Trading Higher Software Piracy for Higher Profits: The Case of Phantom Piracy

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Abstract

This paper analytically explores the effect of software bundling on software piracy. We focus on piracy at individual user level where several individuals illegitimately share a single copy of software. We develop an economic model of software piracy with bundling of two products that are not identically distributed. We derive results for optimal level of piracy and profits for individual products as well as for the bundle. Our results indicate that bundling results in a level of piracy that is always less than the piracy level of one of the products of the bundle. However, it is possible to trade off the piracy level of one product for overall higher profits, i.e., a seller can derive higher profits even with higher levels of piracy for one of the products in the bundle. We derive exact bounds for two cases: (i) where piracy level of the bundle is smaller than the piracy level of both the products in the bundle, and (ii) where the profits from a bundle are always higher even with higher piracy level than one of the products.

1. Introduction

Information technology (IT) and software industry have driven the U.S. and global economy in the last decade. In particular, the U.S. software industry leads the information economy and is a major player in the global market. U.S. Census Bureau data released in 2001\(^1\) shows that software and information revenue totaled $95.4 billion in 1999. The Software & Information Industry Association (SIIA), for the same period, assesses the worldwide losses due to piracy at about $12 billion. The global nature of software markets, the piracy rates differ significantly across different regions of the world. The Business Software Alliance (BSA) and SIIA's joint research shows that the piracy rates are highest in Asia-Pacific region with an average of 51%, with some countries having a piracy rate above 95%. Even in the U.S., where the piracy rates are smallest, the losses due to piracy are estimated at 24%. Figure 1 provides an overview of worldwide software piracy [14].

Broadly defined, software piracy is the illegal act of copying software without explicit permission from and compensation to the copyright holder. However, the software pirates can be divided in three distinct categories: 1) individual users duplicating from a single legitimate copy (Koen and Im [11] call this soft-lifting); 2) individuals duplicating copies of a software to resell the software; and 3) copies of the software in corporations that violate the software licenses.

The industry watchdog groups, such as SIIA, are focusing on the last two categories of software piracy by providing education and highlighting the problem. For example, SIIA documented that over 90% of the software being sold on the Internet auction sites is illegitimate. These watchdog groups then work with the industry, such as auction sites and software manufacturers, to try and develop mechanisms to reduce such piracy. For corporate customers, the industry provides training and audit tools, such as Key Audit\(^2\), to keep track of unlicensed software or to detect violations of any software licenses.

The literature on criminology identifies preventives and deterrents as two measures to combat crime [5]. The objective of preventives is to increase the costs of engaging in the criminal activity by forcing the perpetrator to expend and deplete resources in the pursuit of a goal. Deterrents impose the threat of legal sanctions to hinder individuals from committing crimes. The purpose of deterrents is to prevent the intent from becoming a reality. The examples of preventive control include hardware-based controls such as nonstandard disks, coder cards and hardware locks, and software-based controls such as special password codes and encryption [12]. These techniques have not been widely used as they tend to hurt legitimate buyers, and

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\(^1\) Software & Information Industry Association's (SIIA) analysis of 1999 Annual Survey of Services that is conducted by U.S. Census Bureau.

\(^2\) http://www.sassafras.com/keyaudit.html
determined pirates can overcome the controls. For example, hackers can disassemble the code and bypass the licensing calls completely, as was the case with Ocean's *RoboCop* 3 game software for the Amiga platform. Furthermore, the techniques to defeat the preventative controls can be easily transferred through vehicles such as the Internet [1]. Deterrent controls for software piracy attempt to dissuade users from copying software through legal, investigative and educational campaigns [10, 13]. When effective, an individual refrains from piracy out of a perceived threat or fear of sanctions. Besides the legal dimension, these controls endeavor to highlight the moral force behind the laws to achieve compliance. The Software Publishers Association (SPA), BSA, and SIIA representing over 1200 software companies, actively pursue investigative campaigns by setting up piracy hotlines, filing lawsuits, and engaging in educational campaigns by disseminating information on the legal aspects of software piracy.

