Why Software Piracy Rates Differ – A Theoretical Analysis

by

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Abstract

The pervasiveness of the illegal copying of software is a worldwide phenomenon. However, the level of piracy across various markets as well as across various countries varies a great deal. In this paper, we develop a theoretical model to explain this feature. In this model, the software firm undertakes costly deterrence activity in the form of R&D to stop piracy. In our model existence (or non-existence) of piracy comes out endogenously. We show that piracy survives in the market when the income gap is high among the potential software users, enforcement policy against the pirate(s) is less strict (i.e. cost of piracy is not too high), and when the pirate(s) produces a software copy that is moderately reliable.

Keywords: Software piracy, Copyright Violations, R&D, Raising rival’s cost, Deterrence, Product reliability, Income gap

JEL Classifications: D23, D43, L13, L86

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1. Introduction

The pervasiveness of the illegal copying of software is a worldwide phenomenon. It is not only having a profound effect on the users of the software, but also on the software industry as a whole. It is also having a tremendous effect on the development of digital intellectual properties and technologies. However, the level of piracy across various regions and markets varies a great deal. In some markets, we observe rampant piracy while in some other markets piracy is rare.¹ There exists empirical studies (see Gopal and Sanders (1998, 2000), Husted (2000), Donald and Steel (2000), Holm (2003), Banerjee et. al. (2005), Fischer and Rodriguez (2005)) to explain the varying piracy rates across countries and regions, but to the best of our knowledge no rigorous theoretical framework has been used so far to explain the same phenomenon. In this paper, we attempt to do that. We develop a theoretical model to explain why we may observe varying rates of piracy across nations, and more specifically, between the developed and developing nations.

Two types of piracy are widely observed in reality: (i) End user Piracy (ii) Commercial/Retail Piracy. End user piracy is observed more or less everywhere, whereas commercial piracy is more prevalent in the poor and developing countries where the laws against piracy or in general enforcement against copyright violations are rather weak.² There is a theoretical literature on end user piracy (see Conner and Rumelt (1991), Takeyama (1994), Slive and Bernhardt (1998), Shy and Thisse (1999) among others) which comes up with one explanation of the existence of piracy. The argument basically stands on the feature of network externality that is observed in the software users market. They show that when the network effect is strong (i.e. in the presence of high network externality), the original software firm will allow (limited) piracy as it turns out to be the more profitable option than protection. In this paper, while studying the feature of

¹ Piracy rates defined as the ratio of the number of pirated copies to total installed copies, vary from 21 percent in US to 92 percent in Vietnam in the year 2004. (See BSA and IDC Global Software 2005 for a detailed survey on piracy rates in different countries).

² Widespread corruptions, weak legal systems, lack of enforcements are some of the reasons for that. Also in most developing countries, where the computer literacy and technological know-how among the average people are still very low, a ready-made pirated product at a cheap price is always attractive.
varying piracy rates, we will provide an alternative explanation of the existence (or non-existence) of software piracy without relying on the feature of network externality at all.

There is also another strand of literature which studies various policy instruments (like monitoring and imposing a lump-sum fine on the pirate(s), hardware taxation, subsidy on legitimate purchase etc.) adopted by the software developer or the government to limit or prohibit piracy (see Chen and Png (2003), Banerjee (2003), Gayer and Shy (2003) among others). We do not take that route as well. Instead we develop an economic model where the software firm itself undertakes costly deterrence activity in the form of R&D to stop piracy. Unlike any previous study, we explicitly model how the optimal level of deterrence is actually chosen by the software firm in the presence of piracy. As a result, in our model existence (or non-existence) of piracy comes out endogenously. In the case of commercial piracy, the existence (or non-existence) of piracy comes out as an endogenous outcome of a (dynamic) strategic game between the pirate and the original firm. In the case of end user piracy it is determined by the optimal level of deterrence chosen endogenously by the monopolist software firm.

In end user piracy, pirates are the end users; this is equivalent to private coping; while in commercial/retail piracy, pirates copy and sell their products to consumers with a profit motive. To capture the notion of commercial piracy in a simple way, we consider a model of an original software firm and a retail pirate. Under both types of piracy, we find out under what condition piracy will take place and when it can be stopped. The basic assumption we use here is stopping piracy is a costly activity, but if such costly activity is actively undertaken, it raises the cost of piracy to the pirate, which consequently limits/stops piracy. Investing in R&D by the software firm to raise the cost of piracy or the deterrence level to piracy can be done in different ways. For example, the original firm can develop a technology (like putting a protective device into the software), which increases the cost of copying its software. It can invest in R&D to come up with appropriate method and technology to monitor the pirate(s). In this model, we

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3 In reality, there could be more than one retail pirate, or a group of small retail pirates operate in the product market, but for simplicity in this paper, we just consider one pirate as qualitative results remains unchanged when there are more pirates and all pirates are similar. When the number of pirates gets large indefinitely, then the model of commercial piracy tends to the model of end users piracy where everybody is a potential pirate and making any monetary profit out of pirating software goes to zero.
assume costly R&D undertaken by the software firm will increase the pirate’s unit cost of producing a copy of the original software. Thus higher the R&D investment, higher is the cost of piracy to the pirate. We also assume costly R&D must be undertaken ahead by anticipating that there will be piracy and before the pirate could actually start its operation.

