**BUNDLING OF SOFTWARE PRODUCTS AND SERVICES TO FIGHT AGAINST PIRACY**

*Completed Research*

**Xiong Zhang**  
City University of Hong Kong  
83 Tat Chee Ave, Kowloon Tong  
Hong Kong  
Xiong.Zhang@my.cityu.edu.hk

**Wei T. Yue**  
City University of Hong Kong  
83 Tat Chee Ave, Kowloon Tong  
Hong Kong  
Wei.T.Yue@cityu.edu.hk

**Abstract**

Bundling has been a widely used selling strategy in the software industry. In terms of fighting against software piracy, the bundling of software applications that are prone to different levels of piracy has been proposed as a way to minimize the negative impact due to software piracy. Until recently, software implementations have mostly been at the client’s end, which requires a variety of antipiracy strategies. With the emergence of software as a service model, software implementations move to the server’s end, which gives the software vendor greater flexibility to curb software piracy. In this paper, we analyze software piracy issues where a monopolist software vendor has the option to bundle software as a product and/or a service. Our study yields some interesting managerial perspectives to this newly emerging phenomenon.

**Keywords:** Bundling, Software Service, Digital Piracy, Digital Right Management
Introduction

The bundling of multiple software products has been a commonly used selling strategy in the software industry. For example, Microsoft Office comprises a set of commonly used software applications that support routine business functions. Prior studies have found that bundling a large number of unrelated information goods could be profitable for a monopolist (e.g., Bakos & Brynjolfsson, 1999). Recently, the bundling of multiple software products that are subject to various degrees of piracy has also been considered as a way to minimize the damages due to software piracy threats (Gopal & Gupta, 2010). Indeed, with the traditional software model where the software resides on the client’s end, software piracy remains to be one of the major threats for software firms, which amounted to a worldwide loss of $63.4 billion in 2011 (2011 BSA Global Software Piracy Study, 2012). However, with the emergence of software as a service (SaaS), many have considered that the “cloud” approach has become an increasingly viable way to fight against software piracy.1 Furthermore, Spotify, a music streaming company, found evidence that cloud-based music streaming curbs illegal music download in the Netherlands (Page, 2013). Unlike traditional shrink-wrap software (SWS), software vendors have greater control on who can access the software service (MacDonald, 2011). In fact, it has been acknowledged that Apple, with its iCloud, and Google, with its cloud-storage services, have been more effective in combating digital piracy than other ways (Calamia, 2011).

Software vendors have begun to provide software as a service. For example, Microsoft Office 365 offers many collaborative and online storage features that are not available in the offline version (Leonhard, 2011). Similarly, in the ERP market pure cloud service vendors is offering more standardized services whereas traditional software vendors can offer both bundled on-site and cloud services to their customers (Magnusson, Enquist & Juell-Skielse, 2012). The provision of software as a service essentially allow the software vendor greater flexibility in curbing software piracy as consumers now need to go through the authentication process before using the services. The software vendor can also combat piracy by limiting the number of access for an account, the access origin, etc (Patterson, 2013). However, such a distribution channel requires a costly infrastructure to support the software services. On the other hand, traditional software products run at the client side, where software vendors require the use of antipiracy measures such as digital rights management (DRM) to curb piracy. The use of such technical measures involves various economic trade-offs where the optimal antipiracy level could lead to some level of digital piracy (Sundararajan, 2004).

Since software as a service is becoming more popular, it is not immediately clear whether a software vendor should embrace the model of software as a service or that of software as a product or both (Walse, 2012). Furthermore, so far, no research has analyzed the economic prospects of software piracy when the software vendor can sell the software as a product or service or both. While software being offered as a service can be effective in fighting against piracy, investment in the infrastructure is required to maintain the software service. On the contrary, software being sold as a product does not require such a cost but requires the software vendors to consider the economic tradeoffs that may emerge as a result of the anti-piracy control. In this paper, we consider a problem where a monopolist software vendor has the option of offering the software as a product and/or software as a service. When offering traditional software, the software vendor determines the right antipiracy measure. When offering software as a service, the software vendor needs to pay the cost of information infrastructure to maintain the software service. Essentially, when given the two channels to distribute software, one is prone to piracy and is subjected to antipiracy cost, while the other is subjected to maintenance cost, but is free of piracy. Under such a scenario, we are interested in how the software vendor determines the pricing and antipiracy measure under different selling strategies, namely, pure component, pure bundling, and mixed bundling strategies. We summarize some of the interesting results.