The software industry has focused on creating preventive and deterrent measures for curbing resale of pirated software and to prevent misuse of licenses in large organizations. Little has been done to prevent software piracy at individual level where a small group of individuals may share a single copy of the software without appropriate license. The primary reason has been the inconvenience that preventive measures create. However, with its large install base, Microsoft is trying to use preventive measures to curb individual piracy. For example, Microsoft's Office XP requires users to register online, otherwise the program ceases to operate. Furthermore, even with registration information, it does not let users do more than a couple of installations without explicit directions from customer support. It remains to be seen whether such measures drive users away from upgrading their Microsoft Office products.

In this paper we explore the effect of software product bundling on software piracy among individuals that illegitimately share a single copy of software. These individuals typically derive value from using the software, however, they typically do not intend to gain monetary benefits directly by selling and/or sharing software. Our focus is on strategic measures to reduce the software piracy or losses due to software piracy among this domain of users. We build on the works of Gopal and Saunders [7, 8, 9] that focused on economic theory of clubs and Bakos and Brynjolfsson [2, 3] who focused on the effect of bundling on producers profit.

Economic models of piracy in general study the impact of piracy on profits, and in particular the effect of enforcing copyright. Conventional wisdom suggests that piracy represents a drain on publisher profits and reducing piracy forces consumers to legitimately acquire software. Gopal and Sanders [7] argue that the effect on profits is positive only when the anti-piracy measures appropriate a higher price from the software pirates. The net effect on profits is based on a combination of the market price for the software and the type of anti-piracy controls enforced. Their analytical results show that only deterrent controls improve publisher profits. In the face of increasing preventative controls, individuals do not legitimately acquire software but instead simply do-without the software, and this behavior represents a drain on publisher profits. Their results also show that the welfare of the country increases with deterrent controls and for evidence they point to the increasingly active role of the U.S. Congress in enacting legislation against software piracy. Conner and Rumelt [6] argue that software piracy may not be harmful for certain types of software products that exhibit network externalities. The consumption utility for these products depends on the total user base. The utility of the software consumption increases with software piracy as it increases the total number of individuals using it. Bakos, Brynjolfsson, and Lichtman [4] looked at another aspect of the problem and showed that under certain common assumptions, piracy of software can increase a seller’s profit when the size of the groups sharing the product is constant; they also showed that profits also increase when individuals sharing a good have greater variation in product valuations.

In this paper, we develop an economic model to test the effect of product bundling on software piracy (via sharing). We develop economic models and derive expressions for shared level of piracy with product bundling. We consider bundles of two products under the general assumption that product valuations are not identically distributed. We also introduce the concept of, and derive conditions for, phantom piracy — where the level of piracy for less valued product is greater than the level of piracy for that product alone, however, it is less than the level of piracy for higher valued product.

The rest of this paper is organized as follows. In section 2, we present the model of software sharing and derive expression for optimal level of sharing. In section 3 we present the case of bundling 2 products and derive an expression for optimal sharing level. Section 3 also presents analytical bounds on the relative valuations of two products such that no Phantom Piracy takes place and show that even with piracy profits of the bundle are always higher than the profits obtained by selling the products of the bundle individually. Section 4 presents results from some numerical simulations. Finally, section 5 concludes the paper with summary of results and future research directions.

2. Software Piracy via Sharing

Bakos, Brynjolfsson, and Lichtman [4] found that piracy via sharing can increase a seller's profit. Setting a
price that endogenously assumes a level of sharing can yield such a result. In this section we present a model, based on the model of Gopal and Saunders [7], which assumes that the market price of a product is set assuming that a fixed level of sharing will occur.

The purpose of the model is to analyze the economic behavior of the software publishers and consumers. We assume that each participating entity exhibits a value maximizing behavior. In particular, the software publishers attempt to maximize profits, and consumers endeavor to maximize the net value of acquiring the software.

Since the consumption utility to a consumer does not decrease when the software is shared with other individuals we use the concept of software piracy clubs where individuals in the club purchase one legitimate unit of the software and make copies for the entire club. We model the effect of deterrents by software industry by making the assumption that as the clubs become larger and as they pirate more products, it is easier for them to be detected and penalized. Let \( p_m \) denote the market price of the software product, \( p_i \) denote the component of price that each individual member of a club has to pay, \( b \) denote the number of products in a product bundle, and \( c \) denote the penalty (deterrent control) per product each individual club member has to pay if the club is detected. The effective price paid by an individual in a club of size \( n \) can be represented as

\[
p_i = \frac{p_m}{n} + cb(n-1)
\]