Raising rival’s cost of production in order to induce its rival to exit the industry has been studied earlier by Salop and Scheffman (1983). However, they focused their study in an industry consisting of a dominant firm and a competitive fringe, where the low cost dominant firm can cause injury to the rivals by strategically raising the cost of the fringe firms. Interestingly, further studies of this feature (of raising rival’s cost) were not done much in other type of industries or market structures. In this paper, we introduce this feature in a simple duopoly framework under commercial piracy where one competitor (the original firm) endogenously raises the rival’s (pirate) cost by undertaking costly R&D investment. We believe apart from the piracy aspect of this paper, studying the strategic option of raising rival’s cost endogenously in this fashion is also a contribution to the literature of strategic entry deterrence.

Now, since this investment for deterrence made by the software firm is costly, the question that naturally arises, whether it is profitable to the firm to actually undertake such deterrence operation. And if at all it undertakes such deterrence operation, under what circumstances it will be effective. We show that the answers to these questions depend on the overall profitability of the original firm as well as of the pirate and on the net utility of the potential software users. This in turn depends on some basic features of an economy like, income gap among the potential software users, the strictness of the enforcement policy against the pirate (i.e. enforcement against copyright violations), the quality and reliability of the pirated product, among other factors. For our analysis here we will explicitly take into account of the above mentioned three factors in our model. Analyzing the model, we are able to explain, why sometime pirate(s) operates in the

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4 The only exception is vertically related markets. See Salinger (1988), Ordover et al. (1990), Sibley & Wiseman (1998), and Banerjee & Lin (2003) for studies on this issue.

5 We do acknowledge apart from these factors mentioned here, there are other factors which can influence piracy. But for analytical tractability we restrict ourselves to these factors in this model.
market and the original firm cannot do anything about it; we also show when the original firm will actually be able to stop piracy successfully. All these outcomes come out endogenously in our model of commercial piracy and end-user piracy. We work out the precise conditions when there will be pirate(s) in the market, and when there will be no pirate operating. Our general conclusion is, the pirate(s) survives in the market when the income gap is high among the potential software users, enforcement policy against the pirate is less strict (i.e. cost of piracy is not so high), and when the pirate(s) produces a software copy that is moderately reliable.

The plan of the paper is as follows. In the next section, we describe the model of retail/commercial piracy in detail. In section 3, the main analysis is done under retail piracy and the results are derived. We interpret the results and draw our conclusions by relating them with the various features of an economy. In section 4 we discuss the welfare issues. Section 5 discusses the case end-user piracy. Finally, Section 6 concludes.

2. The Model of Retail/Commercial Piracy

2.1 The Software Firm and the Pirate

Consider an original software firm and a pirate. The pirate has the technology to copy the original software. We assume the pirate produces software copies, which may not be as reliable as the original product. The probability that a pirated software works is $q$, $q \in (0,1)$ and this probability is common knowledge. Therefore $q$ serves as a proxy for the quality of the pirated software. Usually pirated copies does not come with the supporting services or guarantee, so one can think even if the pirated software is exactly same as the original one (because of digital coping), but the lack of supporting services or guarantee makes it a inferior product compared to the original.

There are two time periods, where in the first period $(t = 1)$, the original software developer undertakes costly R&D in order to make piracy costly to the pirate. Costly R&D of the original developer raises the marginal cost of producing a copy by the

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$^6$ $q = 0$ will eliminate the pirated product, while $q = 1$ will make two products identical. Note $q = 1$ is never possible due to the reasons described above.
The potential pirate appears in the market of the original product in the second time period ($t = 2$). We assume the higher the investment in R&D by the original software developer in the first period, the higher the marginal cost of copying by the pirate. The pirate if survives, competes with the original developer in price by possibly producing less reliable yet cheaper products.

### 2.2 Costs and Profits of the Competing Firms

We assume at $t = 1$, the cost of R&D by the original developer to increase the marginal cost of the pirate by an amount of $x$ is given by $c_o(x) = \frac{x^2}{2}$. Let us call $x$ as the level of deterrence.

Thus, if the profit of the software developer at $t = 2$ is denoted by $\pi_o^2 = p_oD_o$, where $p_o$ is the price charged by the developer and $D_o$ is the demand it faces, then the net profit of the developer at $t = 1$ becomes $\pi_o = \pi_o^2 - c_o(x) = \pi_o^2 - \frac{x^2}{2}$.