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1 The U.S. Intellectual Property Enforcement Coordinator articulated this point with reference to Google and Apple (see http://www.reuters.com/article/2011/06/08/us-usa-intellectualproperty-idUSTRE7573AW20110608). Microsoft’s General Manager of corporate strategy also opinioned that the cloud platform curbing piracy is a long-term phenomenon (see http://www.zdnet.com/blog/microsoft/microsoft-moving-more-assets-to-the-cloud-may-curb-piracy/8139).
1. When faced with the situation where it is more expensive to protect against piracy of the software product, instead of relying more on the software as a service to derive revenue, the software vendor offers the software product at a lower price to increase the software product demand.

2. With regard to software piracy, we found that in addition to the mixed bundling selling strategy, the pure component strategy can sometimes be the optimal selling plan.

This paper is organized as follows: We review the related literature in the following section. After that, we present the model analyses in detail. In the last section, we discuss the limitations and future work.

**Literature Review**

There has been a long history of studies on product bundling in the economics and marketing area (e.g., Adams & Yellen, 1976; Venkatesh & Mahajan, 2009). In information systems, the bundling of information goods has received greater attention (e.g., Guo, Koehler, & Whinston, 2012; Goh & Bockstedt, 2012; Pang & Etzion, 2012). The literature on information goods assumes that the marginal cost of the product is zero, whereas in product bundling, the marginal cost is typically assumed to be present. In this paper, while software product has zero marginal cost, software service incurs an infrastructure marginal cost. Indeed, Huang and Sudararajan (2011) make the case that services must be supported by a fixed infrastructure investment along with a software service. To a certain extent, software product and software service are different versions of software. Bhargava and Choudhary (2008) take into account the issue of when it is considered optimal for a firm to offer different versions of information goods. Our work, although not explicitly modeled software product and software services as a different versions of software, could have implications on a software versioning strategy.

Prior studies have often treated software product and software service as competing products that are delivered through different channels. Fan, Kumar, and Whinston (2009) study the competition between SaaS and SWS. Demirkan, Cheng, and Bandyopadhyay (2010) study the arrangement between two critical components of SaaS: (1) the application infrastructure provider (AIP) and (2) the application service provider (ASP). Cheng and Koehler (2003) consider the different pricing menus for ASP along with the IT infrastructure capacity constraint. Zhang and Seidmann (2010) and Choudary (2007) examine the impact of subscription-based versus perpetual pricing for software. Although our study is related to the above studies in different aspects, software product and software service are not considered in the context of bundling in those studies. Furthermore, digital piracy is not considered.

There is a host of recent studies that consider the digital piracy issue from various perspectives. Sundararajan (2004) finds that there was a trade-off between strict DRM protection and loss of sales. Hui & Png (2003) empirically study the impact of piracy and expected penalty on the demand for a legitimate information product. Lahiri and Dey (2013) discover that piracy could lead to a higher-quality product being offered by the firms. Chellappa and Shivendu (2010) propose the use of pricing and sampling strategies together to fight against piracy. Jain (2008) finds that too much legal protection was not of benefit to firms because of the trade-off between the pricing and protection levels in a competitive setting. Vernik, Purohit, and Desai (2011) examine the impact of digital piracy on music. They assume that music can be distributed through two channels: (1) downloaded and (2) via CD. Similar to our study, piracy has been found to be possible on one channel (CD), but not using the other. In addition, it was found that less piracy control leads to less piracy, while an increase in sales through downloads leads to a decrease in sales of CDs. Gopal and Gupta (2010) also explore the effect of bundling products on different piracy levels. They found that it was profitable for a firm to bundle a product that would eventually lead to a higher frequency of piracy of the product in the bundle. To the best of our knowledge, little research has been conducted to understand the strategy for selling software products and software services when piracy is a factor to consider. Our study intends to shed more lights on the above issues.