where \( cb(n-1) \) depicts the cost to an individual due to deterrent controls and it increases monotonically with the size of the club and number of products in a product bundle. This captures the fact that larger clubs and clubs sharing a large number of products are easier to detect. Given the market price and deterrent controls, the software clubs will control their membership to balance the benefits of lowered price along with the threat of detection and ensuing legal sanctions. Thus minimizing equation (1) with respect to \( n \) yields:

\[
n^* = \sqrt{\frac{p_m}{bc}}
\]

where \( n^* \) is the optimal club size for a given \( p_m, b, \) and \( c \). Note that \( n^* \) represents the number of copies of the software in use for each copy of the software that is legitimately purchased from the software publisher. Thus, \( n^* \) measures the "extent of piracy." Since \( \frac{\partial n^*}{\partial c} < 0, \frac{\partial n^*}{\partial b} < 0, \) and \( \frac{\partial n^*}{\partial p_m} > 0, \) it follows that the software publisher can reduce piracy through increased deterrent controls, increased number of products in a bundle, or by reducing the market price of the software.

The aggregate demand for software is dependent on the price paid by individual consumers. For reasons of analytical tractability, we assume that the demand, \( d \), for individual products is uniformly distributed as follows:

\[
d = N - \alpha p_i
\]

\( N \) represents the maximum number of individuals interested in the product, i.e., \( N \) is the maximum possible demand. Figure 1 pictorially represents the demand with proportion in shaded area willing to obtain the product when the perceived cost to an individual in a club in \( p_i \). The parameter \( \alpha \) is the price sensitivity of demand, note that uniformly distributed demand implies that the product valuations are distributed \( U(0,N/\alpha) \) as depicted in figure 1. The parameter \( d \) denotes the total number of software units under use, purchased or copied. In other words, the legitimate purchases made from the publisher equals \( d/n \).

The production of software is characterized by significant fixed costs in developing and marketing the software and negligible marginal production costs [6]. Consequently, the software publisher’s profits \( \Pi \) can be represented by

\[
\Pi = \frac{d}{n} p_m - f
\]

where \( f \) is the fixed cost associated with developing and marketing the product. The publisher’s revenue \( R \) is given by \( \Pi + f \). For a single product, we can use equation (3) for \( d \). Substituting for \( p_m \) using equation (2) in equation (1), equation (3), and equation (4a) we can represent the profit function in terms of \( c, \alpha, \) and \( n \) as follows (note that \( b=1 \) for this case):

\[
\Pi_{\text{single}} = nc [N - \alpha (2n - 1)]\]

Differentiating equation (4b) with respect to club size, \( n \), equation (5) below provides the profit maximizing club size that follows the mapping of market price to individual price as specified in equation (1) for a single product:

\[
\frac{\partial \Pi_{\text{single}}}{\partial n} = nc \left[ -\alpha (2n - 1) - 2 \alpha n \right]
\]

\[
\frac{\partial \Pi_{\text{single}}}{\partial n} = 0 \implies n^* = \frac{N}{3\alpha}
\]
Substituting for $n$ in equation (4b) the optimal profit for a single product can be verified to be:

$$\Pi_{\text{single}}^* = \frac{(N + \alpha_c)^2}{8\alpha}$$  \hfill (6)

Now that we have expressions for the level of piracy for a single product, we can explore the effect of bundling 2 products together on the level of piracy. We first examine the case of bundling 2 identical products, i.e., where demand for both products is uniform and their valuations are the same. In section 4, we will examine the case where the 2 products have uniform demand but their valuations are different.

3. Effect of Bundling on Piracy and Profits

In this section we derive expressions for piracy levels when two products are bundled. We assume that the total market size for the 2 products being bundled is the same, i.e., $N$. Also, we assume that both products have independent uniformly distributed demand, however, we assume that the demand sensitivity of price for these products differ. Let $\alpha_1$ and $\alpha_2$ denote the price sensitivity of demand for the two products being bundled. Also, without loss of generality, assume $\alpha_1 > \alpha_2$. First, let us recall the profit maximizing piracy levels for these products, when sold individually, are:

$$n_1^* = \frac{N + \alpha_1 c}{4\alpha_1}$$ \hfill (7a)

$$n_2^* = \frac{N + \alpha_2 c}{4\alpha_2}$$ \hfill (7b)

Proposition 1 below establishes the relative magnitude of piracy for the 2 products.