On the other hand, if the pirate is in the market at $t = 2$ then its profit function becomes $\pi_p = (p_p - cx)D_p$, where $p_p$ is the price charged by the pirate and $D_p$ is the pirate’s demand and $c$ is a positive constant ($c > 0$) exogenously given. $c = 0$ means piracy is costless or in other words, original firm’s investment effort in the earlier period has no effect in deterring piracy. On the other hand, higher $c$ increases the cost of piracy, which says, original firm’s investment to stop piracy becomes more effective. $c$ is important to our model and we can interpret the exogenous cost coefficient $c$ as follows. It can be interpreted as strictness of the enforcement policy against piracy of a particular country. For example, we can generally find a relatively high $c$ in the developed countries where piracy is taken as a serious crime; hence it raises the cost of piracy significantly. On the other hand, in most of the developing countries, we will probably find $c$ to be relatively

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7 One can imagine when the original firm makes it technologically harder (due to R&D) to copy the product, that would increase one time fixed cost of the pirate, say, to break the security code. However, for simplicity, in this analysis we assume that fixed cost part to be zero. Since it is just a constant, the qualitative results of the analysis remain unaffected without it.

8 Assuming the marginal cost of production of the software is zero for the original firm.
low, because the enforcement policies against piracy may not be as strict as the
developed nations,\textsuperscript{9} hence cost of piracy would remain relatively small. Thus, $c$ can be
interpreted as the legal environment where the market for software operates. It is
understood that the local government or the regulatory authority can influence $c$. In our
model, we assume it as a parameter.

\textbf{2.3 Consumer Demand}

Consider a continuum of consumers indexed by $X$, $X \in [\theta_L, \theta_H]$, $\theta_H > \theta_L \geq 0$. A
consumer’s willingness to pay for the software depends on how much he/she values it –
measured by $X$. A high value of $X$ means higher valuation for the software and low
value of $X$ means lower valuation for the software. Therefore, one consumer differs
from another on the basis of his/her valuation for the particular software. Valuations are
uniformly distributed over the interval $[\theta_L, \theta_H]$ and the size of the market is normalized
to 1.

A consumer’s utility function is given as:

$$
U = \begin{cases} 
X - p_o & \text{if buy original software} \\
qX - p_p & \text{if buy pirated software} \\
0 & \text{if buy none}
\end{cases}
$$

There is no way a consumer can get defected pirated software replaced since there is no
warranty for the pirated software.\textsuperscript{11} Hence, the consumer enjoys the benefit of the pirated
software only with probability $q$. In the event that the pirated software purchased does
not work at all, the loss to the consumer is the price paid for it. The original software is
fully guaranteed to work. $p_o$ and $p_p$ are the prices of the original and pirated software

\textsuperscript{9} Even if the law against piracy is there, the pirate can get away by offering bribes to the authorities due to
widespread corruption in most poor and developing countries.

\textsuperscript{10} $qX - p_p = q(X - p_p) + (1 - q)(-p_p)$. If the pirated software is not working, consumer does not
derive any benefit from the software and instead only incurs a loss equivalent to the amount paid for the
pirated software.

\textsuperscript{11} In most markets pirates operate using some makeshift arrangement, if the parted software turns out to be
defected, there is no chance of getting software replaced.
respectively. It must be true that \( p_o > p_p \cdot (p_o - p_p) \) can be viewed as the premium a consumer pays for buying “guaranteed-to-work” software.

3. Analysis

3.1 Deriving Demand of the Software Developer and the Pirate

\( D_o \) and \( D_p \) can be derived from the distribution of buyers as follows.

**Figure 1: DISTRIBUTION OF BUYERS**

\[
\begin{array}{ccc}
\text{None} & \text{Pirate} & \text{Original} \\
0 & \frac{1}{Y} & \frac{1}{X} & 1
\end{array}
\]

Recall that consumers are heterogeneous with respect to their values towards the software. Thus, the marginal consumer, \( \hat{x} \), who is indifferent between buying the original software and the pirated version is given by:

\[
\hat{x} - p_o = q \hat{x} - p_p
\]

\[
\hat{x} = \frac{p_o - p_p}{1 - q}
\]

The marginal consumer, \( \hat{y} \), who is indifferent between buying the pirated software and not buying any software is:

\[
q \hat{y} - p_p = 0
\]

\[
\hat{y} = \frac{p_p}{q}
\]

Thus the demand for original software is: \( D_o = \int_{\hat{x}}^{\hat{y}} \frac{1}{\theta_H - \theta_L} dx = \frac{\theta_H (1 - q) - (p_o - p_p)}{(\theta_H - \theta_L)(1 - q)} \)

Demand for pirated software is: \( D_p = \int_{\hat{y}}^{\hat{x}} \frac{1}{\theta_H - \theta_L} dx = \frac{q p_o - p_p}{(\theta_H - \theta_L)q(1 - q)} \)
The Game

In the first period of the game, the original firm invests in R&D, while in the second period if the pirate survives, both firms compete in price. We look for subgame perfect equilibrium of the two period game and solve using the usual method of backward induction.