**Model Development**

The seller is a profit-maximizing monopolist selling two products: (1) software as a product and (2) software as a service (hereafter identified as product 1 and product 2, respectively). The two products give rise to three selling strategies: (1) pure component, (2) pure bundling, and (3) mixed bundling. Assume that consumers are surplus maximizers and heterogeneous. Their reservation utility, \( r_1 \) (\( r_2 \)), for product 1
(product 2) is uniformly distributed in $r_1 \in [0,1]$ ($r_2 \in [0,1]$). When product 1 is purchased, it provides more utility in terms of running efficiency. The software process is not subject to network conditions. On the other hand, product 2 provides more online storage and sharing features. Take Microsoft Office 365, for example. It is the cloud version of Microsoft Office. Office 365 comes with features that are not found in the desktop version. They include office-on-the-go features such as Office tools built for mobile phones. Other features not found in the desktop version include built-in features that facilitate user collaborations. Those features are not equivalent to having a hosting service; they go beyond just putting Office in the web. Thus, there are features that are complementary in the two products. Depending on the complementarity of the two products, the reservation utility for the bundle, $r_{12}$, can be higher or lower than the sum of the individual reservation utilities, $r_1 + r_2$. The parameter $\alpha$ denotes that the complementarity/substitutability between product 1 and product 2 is $\frac{r_{12} - r_1 - r_2}{r_1 + r_2}$ (Venkatesh & Kamakura, 2003). When $\alpha > 0$, product 1 and product 2 complement each other. When $\alpha < 0$, the two products are substitute products. For modeling purposes, we assume that each potential consumer’s reservation utility for a bundle is equivalent to the reservation utility when he/she purchases a bundle or product 1 and 2 separately (i.e., $\alpha = 0$). When both products are purchased, we assume that the reservation utility is the sum of the two products. The seller’s unit price for product 1 (product 2 or bundle) is $p_1$ ($p_2$ or $p_B$). The seller’s marginal cost for the traditional software is negligible, as assumed by the study of Bakos, Brynjolfsson, and Lichtman (1999). To offer the software service, there is a marginal infrastructure cost $c$ (which we will just refer to as infrastructure cost). The demand for product 1 (product 2 or bundle) is $d_1$ ($d_2$ or $d_B$). Our model setup is similar to that of Venkatesh and Kamakura (2003), where a two-product bundling problem is considered. Unlike their model, where the seller incurs a marginal cost for both products, we assume zero marginal cost for the software product, and there is an infrastructure cost for the software service. Furthermore, we also incorporate software piracy into the model.

### Base Model

To study how the software vendor would fight against piracy, we first assume a base model where piracy does not exist. The purchase options of consumers under these three selling strategies in the base model are listed in Table 1.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Alternative Options</th>
<th>Respective Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure Component</td>
<td>Purchase product i</td>
<td>$r_i - p_i$</td>
</tr>
<tr>
<td></td>
<td>($i = 1$ or $2$)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purchase products 1</td>
<td>$(1 + \alpha) \sum_{i=1}^{2} r_i - \sum_{i=1}^{2} p_i$</td>
</tr>
<tr>
<td></td>
<td>and 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No purchase</td>
<td>0</td>
</tr>
<tr>
<td>Pure Bundling</td>
<td>Purchase the bundle</td>
<td>$(1 + \alpha) \sum_{i=1}^{2} r_i - p_B$</td>
</tr>
<tr>
<td></td>
<td>No purchase</td>
<td>0</td>
</tr>
<tr>
<td>Mixed Bundling</td>
<td>Purchase product i</td>
<td>$r_i - p_i$</td>
</tr>
<tr>
<td></td>
<td>($i = 1$ or $2$)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purchase the bundle</td>
<td>$(1 + \alpha) \sum_{i=1}^{2} r_i - p_B$</td>
</tr>
<tr>
<td></td>
<td>No purchase</td>
<td>0</td>
</tr>
</tbody>
</table>

In our model, the software vendor sets prices \((p_1, p_2, \text{and/or } p_B)\) to maximize its profit under different selling plans. The corresponding demands and profits are then realized. The sales levels under these three selling strategies are illustrated in Figure 1.