**Proposition 1:** If $\alpha_1 > \alpha_2$, then the profit maximizing piracy level for product 1 is less than the profit maximizing piracy level for product 2.

**Proof:** we need to prove

$$\frac{N + \alpha_1 c}{4\alpha_1} < \frac{N + \alpha_2 c}{4\alpha_2}$$

$$\Rightarrow N(\alpha_1 - \alpha_2) < 0 \quad \text{(after simple algebraic manipulation)}$$

Which is true since $\alpha_1 > \alpha_2$.

The optimal profits for these products, when sold individually, are given by the following equations:

$$\Pi_1^* = \frac{(N + \alpha_1 c)^2}{8\alpha_1}$$ \hfill (8a)

$$\Pi_2^* = \frac{(N + \alpha_2 c)^2}{8\alpha_2}$$ \hfill (8b)

Therefore, the total profit when selling the products individually, $\Pi_{1,2}^*$, is given by:

$$\Pi_{1,2}^* = \frac{N^2(\alpha_1 + \alpha_2) + 4Nc\alpha_1\alpha_2 + c\alpha_1\alpha_2(\alpha_1 + \alpha_2)}{8\alpha_1\alpha_2}$$ \hfill (8c)

Now let us consider the bundle of product 1 and 2. The distribution function of the demand, $f_d(p_i, \alpha_1, \alpha_2)$, for the bundle will be the convolution of the two independent uniformly distributed demand distribution. This distribution function is given by:

$$f_d(p_i, \alpha_1, \alpha_2) = \begin{cases} \frac{\alpha_1 \alpha_2}{N^2}, & p_i \leq \frac{N}{\alpha_1} \\ \frac{\alpha_1}{N}, & \frac{N}{\alpha_1} < p_i \leq \frac{N}{\alpha_2} \\ \left[ \frac{\alpha_1 + \alpha_2}{N} - \frac{\alpha_1 \alpha_2}{N^2} \right], & \frac{N}{\alpha_2} < p_i \leq \frac{N}{\alpha_1} \end{cases}$$ \hfill (9)

Figure 2 graphically demonstrates the distribution. It can be shown that the optimal price will be between $N/\alpha_2$ and $N/\alpha_1$. The demand corresponding to such a price is shown in figure 2 in shaded area.

**Figure 2 - Demand for Bundled Product**

Equation (10) algebraically represents the bundled product demand, $d_b$, which is represented in the shaded area in figure 2.

$$d_b = \left( 1 + \frac{\alpha_2}{2\alpha_1} \frac{\alpha_2}{N} p_i \right)$$  \hfill (10)

To compute the profit function, we can use equation (2) to compute market price $p_m = 2n^* c$ since the bundle size here is 2. We can then use this value of $p_m$ to compute $p_i = 2c(2n-1)$ and then use these values of $p_i$, $p_m$, and $d_b$ in equation (4b) to compute the profit function as represented in equation (11) below:
\[ \Pi_b = 2nc \left( 1 + \frac{\alpha_2}{2\alpha_1} - \frac{\alpha_2}{N} 2c(2n-1) \right) \]  
(11)

Differentiating equation (11) with respect to \( n \) provides the optimal profit maximizing level of piracy as follows:

\[ n^*_b = \frac{N(2\alpha_1 + \alpha_2) + 4c\alpha_1\alpha_2}{16c\alpha_1\alpha_2} \]  
(12)

An interesting question at this point is whether we can say something about \( n^*_b \) in comparison with \( n^*_1 \) and \( n^*_2 \). Proposition 2 specifies the relationship between these three levels of piracy.

**Proposition 2:** The level of piracy for a bundle of two products will always be less than the individual level of piracy for the product with higher mean valuation in the bundle. In other words \( n^*_b < n^*_2 \).

**Proof:** By Contradiction

Suppose \( n^*_b \geq n^*_2 \) or

\[ \frac{N(2\alpha_1 + \alpha_2) + 4c\alpha_1\alpha_2}{16c\alpha_1\alpha_2} \geq \frac{N + \alpha_2 c}{4\alpha_2 c} \]  
(P2.1)

Let, \( \alpha_1 = \beta \alpha_2 \) (note that since \( \alpha_1 > \alpha_2 \Rightarrow \beta > 1 \)) (P2.2)

Substituting for \( \alpha_1 \) in the L.H.S. of inequality (P2.1) and rearranging we get

\[ 2\beta + 1 > 4\beta \]  -- a contradiction since \( \beta > 1 \).

