frac{1}{16} + \frac{9}{32} - c(\alpha)\right) + \\
 &\quad \alpha h(x^{ac^*})\left(\frac{1}{4} - x^{ac^*} - G + \frac{1}{8} + G - c(\alpha)\right) + \\
 &\quad (1 - h(x^{ac^*}))\left(\frac{1}{4} - x^{ac^*} + \frac{1}{8} - c(\alpha)\right) = \frac{3}{8} + \frac{3h(x^{ac^*})(1 - \alpha)}{32} - x^{ac^*} - c(\alpha).
 \end{aligned} \tag{7}$$

Let  $\alpha^{i^*}$  be the monitoring rate that maximizes  $SW^i(\alpha)$ ,  $i \in \{nc, ac, ag\}$ . Let  $\alpha^*$  be the socially optimal monitoring rate. Proposition 4 summarises the results for the socially optimal monitoring rate and the monopolist's subgame perfect equilibrium strategy which is the main finding of this paper. The proof is given in the Appendix.

**Proposition 4.** (i) If  $\bar{x} \geq \frac{h(x^{ac^*}(\alpha = 0))}{8} + x^{ac^*}(\alpha = 0)$  then there exists a socially optimal

monitoring rate only if  $\alpha^{ac^*} \in [0, \bar{\alpha}]$ . The socially optimal monitoring rate is  $\alpha^* = \alpha^{ac^*}$

and the *ac-strategy* is the subgame perfect equilibrium.

(ii) If  $\bar{x} < \frac{h(x^{ac*}(\alpha = 0))}{8} + x^{ac*}(\alpha = 0)$  then not monitoring is the socially optimal

outcome, that is,  $\alpha^* = 0$  and the *nc-strategy* is the subgame perfect equilibrium.

Proposition 4 shows that monitoring may or may not be the socially optimal policy. If not monitoring is the socially optimal outcome then either the *nc-strategy* that guarantees the prevention of copying with certainty or the *ac-strategy* is the subgame perfect equilibrium strategy. In the latter case the equilibrium anti-copying investment does not guarantee the prevention of copying with certainty. This is because from Proposition 2 we know that the equilibrium anti-copying investment,  $x^{ac*}(\alpha^* = 0)$ , that satisfies  $h'(x^{ac*}(\alpha^* = 0)) = -8$ , is strictly less than  $\bar{x}$ .

Alternatively, if monitoring is the socially optimal outcome then the *ac-strategy* is the subgame perfect equilibrium and using Proposition 2, the equilibrium anti-copying investment is  $x^{ac*}(\alpha^*)$  that satisfies  $h'(x^{ac*}(\alpha^*)) = -\frac{8}{1-\alpha^*}$ . However,  $x^{ac*}(\alpha^*)$  does not guarantee the prevention of copying with certainty because from Proposition 2 we know that  $x^{ac*}(\alpha^*) < \bar{x}$ .

Proposition 4 implies that the monopolist always makes a positive anti-copying investment in equilibrium and there may be a combination of enforcement policy and anti-copying investment in equilibrium. It may also be the case that the fake-producer cannot copy the monopolist's product in the absence of monitoring. Thus it is possible to prevent copyright infringement through anti-copying investment rather than depending on enforcement infringement policies, which are rather weak or lacking in developing

countries. Further, we also see that the entry-detering limit output aggressive strategy is never a subgame perfect equilibrium.

## 5. CONCLUSION

The focus of the literature on software piracy was on enforcement policies targeted towards piracy and its effectiveness in preventing copyright infringement. The general assumption in this literature was that the pirated products are imperfect substitutes of the legitimate ones. Unlike this literature, in this paper we considered the case where a firm illegally reproduces and distributes identical copies of a product thereby commercially competing with the legitimate producer. While the government is responsible for monitoring the illegal activities of the fake-producer, we allowed the monopolist to play an active role in the prevention of copyright infringement by considering an entry-deterrence framework and introducing the anti-copying investment by the monopolist. We assumed that the probability of copying is inversely related to the anti-copying investment and above a certain critical level it guarantees the prevention of copying with certainty.

The monopolist's strategies consisted of output and anti-copying investment that either allowed or deterred the fake-producer's entry or prohibited copying by the fake-producer with certainty. We called them the accommodating, aggressive, and no-copying strategies. The government's social welfare maximizing monitoring rate endogenously determined the monopolist's subgame perfect equilibrium strategy.

We showed that if not monitoring is socially optimal then either the accommodating or the no-copying strategies are the subgame perfect equilibrium. In the former case the equilibrium anti-copying investment does not guarantee the prevention of copying while in the latter case copying is prevented with certainty. If monitoring is socially optimal

then the accommodating strategy is the subgame perfect equilibrium and copying is not prevented with certainty.

Our findings suggest that in developing countries where enforcement policies are rather weak it is possible to prevent copyright infringement through the adoption of anti-copying investment by producers. The Mughal-E-Azam case mentioned in the Introduction is an example that supports our results.