The software vendor compares the different selling plans and selects the plan with the highest profit. Table 2 lists profit functions under different product offering options. As an optimization model in the mixed bundling strategy has been proven analytically unsolvable, we derive a highly precise analytical approximation for equilibria in mixed bundling according to the approach of Bhargava (2011). Results are presented in the following proposition. Analytical results for the pure component and pure bundling strategies are presented in the Appendix.

**Table 2. Profit Functions in Base Model**

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Profit Function</th>
</tr>
</thead>
</table>
| Pure Component   | \[
| \pi = p_1 d_1 + (p_2 - c) d_2 \]
| w.r.t. \(p_1, p_2\) & s.t. \(0 < p_1 < 1 \) & \(c < p_2 < 1\) |
| Pure Bundling    | \[
| \pi = (p_B - c) d_B \]
| w.r.t. \(p_B\) & s.t. \(c < p_B < 2\) |
| Mixed Bundling   | \[
| \pi = p_1 d_1 + (p_2 - c) d_2 + (p_B - c) d_B \]
| w.r.t. \(p_1, p_2, p_B\) & s.t. \(0 < p_1 < \min(1, p_B) \) & \(c < p_2 < \min(1, p_B)\) & \(c < p_B < p_1 + p_2\) |

**Proposition 1:** The optimal prices for product 1, product 2, and the bundle under the three selling plans are the following:

**Table 3. Optimal Prices in Base Model**

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Optimal Prices</th>
</tr>
</thead>
</table>
| Pure Component   | Product 1: \(p_1^* = \frac{1}{2 + c}\)  
|                  | Product 2: \(p_2^* = \frac{1 + c}{2}\)  
| Pure Bundling    | Bundle: \(p_B^* = \begin{cases} \frac{(c + \sqrt{2 + 6 + 12c} - 2c)}{2(1 + c) + 2c}, & 0 < c < \frac{1 + c}{2} \\ \frac{c + \sqrt{2 + 6 + 12c} - 2c}{2(1 + c) + 2c}, & \frac{1 + c}{2} < c < 1 \end{cases}\)
Mixed Bundling

- **Product 1:** \( p_1 = \frac{1}{48} (3c + 38 - \sqrt{9c^2 + 292c + 36}) \)
- **Product 2:** \( p_2 = \frac{2+c}{3} \)
- **Bundle:** \( p_b = \frac{22+11c}{24} \)

i. In pure component, product 2’s optimal price increases with higher infrastructure cost, while product 1’s optimal price is independent of infrastructure cost.

ii. In pure bundling, bundle’s optimal price increases with higher infrastructure cost.

iii. In mixed bundling, product 1’s optimal price decreases with higher infrastructure cost; however, the optimal prices of both product 2 and bundle increase with higher infrastructure cost.

All proofs can be found in the Appendix.

The optimal prices would allow us to derive the equilibrium demands and profits. From Proposition 1, it can be seen that a higher marginal cost on service infrastructure would lead to a greater equilibrium price. For pure bundling, as the infrastructure cost increases, the optimal bundle price increases. For mixed bundling, through comparative analysis, we have \( \frac{\partial p_1}{\partial c} < 0, \frac{\partial p_2}{\partial c} > 0, \) and \( \frac{\partial p_b}{\partial c} > 0. \) When the infrastructure cost for software service increases, the optimal price for software service and the bundle increases, but interestingly, the optimal price of traditional software decreases. The insight here is when facing a higher marginal cost for service infrastructure, the software vendor would set higher prices for product 2 and the bundle. To offset this profit loss, the software vendor would set a lower price for the traditional software product to attract more consumers. Comparing the three selling plans in the base model, we state the following lemma:

**Proposition 2:**

Mixed bundling is the most profitable selling plan for all infrastructures.

This analysis is consistent with the study of Schmalensee (1984) and Venkatesh and Mahajan (2009). In general, the pure component strategy attracts consumers whose utility is high for one product but not the other. Pure bundling reduces consumer heterogeneity and attracts consumers who value both products. Mixed bundling is optimal among the three selling plans regardless of the level of infrastructure cost of software services because it combines the advantages of both pure component and pure bundling. The software vendor would be able to set higher equilibrium prices for the two products and the bundle in mixed bundling.