3.2 Price Competition in the Product Market

In the second period, if the pirate operates, the two firms engage in a Bertrand price competition and choose the profit maximizing prices of the respective products.

The profit function of the pirate is: $\pi_p = (p_p - cx)D_p = \left( p_p - cx \right) \frac{qP_o - p_p}{\left( \theta_H - \theta_L \right)q(1-q)}$

The profit function of the original firm is: $\pi_o^2 = p_oD_o = p_o \frac{\theta_H (1-q) - (p_o - p_p)}{\left( \theta_H - \theta_L \right)(1-q)}$

Firms maximize their respective profits with respect to price.

The reaction functions of the original firm and the pirate are as follows.

$R_o(p_p) = \frac{p_p}{2} + \frac{(1-q)\theta_H}{2}$; $R_p(p_o) = \frac{qP_o}{2} + \frac{cx}{2}$

Notice that as the original firm increases investment effort in the first period, higher will be $x$ in the second period, which means higher will be the marginal cost of copying to the pirate. Thus a increase in $x$ (or an increase in the exogenous parameter $c$) will shift the reaction function of the pirate upward. This will result higher equilibrium prices for both the original firm and the pirate. It is easy to see that the original firm will gain from this change in the product market competition stage as it is now charging higher price while its costs in that period remains the same. However, for the pirate since the total cost of piracy goes up for this change, the net effect in the change in total profit remains ambiguous. The possibility that there could be no real change in profit or even a decline in profit of the pirate cannot be ruled out.

The Nash equilibrium in prices are given by

$p_o = \frac{1}{4-q} \left[ 2\theta_H (1-q) + cx \right], p_p = \frac{1}{4-q} \left[ \theta_H q (1-q) + 2cx \right]$
Equilibrium demands are given by

\[ D_o = \frac{1}{(4-q)(1-q)(\theta_H - \theta_L)} \left[ 2\theta_H (1-q) + cx \right] ; \]

\[ D_p = \frac{1}{(4-q)q(1-q)(\theta_H - \theta_L)} \left[ \theta_H q (1-q) - cx (2-q) \right] \]

The equilibrium profits are given by

\[ \pi_o^2 = p_o D_o \quad \text{and} \quad \pi_p = (p_p - cx) D_p \]

3.3 Pirate’s Decision

The pirate will be in business as long as it can make positive profit, which consequently puts an upper bound on \( x \).

Equating \( \pi_p = 0 \), we get \( \hat{x} = \frac{\theta_H q (1-q)}{c(2-q)} \)

Thus for all \( x \geq \hat{x} \), the profit of the pirate becomes non-positive hence, the pirate will not operate, and piracy will be deterred.

3.4 Choice of Optimal Level of Deterrence by the Software Developer

Now we move on to the first period of the game. In this period, original firm decides on its optimal choice on the level of \( x \) to deter piracy.

Thus it maximizes its net profit \( \pi_o = \pi_o^2 - c_o (x) = \pi_o^2 - \frac{1}{2} x^2 \) with respect to \( x \).

Solving, we get the optimal level of deterrence \( x^* = \frac{4\theta_H c (1-q)}{(4-q)^2 (1-q)(\theta_H - \theta_L) - 2c^2} \)

Now given the fact that when \( x = \hat{x} \), the pirate stays out; the actual optimal level of deterrence is given by \( \min (x^*, \hat{x}) \).\(^{12}\)

\(^{12}\) Note that if \( c = 0 \) i.e. when the original firm’s investment effort has no effect in deterring piracy, the original firm will not choose any R&D investment in the first place, hence \( x^* = 0 \).
To ensure \( x^* > 0 \) we must have \( (4-q)^2(1-q)(\theta_H-\theta_L) > 2c^2 \) i.e. when \( c < \sqrt{\frac{(1-q)(\theta_H-\theta_L)}{2}(4-q)} = \alpha(q,\theta_L,\theta_H) \); (say). Hence, the effective range of \( c \) for which the analysis is valid is given by \( 0 < c < \alpha(q,\theta_L,\theta_H) \).  

3.5 Results

Now we would like to see under what condition the optimal level of deterrence \( x^* \geq \hat{x} \), where \( \hat{x} \) is the actual level of deterrence of the pirate.

\[ x^* \geq \hat{x} \text{ implies } c \geq \sqrt{\frac{q(4-q)(1-q)(\theta_H-\theta_L)}{2}} = \beta(q,\theta_L,\theta_H) \]; (say).

Note that this condition is well defined. Each term of the expression in the right hand side is non-negative, hence \( \beta(q,\theta_L,\theta_H) \geq 0 \). Also it is easy to verify \( \beta(q,\theta_L,\theta_H) < \alpha(q,\theta_L,\theta_H) \). Thus we have the following result.