## APPENDIX

### Proof of Proposition 1

In case of the *ag-subgame*, the equilibrium entry deterring limit output is

$$q_m^{ag*} = 1 - 2\sqrt{\frac{\alpha G}{1-\alpha}}, \text{ for } 0 \leq \alpha \leq \alpha_{\max}, \frac{\alpha_{\max} G}{1-\alpha_{\max}} = \frac{1}{16}. q_m^{ag*} \text{ is decreasing in } \alpha, \text{ since}$$

$$\frac{\alpha G}{1-\alpha} \text{ is increasing in } \alpha. \text{ At } \alpha = \alpha_{\max}, q_m^{ag*} = \frac{1}{2}. \quad \text{Q.E.D.}$$

### Proof of Proposition 2

$$q_m^{ac*} = \frac{1}{2} \text{ and } q_f^{ac*} = \frac{1}{4}, \text{ if the fake producer can copy which occurs with probability}$$

$$h(x). \text{ Substituting this in the fake-producer's expected profit we get } \pi_f^{ac*} = \frac{(1-\alpha)}{16} - \alpha G.$$

The fake producer cannot enter the market given that he can copy if

$$\pi_f^{ac*} = \frac{(1-\alpha)}{16} h(x) - \alpha h(x) G \leq 0 \text{ which on rearrangement becomes } \frac{\alpha G}{1-\alpha} \geq \frac{1}{16}. \text{ Let } \alpha_{\max}$$

be the monitoring rate that satisfies the no-entry condition with equality. The fake-producer cannot enter if the monitoring rate satisfies the condition  $\alpha_{\max} \leq \alpha \leq 1$  because

$$\frac{\alpha}{1-\alpha} \text{ is increasing in } \alpha, 0 \leq \alpha < 1. \text{ However, the relevant range of the monitoring}$$

assumed is  $\alpha \in [0, \alpha_{\max}]$ . Let us consider the range  $\alpha \in [0, \alpha_{\max})$ . Substituting  $q_m^{ac*} = \frac{1}{2}$

in the monopolist's expected profit function given in equation (2) and maximizing it with

respect to  $x$ , that is  $\frac{d\pi_m}{dx} = -\frac{(1-\alpha)h'(x)}{8} - 1 = 0$ , yields the solution  $x^{ac*}$ . Now  $x^{ac*}$

cannot guarantee that the fake-producer cannot copy with certainty because

$$h'(x^{ac*}) = -\frac{8}{1-\alpha} < 0 \text{ which implies that } x^{ac*} < \bar{x}. \text{ By assumption } h'(x) < 0 \text{ for } x < \bar{x}.$$

Now maximization requires  $\frac{d^2\pi_m}{dx^2} = -\frac{(1-\alpha)}{8}h''(x) < 0$ . This implies that it must be the

case that,  $h''(x) > 0$ . From  $h'(x^{ac*}) = -\frac{8}{1-\alpha}$  we get  $\frac{dx^{ac*}}{d\alpha} = -\frac{8}{h''(x^{ac*})(1-\alpha)^2} < 0$ , since

$h''(x^{ac*}) > 0$ . At  $\alpha = \alpha_{\max}$  the issue of detecting the fake-producer and whether he can

copy or not do not arise because he does not enter and  $\alpha_{\max}$  is independent of  $x$ .

Therefore,  $x^{ac*} = 0$  at  $\alpha = \alpha_{\max}$  and hence the monopolist's profit is

$$\pi_m^{ac*}(\alpha_{\max}) = q_m^{ac*} - q_m^{ac*2} \text{ which on substituting } q_m^{ac*} = \frac{1}{2} \text{ yields, } \pi_m^{ac*}(\alpha_{\max}) = \frac{1}{4}. \text{ Q.E.D.}$$

### Proof of Proposition 3

$$\frac{d\pi_m^{ac*}(\alpha)}{d\alpha} = \frac{h(x^{ac*})}{8} - \frac{(1-\alpha)}{8}h'(x^{ac*})\frac{dx^{ac*}}{d\alpha} - \frac{dx^{ac*}}{d\alpha} = \frac{h(x^{ac*})}{8} > 0 \text{ for } \alpha \in [0, \alpha_{\max}). \text{ We}$$

$$\text{get this using the first order condition } -\frac{(1-\alpha)h'(x)}{8} - 1 = 0 \Rightarrow h'(x^{ac*}) = -\frac{8}{1-\alpha}.$$

$$\frac{d^2\pi_m^{ac*}(\alpha)}{d\alpha^2} = \frac{h'(x^{ac*})}{8}\frac{dx^{ac*}}{d\alpha} > 0 \text{ because } h'(x^{ac*}) \text{ and } \frac{dx^{ac*}}{d\alpha} \text{ are both negative. So in the}$$

interval  $\alpha \in [0, \alpha_{\max})$ ,  $\pi_m^{ac*}(\alpha) = \frac{1}{4} - \frac{(1-\alpha)h(x^{ac*})}{8} - x^{ac*}$  is a strictly increasing and a

convex function of  $\alpha$ . At  $\alpha = 0$ ,  $\pi_m^{ac*}(0) = \frac{1}{4} - \frac{h(x^{ac*})}{8} - x^{ac*}$ . The monopolist's profit

for the equilibrium ag-strategy is  $\pi_m^{ag*} = q_m^{ag*} - q_m^{ag*2}$  which equals the monopoly profit at