**Piracy Model**

We assume piracy is possible for software product, but not for software service. Consumers discount pirate product by a factor of \( \mu, \) where \( 0 < \mu < 1. \) They also incur a pirating cost \( g, \) which includes legal costs and searching costs for consuming the pirate product (Lahiri & Dey, 2013). It’s reasonable to assume that \( \mu > g. \) The software vendor can control piracy by using DRM. We assume stricter DRM would increase the pirating costs for the consumers and decrease the reservation utility from a pirated software product (i.e., \( \frac{\partial g(t)}{\partial t} > 0 \) and \( \frac{\partial \mu(t)}{\partial t} < 0, \) where \( t \) is the control level of DRM). The software vendor invests \( k(t) \) for DRM with control level \( t \) for all the software products and incurs a cost \( k(t) = st^2, \) where \( 0 < s < 1 \) is the DRM (antipiracy) cost coefficient. When the coefficient is higher, DRM becomes more expensive for the same DRM control level as the rate of increase in cost is higher. Therefore, in markets where strong intellectual property enforcement exists, such as the United States and Western Europe, \( s \) should be smaller when compared with markets with less intellectual property enforcement. A consumer will choose the pirate product if both the conditions \( \mu(t) - g(t) > \mu(t) - g(t) > p_1 \) and \( \mu(t) > g(t) > 0 \) are satisfied. Compared with the base model, consumers not only have purchasing options in Table 1, but also have the extra options under each selling plan listed in Table 4.
Table 4. Consumers’ Extra Options and Respective Utility

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Alternative Options</th>
<th>Respective Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure Component</td>
<td>Use pirated product 1</td>
<td>( \mu(t)r_1 - g(t) )</td>
</tr>
<tr>
<td></td>
<td>Use pirated product 1 and purchase product 2</td>
<td>( \mu(t)r_1 - g(t) + r_2 - p_2 )</td>
</tr>
<tr>
<td>Pure Bundling</td>
<td>Use pirated product 1</td>
<td>( \mu(t)r_1 - g(t) )</td>
</tr>
<tr>
<td>Mixed Bundling</td>
<td>Use pirated product 1</td>
<td>( \mu(t)r_1 - g(t) )</td>
</tr>
<tr>
<td></td>
<td>Use pirated product 1 and purchase product 2</td>
<td>( \mu(t)r_1 - g(t) + r_2 - p_2 )</td>
</tr>
</tbody>
</table>

The software vendor first sets piracy control level \( t \) for DRM, followed by prices \( p_1, p_2, \) and \( p_B \) to maximize profit. Finally, the software vendor compares the different selling plans and selects the plan with the highest profit. Demand levels in different selling plans in the piracy model are illustrated in Figure 2.

Table 5 lists profit functions under different product offering options in the piracy model.

Table 5. Profit Functions in Piracy Model

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Profit Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure Component</td>
<td>[ \max_{p_1, p_2} \pi = p_1 d_1 + (p_2 - c) d_2 - k(t) \quad \text{s.t.} \quad 0 &lt; p_1 &lt; 1 \quad &amp; \quad c &lt; p_2 &lt; 1 \quad &amp; \quad 0 &lt; t &lt; 1 ]</td>
</tr>
<tr>
<td>Pure Bundling</td>
<td>[ \max_{p_B} \pi = (p_B - c) d_B - k(t) \quad \text{s.t.} \quad c &lt; p_B &lt; 2 \quad &amp; \quad 0 &lt; t &lt; 1 ]</td>
</tr>
<tr>
<td>Mixed Bundling</td>
<td>[ \max_{p_1, p_2, p_B} \pi = p_1 d_1 + (p_2 - c) d_2 + (p_B - c) d_B - k(t) \quad \text{s.t.} \quad 0 &lt; p_1 &lt; \min(1, p_B) \quad &amp; \quad c &lt; p_2 &lt; \min(1, p_B) \quad &amp; \quad c &lt; p_B &lt; p_1 + p_2 \quad &amp; \quad 0 &lt; t &lt; 1 ]</td>
</tr>
</tbody>
</table>

Since a closed-form solution is not feasible, we turn to numerical analysis to derive the following findings:
1. **Pure Component**

In Figure 3a (Figure 3b), we illustrate the optimal control level of DRM in pure component with different levels of marginal cost on service infrastructure (different DRM cost coefficients). In Figure 4a (Figure 4b), we show the optimal prices for the products with different levels of marginal cost on service infrastructure (different DRM cost coefficients).