While proposition 2 guarantees that the level of piracy of the bundle will always be less than the piracy level of higher valued item, we can not make such a statement about the product with the lower level of individual piracy, i.e., product 1 in our case. However, the proposition 3 below specifies a lower bound on the demand sensitivity of the higher valued product as compared to the lower valued product such that the piracy level of the bundle is always lower than the individual piracy level of both the products in the bundle.

**Proposition 3:** Let, \( \alpha_1 = \beta \alpha_2 \). As long as \( \beta < (3/2) \), \( n^*_b \) < \( n^*_1 \).

**Proof:**

If \( \frac{N(2\alpha_1 + \alpha_2) + 4c\alpha_1\alpha_2}{16c\alpha_1\alpha_2} < \frac{N + \alpha_2 c}{4\alpha_2 c} \)

By substituting \( \alpha_1 = \beta \alpha_2 \), we obtain

\[ \frac{N(2\beta \alpha_2 + \alpha_2) + 4c\beta^2 \alpha_2^2}{16\beta^2 \alpha_2^2} < \frac{N + \beta \alpha_2 c}{4\beta \alpha_2 c} \]

Simplifying, we get \( \beta < (3/2) \).

What happens if \( \beta \geq (3/2) \)? Clearly, in such situations, \( n^*_b \geq n^*_1 \). We define such a situation as **Phantom Piracy**. Phantom piracy may in-fact be desirable from a profit perspective. Essentially, when phantom piracy occurs, a seller is essentially trading the lower rate of piracy for one product (product number 2 here) for a higher rate of piracy for the other product (product 1 here). To investigate whether phantom piracy is desirable, we need to investigate the profits of the bundled products. Substituting the value of optimal level of piracy, \( n^*_b \), from equation (12) into equation (11), we get the optimal profit as:

\[ \Pi^*_b = \frac{(N(2\alpha_1 + \alpha_2) + 4c\alpha_1\alpha_2)^2}{32c\alpha_1^2 \alpha_2} \]  
(13)

We next derive the condition such that the profits from the bundled product are higher than that of the two products sold individually, i.e., the condition for \( \Pi^*_b > \Pi^*_{1,2} \). Using equations (8c) and (13) we need the following condition:

\[ \frac{(N(2\alpha_1 + \alpha_2) + 4c\alpha_1\alpha_2)^2}{32c\alpha_1^2 \alpha_2} > \frac{N^2(\alpha_1^2 + \alpha_2^2) + 4Nc\alpha_1\alpha_2 + c\alpha_1\alpha_2(\alpha_1 + \alpha_2)}{8\alpha_1^2 \alpha_2} \]  
(14a)

Upon simplification we get:

\[ 4N^2 \alpha_1^2 + 4N^2 \alpha_1 \alpha_2 + N^2 \alpha_2^2 + 16c^2 \alpha_1^2 \alpha_2^2 + 16Nc \alpha_1 \alpha_2 + 8Nc \alpha_1 \alpha_2^2 > 4N^2 \alpha_1^2 + 4N^2 \alpha_1 \alpha_2 + 4c^2 \alpha_1^2 \alpha_2^2 + 16Nc \alpha_1 \alpha_2 + 4c^2 \alpha_1 \alpha_2 \]  
(14b)

Canceling common terms and moving all the terms to LHS we get:

\[ N^2 \alpha_1^2 + 12c^2 \alpha_1^2 \alpha_2^2 + 8Nc \alpha_1 \alpha_2 - 4c^2 \alpha_1^3 > 0 \]  
(14c)

By substituting \( \alpha_1 = \beta \alpha_2 \) and simplifying, we get:

\[ N^2 + 8Nc \alpha_1 + 4\beta^2 c^2 \alpha_1^2 (3 - \beta) > 0 \]  
(14d)

Note that, in inequality (14d), the first 2 terms are always positive. However, the third term becomes negative when \( \beta > 3 \). Recall from proposition 3 that if \( \beta > (3/2) \) corresponds to the case of phantom piracy. Therefore, we can conclude from proposition 3 and inequality (14d) that in many instances Phantom piracy
may result in larger profits. For example, we can be sure that bundle profits are higher with Phantom piracy if \((3/2) < \beta \leq 3\). Proposition 4 provides a tight upper bound on the value of \(\beta\) such that the profits from the bundled product are always higher than those by selling the two products individually.