**Proposition 1**

When the commercial pirate faces a deterrent to operate and stopping piracy is also a costly activity to the software firm,

(i) piracy will actually be stopped if \( c \geq \beta(q,\theta_L,\theta_H) \).

(ii) the pirate survives in the market if \( 0 < c < \beta(q,\theta_L,\theta_H) \).

**Economic Interpretation**

Now we concentrate on some features of an economy that affect the above two conditions (i) \( c \geq \beta(q,\theta_L,\theta_H) \) and (ii) \( 0 < c < \beta(q,\theta_L,\theta_H) \). This in turn would determine whether in this economy, piracy will take place or not. These factors are (1) the valuation (recall \( X \sim U[\theta_L,\theta_H] \)) of the software user towards the software, which is same as the willingness to pay for the software. We assume the willingness to pay for software is

\[ ^{13} \text{Enough heterogeneity in the market i.e. a wide income gap in the economy guaranties that this condition will always be satisfied. This restriction is coming on the range of } c \text{ because our concerned } q \text{ is less than one.} \]
positively correlated proportional to the income of the consumer, and for our analysis we look into the income gap of the potential software users in the economy; (2) the strictness of the legal enforcement system against the pirate measured by \( c \); which effectively determines how costly for the pirate to survive in the market; (3) the quality and reliability \( q \) of the available pirated product. This last parameter also determines how much the pirated product is differentiated from the original one. In our analysis, we find that the interaction of these three parameters broadly determine the existence (or non-existence) of piracy in the economy.

First we would like to explain that given a certain degree of income gap among the potential software users under what situations (i.e. parametric configurations of \( c \) and \( q \)), it is more likely that one of the above inequalities ((i) and (ii) in proposition 1) will be satisfied, and as a result piracy will be stopped or continue. Later, we will discuss the impact of income gap itself on the existence of piracy. Income gap among the potential software users is measured by \( \theta_H - \theta_L \).

Environment conducive to stop piracy:
In condition (i), \( c \) becomes higher as the legal enforcement against the pirate gets stronger. For example, a country with a tough legal enforcement system can make the cost of piracy high for the pirate, which naturally makes difficult for the pirate to survive. On the other hand, in condition (i) \( \beta(q, \theta_L, \theta_H) \) will be lower if the pirate produces a copy which is either very unreliable (i.e. \( q \) close to zero) or very similar to the original product (i.e. \( q \) close to 1). The first case is straightforward to understand while the latter is bit counter intuitive. First of all, if it produces unreliable (low quality) product then very few people will buy from the pirate, hence that will make difficult for the pirate to survive in the market. While if it produces a product very similar to the original one, a very tough price competition will drive down the price. In this case, to protect its market the original firm has a higher incentive to raise the deterrence for the pirate, so that the pirate indeed produces at a significant cost disadvantage in the price competition stage and drops out of the market. This result is counter intuitive in a sense that even if the
pirate produces a reasonably high quality product, it still fails to survive in the market. This happens because of the existing cost asymmetry between the software developer and the pirate at the price competition stage. Hence, under these situations, it is more likely that the inequality (i) will be satisfied and piracy will be stopped.

Environment conducive for the pirate’s survival:
On the contrary, the inequality (ii) is more likely to be satisfied, when the legal enforcement system against the pirate is not strong i.e. low $c$, hence piracy is not that costly to the pirate. At the same time $\beta(q, \theta_L, \theta_H)$ gets bigger when the pirate produces a product which is moderately reliable (i.e. $q$ is away from zero) but not too close to the original product (i.e. $q$ is away from one). Note that in most cases the pirated product does not come with any supporting service or guarantee, making $q$ away from 1 anyway. Thus the combining effect of low $c$ and moderate $q$ will make it easier for the pirate to survive. Also note that in this case, the two products are enough (vertically) differentiated, the price competition is softened and as a result the original firm has less incentive to deter the pirate. Thus, the pirate survives. It will be too costly for the original firm to stop piracy in this situation. Thus we have the following result.

**Proposition 2**

*For a given level of income gap among the software users if the pirated product is moderately reliable and the legal enforcement against the commercial pirate is low, piracy will continue. Otherwise piracy is more likely to be stopped by the original software firm.*

In the following analysis, we see the effect of income gap in the society on the existence of piracy. We will vary $(\theta_H - \theta_L)$ while taking $(c)$ and $(q)$ as given. First, we start with some limit results.
Some Limit Results

We have $\beta(q, \theta_L, \theta_H) = \sqrt{\frac{q(4-q)(1-q)(\theta_H - \theta_L)}{2}}$

Note that as $(\theta_H - \theta_L) \to \infty; \beta(q, \theta_L, \theta_H) \to \infty$. Now from proposition 1 it is easy to see when income gap is very high in the economy even a very high level of enforcement policy may not eliminate piracy.