<table>
<thead>
<tr>
<th>Figure 3a. Optimal Control Level with Infrastructure Cost</th>
<th>Figure 3b. Optimal Control Level with DRM Cost Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Figure 4a. Optimal Prices with Infrastructure Cost</th>
<th>Figure 4b. Optimal Prices with DRM Cost Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3.png" alt="Diagram" /></td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**Proposition 3:** In pure component,

- **i.** the optimal control level of DRM is independent of infrastructure cost, but it decreases when DRM cost coefficient becomes higher;
- **ii.** the optimal price for product 1 is independent of infrastructure cost, but it decreases when DRM cost coefficient becomes higher; and
- **iii.** the optimal price for product 2 increases with higher infrastructure cost, but it is independent of DRM cost coefficient.

With the pure component strategy, a higher infrastructure cost only has an impact on software service
pricing. The software vendor needs to set a higher price for the software service to offset the increase in cost when infrastructure cost increases, and it will lead to a lower profit. On the other hand, when using DRM, which is associated with higher costs, setting a strict DRM level becomes costly to the vendor. The outcome is that the vendor will set a lower DRM control level. However, the lower DRM control level has an effect on the vendor’s pricing for product 1 as it makes the product more susceptible to piracy. As a result, the optimal strategy for the vendor is to lower the pricing for product 1. Note that in this case, a higher DRM cost does not impact the price of product 2.

2. Pure Bundling

![Figure 5a. Optimal Control Level with Infrastructure Cost](image1)

![Figure 5b. Optimal Control Level with DRM Cost Coefficient](image2)

![Figure 6a. Optimal Price with Infrastructure Cost](image3)

![Figure 6b. Optimal Prices with DRM Cost Coefficient](image4)

Figure 5a (Figure 5b) illustrates the optimal control level of DRM in pure bundling with respect to different levels of infrastructure cost (different levels of DRM cost coefficient). In Figure 6a (Figure 6b), we illustrate the optimal bundle price in pure bundling with respect to different infrastructure costs (different levels of DRM cost coefficient). Based on the above figures, we state the following proposition:

**Proposition 4:** In pure bundling,

i. the optimal control level of DRM decreases when infrastructure cost increases and when DRM cost coefficient becomes higher, and

ii. the optimal bundle price increases with higher infrastructure cost, but it decreases when DRM cost coefficient becomes higher.

With the pure bundling strategy, there is a clear trade-off between pricing and DRM control with the change of infrastructure cost. This is because a higher infrastructure cost needs to be supported by a higher price for the bundle, and as a result, a looser DRM control is set and resulted in a lower DRM cost for the vendor. In other words, the looser DRM control is to offset the decline in demand as a result of a
higher infrastructure cost and higher pricing for the bundle. On the other hand, when it is more expensive to fight against piracy on product 1, the software vendor will choose to set a lower control level. This will result in losing the market share to piracy. In response, the software vendor will choose a lower price to counter the loss of demand. Thus, the pricing and DRM control strategy balance out each other in generating profits.

In terms of the effect of the complementarity of the product and service, we found that when the product and service are more complementary to each other (i.e., \(\alpha > 0\)), the equilibrium optimal control and optimal price will be higher. The results are omitted due to space limitation.