**Proposition 4:** Define \(\gamma = \frac{N}{c\beta\alpha_2}\), then if \(\beta < \left[\frac{3 + \gamma(8 + \gamma)}{4}\right]\) we will always have \(\Pi_b^* > \Pi_{1,2}^*\), i.e., higher profits from the bundled product as opposed to profits from selling the two products individually.

**Proof:**

Substituting \(c\beta\alpha_2 = \frac{N}{\gamma}\) in inequality (14d) we obtain

\[
N^2 + 8N\frac{N}{\gamma} + 4\left(\frac{N^2}{\gamma^2}\right)(3 - \beta) > 0 \quad \text{(P4.1)}
\]

Upon simplification, we get

\[
\left[3 + \gamma(8 + \gamma)/4\right] > \beta.
\]

As an example of proposition 4, if \(c = N/\alpha\beta\) (i.e., \(\gamma=1\)) then we will have greater profits from the bundle up to a value of \(\beta < 5.25\). Since sellers set the deterrent cost, \(c\) (which affects \(\gamma\)), a seller can always ensure that the bundle provides higher profits than the individual products. However, to increase the value of \(\beta\) we need to increase increasing the value of \(\gamma\), which in turn requires a lower value for \(c\). Since the profits are proportionately related to \(c\), the overall profits may go down.

In the next section, we provide results from some numerical simulations to provide further insights into the profits and relationship between profits and parameters \(N, c, \alpha, \beta,\) and \(\gamma\).

4. Numerical Simulations

Below we present two key numerical results that verify and graphically present the results derived in propositions 1-4. The data is presented in table 1. For these numerical computations, we fix the value of \(N = 10,500\) and \(c=1000\). We also fix the value of \(a_2=2\). We then vary the value of \(a_1\) to compute values of piracy levels and profits, both for individual products and the bundle. Figure 3 provides the verification of propositions 1 and 2. Note that piracy levels for product 1 (with higher \(a\)) is always lower than piracy levels of product 2. Also, note that when \(b < 1.5\) the piracy levels of product 1 is larger than that of the bundle and if \(b > 1.5\) the piracy level of the bundled product is higher than that of product 1.

![Figure 3 -- Piracy Levels of Individual and Bundled Products](image)
Figure 4 presents the results for the joint profits of the two products being sold individually and the bundled product. It also presents the comparison of actual $b$ and the bound according to proposition 4. The left hand side y-axis is for the profits and the right hand side y-axis is for comparing the upper bound versus the actual $b$ according to the parameterization. As the figure indicates as long as $b$ is below the bound, the profits from bundle are higher. However, if the $b$ is above the bound the profits of the bundle become smaller than that of the profits obtained from selling the products individually. The figure also demonstrates the region where Phantom piracy yields higher profits, i.e., the region where sellers can profitably trade the level of piracy for one product for higher profits.

5. Summary and Conclusions

In this paper we studied the effect of bundling on software piracy among individuals via illegitimately sharing a single copy of the software. The paper makes several new contributions to the literature both in commodity bundling and in the area of software piracy as summarized below.

We developed analytical models of software piracy and bundling by using economic theory of clubs. We showed that if two products have uniform demands with varying levels of demand sensitivity to price then bundling results in higher profits under certain circumstances. More importantly, though, we show that bundling does not always result in higher profits if piracy is a concern. We derive exact bounds on the relative price sensitivity for two products that would result in higher profits for the bundle. We also define a concept termed Phantom Piracy that occurs when the piracy level of a bundle is higher than one product's individual piracy level, however, it is less than the piracy level of the other product in the bundle. We derive exact bounds on the relative price sensitivity for two products beyond which such Phantom piracy takes place. The profitable region of Phantom piracy is derived in the paper. Note that, the profitable Phantom piracy region is a situation where sellers trade off higher piracy for one product in favor of lower piracy for other product while deriving overall higher profits.

In this paper we have derived results for bundling 2 products whose demand is independent from each other. In future, we will develop models for cases where demands for the products are correlated both positively and negatively. We will also explore generalizability of the results for more than 2 products. Furthermore, we will perform empirical studies to validate and enhance the results of the analytical models.
References