$\alpha = \alpha_{\max}$ . Now  $\frac{d\pi_m^{ag*}}{d\alpha} = (1 - 2q_m^{ag*}) \frac{dq_m^{ag*}}{d\alpha} \geq 0$  because  $\frac{dq_m^{ag*}}{d\alpha} \leq 0$  and  $(1 - 2q_m^{ag*}) \leq 0$

since  $\frac{1}{2} \leq q_m^{ag*} \leq 1$ . So  $\pi_m^{ag*}(\alpha)$  is maximized at  $\alpha_{\max}$ . At  $\alpha = 0$ ,  $\pi_m^{ag*}(\alpha) = 0$ . So

$\pi_m^{ac*}(0) > \pi_m^{ag*}(0)$  and at  $\alpha = \alpha_{\max}$ ,  $\pi_m^{ac*}(\alpha_{\max}) = \pi_m^{ag*}(\alpha_{\max}) = \frac{1}{4}$ . So  $\pi_m^{ag*}(\alpha)$  is steeper

than  $\pi_m^{ac*}(\alpha)$ , and therefore, the single crossing property is satisfied in the range

$\alpha \in [0, \alpha_{\max})$ .

*Q.E.D.*

#### Proof of Proposition 4

$\alpha^{nc*} = 0$  because  $SW^{nc'}(\alpha) = -c'(\alpha) < 0$ .  $SW^{ag'}(\alpha) = (1 - q_m^{ag*})q^{ag*'}(\alpha) - c'(\alpha) < 0$  since  $q_m^{ag*'}(\alpha) < 0$ ,  $(1 - q_m^{ag*}) \geq 0$ , and  $c'(\alpha) > 0$ . So  $\alpha^{ag*} = 0$ .

$SW^{ac'}(\alpha) = \frac{3}{32} \left( (h'(x^{ac*})(1 - \alpha) - 1)x^{ac*'}(\alpha) \right) - \left( \frac{3}{32}h(x^{ac*}) + c'(\alpha) \right)$ . The first expression

is positive because  $h'(x^{ac*}) < 0$  and  $x^{ac*'}(\alpha) < 0$ , and the second expression is negative

for  $\alpha^{ac} \in [0, \alpha_{\max})$ . Therefore, the sign of  $SW^{ac'}(\alpha)$  is ambiguous. So  $\alpha^{ac*} \in [0, \alpha_{\max})$ .

.Parts (i) and (ii) of Proposition 4 are proved using Figures 1 and 2.

$\pi_m^{ac*}(\alpha = 0) \geq \pi_m^{nc*} \Rightarrow \bar{x} \geq \frac{h(x^{ac*}(\alpha = 0))}{8} + x_1^{ac*}(\alpha = 0)$ . So the *ac-strategy* weakly

dominates the *nc-strategy*. This is represented in Figure 1. An equilibrium does not exist

if  $\alpha^{ac*} > \bar{\alpha}$  because of the following reason. Suppose  $\alpha^{ac*} > \bar{\alpha}$ . Then if the government

chooses  $\alpha^{ac^*}$ , the monopolist chooses the *ag-strategy* which do not maximize  $SW^{ag}$ . If the government chooses  $\alpha^{ag^*} = 0$  then the monopolist chooses the *ac-strategy* which do not maximize  $SW^{ac}(\alpha)$ . Therefore, an equilibrium exists only if  $\alpha^{ac^*} \in [0, \bar{\alpha}]$ . In this range the *ac-strategy* weakly dominates the *ag-strategy* and  $\alpha^{ac^*}$  also maximizes social welfare. Therefore,  $\alpha^* = \alpha^{ac^*}$ ,  $\alpha^{ac^*} \in [0, \bar{\alpha}]$  is the socially optimal monitoring rate and the *ac-strategy* is the subgame perfect equilibrium. Part (ii) of the proposition follows from the fact that,  $\pi_m^{ac^*}(\alpha = 0) < \pi_m^{nc^*} \Rightarrow \bar{x} < \frac{h(x^{ac^*}(\alpha = 0))}{8} + x^{ac^*}(\alpha = 0)$ . In the range  $\alpha \in [0, \bar{\alpha}]$  the *nc-strategy* dominates the *ac-strategy*. If  $\alpha^{ac^*} \in [\bar{\alpha}, \alpha_{\max})$  then the government will not choose  $\alpha^{ac^*}$  even if  $SW^{ac}(\alpha^{ac^*}) > SW^{nc}$  because of reasons explained above. Therefore,  $\alpha^* = 0$  is socially optimal and the *nc-strategy* is the subgame perfect equilibrium. Q.E.D.

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