On the other hand, as $(\theta_H - \theta_L) \to 0; \beta(q, \theta_L, \theta_H) \to 0$, implying even a small level of enforcement policy may be just enough to eliminate piracy, when income gap is low in the economy.

Combining above two possible features of income gap with legal enforcement situation we have the following result.

Proposition 3

(i) If the income gap among the software users is high and the enforcement policy against piracy is weak i.e. $c$ is low, then piracy may not be stopped.

(ii) If the income gap among the software users is not high, then for any moderate (or even small) degree of enforcement against piracy is likely to eliminate piracy.

3.6 Effect of Income Disparity on Piracy with reference to Developed and Developing nations

In many developing nations the income gap between rich and poor is rather high. It is also true that the enforcement policies against piracy or in general copyright violations are rather weak (as compared to developed nations due to the existence of widespread corruption, bribery etc.) in these countries, giving rise to a lower value of $c$. Hence, the possibility of piracy looms large in such situations. This is also evident from the data (source: BSA and IDC 2005), where it shows the rates of piracy in most of the developing countries are rather high. On the other hand, in general (although there are exceptions), relatively less income gap is observed in the rich and developed nations compared to developing nations. One can expect a higher $c$ in the developed nations due
to strict enforcement policies against copyright violations. Hence, given a certain quality \( q \) of the pirated software, according to this analysis, we will expect less piracy in the developed countries compared to developing countries. This is also evident from the data (source: BSA and IDC 2005), which shows that the rates of piracy in general are much lower in developed nations compared to developing nations.

Following some literature on piracy, we are also tempted to provide an alternative explanation here. We argue that the existence of a significant proportion of middle income group could also be an explanation for higher piracy rates in the society. This is also evident from our analysis (refer figure 1 also). The consumers who are mostly attracted to the pirated software are those whose valuations for software is not too high or low, in other words, according to this analysis they mostly belong to middle income group of the society. We argue that lower and higher income group will usually contribute less towards piracy; while the middle income group contributes to it to a great extent. This is because of the following reason. Generally speaking, low income group people (this is truer in developing countries) are too poor to buy a computer in the first place, and also because of their lower skill level, their computer usage is generally low. Hence, they do not require software (pirated or otherwise) for most of their activities. On the other hand, the high income group is rich enough to buy original software if they need it. That leaves us with the middle income group of people, who are generally educated and skilled, and usually have a lot of computer usage for professional and private purpose. Now even if they can somehow afford to buy the computer but purchasing all the original software at the high retail price is not always possible. However, since they need the software anyway for their work, they have to find a way around and piracy is one such easy option to them. Thus, in general, we expect to see higher rates of piracy in a country where there is a sizeable and growing middle class. Countries like India, China, Indonesia, Mexico would be good examples where there are sizeable and growing middle class. Data confirms that these are the places where the average piracy rates are quite high compared to other developed countries.
4. Welfare Issues and Other Possible Deterrence

To discuss the welfare issues and other possible deterrence in this framework, we provide an example assuming that the continuum of consumers, denoted by \( X \) is uniformly distributed over the interval \([0,1]\). The size of the market is normalized to 1.

4.1 Welfare

We try to make a comparison on social welfare in two cases, namely (i) when the pirate is out of the market due to successful entry deterrence by the original firm, and (ii) when the original firm is unable to deter the pirate.

Case (i) corresponds to a monopoly situation and it is true when \( \min(x^*, \hat{x}) = \hat{x} \)

Welfare is defined as sum of consumer surplus (CS), industry profit (\( P \)) minus the cost of deterrence (\( DC \)). In this monopoly situation, let’s say welfare \( W^M \) is given by,

\[
W^M = CS + P - DC = \frac{1}{8} + \frac{1}{4} - \frac{1}{2} \left( \frac{q(1-q)}{c(1-q)} \right)^2 = \frac{3}{8} - \frac{1}{2} \left( \frac{q(1-q)}{c(1-q)} \right)^2
\]

(3)

Case (ii) corresponds to the duopoly situation when the pirate is present and it is true when \( \min(x^*, \hat{x}) = x^* \) and \( \pi^A(x^*) > \pi^M_O(\hat{x}) \), where \( \pi^A \) denotes the profit of the original firm under accommodation and \( \pi^M_O \) denotes its profit under deterrence.

In this case, total welfare \( W \) is given by,

\[
W = \pi_O + \pi_P + CS_O + CS_P - \frac{1}{2} \left( \frac{4c(1-q)}{(4-q)^2(1-q)-2c^2} \right)^2
\]

(4)

The following is true.

**Lemma**

In the case of successful deterrence, the monopoly price \( p_M = \frac{1}{2} \) is greater than the price of the original firm \( p_O \) in the duopoly case.

**Proof:** To show \( p_M = \frac{1}{2} > p_O = \frac{2(1-q)+cx}{4-q} \) when \( x = x^* \)

Above implies \( 3q > 2cx^* \)
Here, \( x^* = \frac{4c(1-q)}{(4-q)^2(1-q)-2c^2} \) when \( X \) follows \( U[0,1] \).