3. Mixed Bundling

Figure 7a (Figure 7b) illustrates the optimal control level of DRM in mixed bundling with respect to different levels of infrastructure cost (different levels of DRM cost coefficient). In Figure 8a (Figure 8b), we illustrate the optimal prices of product 1, product 2, and the bundle in mixed bundling with respect to different levels of infrastructure cost (different levels of DRM cost coefficient). On the basis of the numerical analysis in Figures 7 and 8, we claim the following:

**Proposition 5:** In mixed bundling,
i. the optimal control level of DRM decreases when infrastructure cost increases and when DRM cost coefficient becomes higher;

ii. the optimal price for product 1 decreases with higher infrastructure cost and when DRM cost coefficient becomes higher;

iii. the optimal price for product 2 increases with higher infrastructure cost, but it decreases when DRM cost coefficient becomes higher; and

iv. the optimal bundle price increases with higher infrastructure cost, but it decreases when DRM cost coefficient becomes higher.

Unlike the pure component case, when infrastructure cost increases, instead of staying constant, the optimal price for product 1 will decrease. On the other hand, the DRM control level also decreases with infrastructure cost. Furthermore, both the prices of product 2 and the bundle increase as a result of higher infrastructure cost. Thus, we see that as the infrastructure cost increases, the software vendor will increase the price of the service and bundle but, at the same time, make product 1 compete more intensely with the pirated product.

When the DRM cost is higher, the software vendor will set a lower control level, which will result in product 1 facing a more intense competition from the pirated product. Although the software vendor reduces the prices of product 2 and the software bundle, the decrease is much less significant than the decrease of price for product 1. Interestingly, as a result, the demand for product 1 would increase, and the demands for product 2 and the bundle would decrease or stay relatively flat (see Figure 9a). Hence, rather than relying more on the software service, which is free of piracy to derive revenue, the software firm would lower the prices for product 1 and the bundle to derive profits (see Figure 9b). At equilibrium, the software vendor would use lower pricing to “balance out” the effect of having a higher DRM cost. But such pricing is most aggressive with product 1 and the bundle, which essentially increases the market share for product 1 and preserves the market share for product 2.

4. Optimal Selling Plan

Comparing these three selling plans, we have the following:

**Proposition 6:** Mixed bundling is the optimal selling plan when the infrastructure cost is smaller than the threshold level. When the infrastructure cost is higher than the threshold level, the pure component strategy is the optimal selling plan.

When infrastructure cost of software services is relatively low (i.e., when the infrastructure cost is smaller than 0.82), most consumers would purchase the bundle, and mixed bundling is the best-selling plan for
the software vendor. However, when the infrastructure cost becomes significantly high (i.e., larger than 0.82), both the bundle and software service lose their attractiveness to consumers because of their high prices. As a result, the pure component strategy is more profitable for the software vendor because both traditional software product price and software service price are lower in pure component when compared with mixed bundling. We illustrate this result in Figure 10.

![Figure 10. Optimal Selling Plan for Vendor](chart)

**Conclusion and Future Work**

How should a software vendor embrace the newly emerging trend of selling software as a service, together with the traditional software products? In this paper, we examine this question from the perspective of software piracy. We examine the optimal DRM control and bundle pricing strategies. Our work complements the literature on bundling and digital piracy. When pricing the software bundle, our results show an interesting conclusion, where the software vendor would “sacrifice” the software as a service that is piracy-free when faced with a higher cost of fighting against software piracy of the traditional software product. We also show an uncommon result where the pure component strategy can be the best selling plan. The results indicate that despite having the ability to curb software piracy, the software vendors would still prefer the traditional software instead of offering the newly emerging software as a service. This is because software as a service requires maintenance cost, which makes it relatively more costly. In addition, with the traditional software product, the software vendor has a greater flexibility to optimize profit with DRM control and pricing strategy.

There are a few directions along which we can extend the current work. First, we have not considered network externality in our model. Literature suggests that network externality is an important factor that affects how a software vendor would exert effort in combating software piracy (Shy & Thisse, 1999; Conner & Rumelt, 1991) and making bundle pricing decisions (Prasad, Venkatesh, & Mahajan, 2010). Furthermore, we can also extend the model to a duopoly setting, where firms compete along the lines of an antipiracy effort and different bundle options. Such a model could capture a competitive landscape in the software industry where firms could have different competitive advantages in the area of traditional software products or newly emerging cloud services.