After simplification \( 3q > 2cx^* \) implies \( c < \sqrt{3} \beta(q) \).

Now since we are under the sub case (i.e. the case of piracy) \( c < \beta(q) \), the above is true. Hence, the result follows. Q.E.D.

Thus we have the following: \( p_M > p_O > p_P \) which implies the total consumer surplus (CS) is higher in the presence of the pirate (duopoly case) compared to the monopoly situation. On the other hand, the total industry profit in the duopoly case is lower than the industry profit in the monopoly case.

Finally, \( c(\hat{x}) \) in case (i) is greater than \( c(x^*) \) in case (ii) as \( x^* < \hat{x} \).

So comparing (3) and (4) we get,

\[
W^M - W = \Delta CS + \Delta P + \Delta DC
\]

From above we get \( \Delta CS < 0, \Delta P > 0, \) and \( \Delta DC < 0 \), so the overall difference is ambiguous.

Thus, the overall effect on social welfare due to the presence of the pirate is ambiguous. Contrary to other situations (where piracy hugely increases the usage of software in a society, and thus enhances welfare, see Chen and Png, 2003) here we find the overall effect on social welfare due to the presence of the pirate may not be necessary welfare improving. This is mainly because the pirate faces a significant deterring cost of piracy while operating and at the same time cost of monitoring/R&D results in lower producer profit.

4.2 Other Possible Deterrence

When \( x^* < \hat{x} \) (i.e. optimal level of deterrence is less than the actual deterrence level of the pirate), whether piracy will be actually deterred or not by the original producer depends on whether entry-deterring monopoly profit \( \pi^M_O \) of the original producer is more or less than its accommodating duopoly profit \( \pi^*_O \).

In this case, the entry deterring monopoly profit of the original producer is given by
\[ \pi^M_o(\hat{x}) = \frac{1}{4} - c_o(\hat{x}) = \frac{1}{4} - \frac{1}{2}(\hat{x})^2 = \frac{1}{4} - \frac{1}{2}\left(\frac{q(1-q)}{c(2-q)}\right)^2 \]  

(1)

On the other hand, the accommodating duopoly profit the original producer is given by

\[ \pi^A_o(x^*) = \frac{2(1-q) + c}{(4-q)^2(1-q) - 2c^2} \left(\frac{4c(1-q)}{(4-q)^2(1-q) - 2c^2}\right) - \frac{1}{2}\left(\frac{4c(1-q)}{(4-q)^2(1-q) - 2c^2}\right)^2 \]  

(2)

**Proposition 4**

*When optimal level of deterrence is less than the actual deterrence level of the pirate (i.e. \( x^* < \hat{x} \)), piracy will be stopped if and only if \( \pi^M_o(\hat{x}) > \pi^A_o(x^*) \).*

If the above fails to hold, the original producer will fail to deter the pirate and as a result piracy will take place anyway.

**5. End User Piracy**

Under this situation, for simplicity we assume there is no commercial pirate in the economy. The consumers (i.e. all potential software users) are the potential pirates. As before, there is one original software developer (monopoly) and consumers’ valuations are uniformly distributed over the interval \([\theta_L, \theta_H]\); \( \theta_H > \theta_L \geq 0 \) and the size of the market is normalized to 1. Consumers can buy the original product from the monopolist or pirate without paying anything. We assume the probability that a pirated software works is \( q \), \( q \in (0,1) \) and this probability is common knowledge. Interpretation of \( q \) is same as before. The activity of the original software firm remains exactly the same as before, except that now it targets the end user pirates to stop piracy as opposed to commercial pirate. Unlike the previous case, here it does not face any direct competition from anybody in the market; however, it stands to lose its potential market because of end
user piracy. Under this circumstance, it invests in R&D to raise the cost of piracy to the end users.\textsuperscript{14} Thus a consumer’s utility function is given as:

\[
U = \begin{cases} 
X - p & \text{if buys original software} \\
qX - cx & \text{if pirates} \\
0 & \text{otherwise}
\end{cases}
\]

where $x$ is the level of deterrence for piracy and $c > 0$ is the exogenous cost coefficient like before which measures the strictness of enforcement policy against copyright violations.

5.1 Deriving Demand of the Original and Pirated Software

![Figure 2: DISTRIBUTION OF BUYERS](image)

The marginal consumer, $\hat{X}$, who is indifferent between buying the original software and pirating is given by:

\[
\hat{X} - p = q \hat{X} - cx
\]

\[
\hat{X} = \frac{p - cx}{1 - q}
\]

The marginal consumer, $\hat{Y}$, who is indifferent between pirating the software and not buying any software is:

\[
q \hat{Y} - cx = 0
\]

\[
\hat{Y} = \frac{cx}{q}
\]

\textsuperscript{14} Here, we do not need the two period time structure as before, everything can be formulated within a single period.
Thus, the demand for the software firm is: 
\[
D_o = \int_\theta_H^\theta_L \frac{1}{\theta_H - \theta_L} \, d\theta = \frac{\theta_H (1-q) - (p-cx)}{(\theta_H - \theta_L)(1-q)}
\]

Demand for the pirated software is: 
\[
D_p = \int_\theta_H^\theta_L \frac{1}{\theta_H - \theta_L} \, d\theta = \frac{q \theta_H - \theta_L}{(\theta_H - \theta_L)q(1-q)}
\]

### 5.2 Choice of Optimal Price and Level of Deterrence by the Software Developer

The developer maximizes its net profit: 
\[
\pi_o = pD_o - c_o(x) = p \left( \frac{\theta_H (1-q) - (p-cx)}{(\theta_H - \theta_L)(1-q)} \right) - \frac{1}{2} x^2 \text{ with respect to } p \text{ and } x.
\]

Solving, we get, optimal price \( p^* = \frac{\theta_H (\theta_H - \theta_L)(1-q)^2}{2(\theta_H - \theta_L)(1-q) - c^2} \)

and the optimal level of deterrence \( x^* = \frac{\theta_H c(1-q)}{2(\theta_H - \theta_L)(1-q) - c^2} \).

### 5.3 Condition for No Piracy

Nobody will find piracy worthwhile if the person, who is just indifferent between buying the original product and pirating finds it not worthwhile to pirate. In other words, piracy is not worthwhile for anybody if \( q \left( \frac{p-cx}{1-q} \right) - cx \leq 0 \Rightarrow cx \geq pq \) (Recall \( \hat{x} = \frac{p-cx}{1-q} \) is the indifferent person between buying and pirating)

Hence the condition for no piracy is given by: \( cx \geq pq \).

### 5.4 Result

Substituting the optimal price \( p^* \) and optimal level of deterrence \( x^* \) into no piracy condition, we get the following result.

---

\(^{15}\) To have \( x^* > 0 \) implies \( c < \sqrt{2(1-q)(\theta_H - \theta_L)} \), otherwise deterrence is unnecessary.
Proposition 5

When the pirates are the end users and stopping piracy is a costly activity to the software firm, the piracy will actually be stopped if \( c \geq \sqrt{q(1-q)(\theta_H - \theta_L)} \).

Economic Interpretation

Here also we find that the existence (or non existence) of piracy depends on those factors we considered before, namely, income gap, legal enforcement, and the quality of pirated software. High income gap (i.e. when \((\theta_H - \theta_L)\) is high) associated with reliable pirated product (i.e. medium \(q\)) will make RHS of the condition (proposition 5) bigger. This in association with weak legal enforcement against pirates (i.e. low \(c\), LHS) will make much harder to satisfy the condition. Hence, in such situations we would expect more piracy to happen. It is not hard to see that most developing countries generically satisfy those conditions, which also explains higher rates of piracy in those countries. On the other hand, in most developed countries except for the quality of the pirated software, which could possibly vary to a large extent, the reverse is true. Hence, it is more likely that the above inequality would be satisfied in such conditions, and consequently, we should observe relatively less piracy in those countries as is evident from the data (Source: BSA and IDC 2005). The other possible explanation which we provided in section 3.6 (regarding the presence of a large middle income group in the society) is also applicable here. Thus, the model of end users piracy can provide a rational for the varying piracy rates across countries and in particular, developed and developing countries.

6. Conclusion

In this paper, we looked for a theoretical justification to explain the phenomenon, why do we observe big differences in software piracy rates across regions and in particular, why there exists a wide gap in the piracy rates between developed and developing nations. Although there are empirical studies to understand this phenomenon, but to the best of our knowledge no theoretical framework has been used explicitly to address this question. In this paper, we develop a theoretical model where the software firm
undertakes costly deterrence activity in the form of R&D to stop or limit piracy. Existence (or non-existence) of piracy is solved endogenously in a model of commercial piracy and end-users piracy. In the case of commercial piracy, the existence (or non-existence) of piracy comes out as an endogenous outcome of the strategic game between the pirate and the original software firm; and in the case of end user piracy it comes out as a result of endogenously determined optimal level of deterrence by the monopolist software firm. We show that the variance in piracy rates across markets and across countries can well be understood through certain important features of an economy like: the income gap of all potential software users (i.e. population in general); the strictness of the enforcement policy against piracy in a particular society or country, which effectively determines the cost of piracy in that country/society; the quality and reliability of the pirated software product. If we have reasonably good information on these parameters (or if we can estimate the values from data) for various software markets, our analysis provides a platform to empirically address the question as well. Although our model depicts a much simplified situation, nevertheless, the analysis does give some insights about the phenomenon of varying degree of software piracy rates across regions. We hope that the explanations provided here verify our natural intuitions on this phenomenon as well.

Reference