**References**


Appendix

Proof of Proposition 1

In the pure component strategy, the demands of products 1 and 2 are \( d_i = 1 - p_i \), with \( i = 1 \) or 2. If we let the first derivatives of profit function with respect to \( p_1 \) and \( p_2 \) be zero, we have \( p_1^* = \frac{1}{2} \) and \( p_2^* = \frac{1+c}{2} \).

In the pure bundling strategy, the demand of the bundle is \( d_B = \begin{cases} 1 - \frac{1}{2} p_B^3, & \text{if } c < p_B < 1 \\ \frac{1}{2} (2 - p_B)^2, & \text{if } 1 < p_B < 2 \end{cases} \). When \( c < p_B < 1 \), according to the first derivative condition \( \frac{dn}{dp_B} = 1 - \frac{3}{2} p_B^2 + c p_B = 0 \), we have \( p_B = \frac{c+\sqrt{c^2+4}}{3} \).

Another root \( p_B = \frac{c-\sqrt{c^2+4}}{3} \) is removed since it’s negative. It’s easy to check that \( c < p_B = \frac{c+\sqrt{c^2+4}}{3} < 1 \) when \( c < \frac{1}{2} \). When \( 1 < p_B < 2 \), according to the first derivative condition \( \frac{dn}{dp_B} = \frac{1}{2} (2 - p_B)(2 + 2c - 3p_B) = 0 \), we have \( p_B = \frac{2+2c}{3} \). Another root \( p_B = 2 \) can be ignored. It’s easy to check \( p_B = \frac{2+2c}{3} > 1 \) when \( c > \frac{1}{2} \).

To summarize, we have the following:

1. When \( 0 < c < \frac{1}{2} \), the bundle’s optimal equilibrium price is \( p_B^* = \frac{c+\sqrt{c^2+4}}{3} \).
2. When \( \frac{1}{2} < c < 1 \), the bundle’s optimal equilibrium price is \( p_B^* = \frac{2+2c}{3} \).

In the mixed bundling strategy, the demands of product 1, product 2, and the bundle are as follows:

\[
\begin{align*}
    & d_1 = (1 - p_1)(p_B - p_1) \\
    & d_2 = (1 - p_2)(p_B - p_2) \\
    & d_B = (1 - p_B + p_1)(1 - p_B + p_2) - \frac{1}{2}(p_1 + p_2 - p_B)^2
\end{align*}
\]

For the profit function, if we take its first derivative with respect to \( p_1 \), \( p_2 \), and \( p_B \), we have the following:

\[
\begin{align*}
    & 3 p_1^2 - (2 + 3 p_B - c) p_1 + 2 p_B - c = 0 \\
    & (p_B - p_2)(2 - 3 p_2 + c) = 0 \\
    & p_1(1 - p_1) + (p_2 - c)(1 - p_2) + \left[ (1 - p_B + p_1)(1 - p_B + p_2) - \frac{1}{2}(p_1 + p_2 - p_B)^2 \right] + (p_B - c)(p_B - 2) = 0
\end{align*}
\]

This is a third-order quadratic equation set. We can solve \( p_1 \) and \( p_2 \) in terms of \( p_B \). From the first equation, we can get \( p_1 = \frac{1}{6} (2 - c + 3p_B - \sqrt{(3p_B - 2 + c)^2 + 12c(1 - p_B)}) \). The negative square root root can be removed since \( p_1 \) will be larger than \( p_B \) when \( p_B < 1 \), which contradicts with feasible conditions. From the second equation, we have \( p_2 = \frac{2+c}{3} \). Another root can be removed since it contradicts with feasible conditions. However, \( p_B \) is intractable, even we already have \( p_1 \) and \( p_2 \) in terms of \( p_B \). Although we can’t explicitly find the closed-form solution for \( p_B \), we can have a highly precise approximation of \( p_B \) as \( p_B^* = \frac{2+4c}{24} \), according to Bhargava (2011). Furthermore, we can have the highly precise approximation of \( p_1 \) as \( p_1^* = \frac{1}{48} (3c + 38 - \sqrt{9c^2 + 292c + 36}) \). Demands \( d_i, i = 1, 2, B \), and profit \( \pi \) can be obtained easily by substituting \( p_i^* \), \( i = 1, 2, B \).
Propositions 3, 4, 5 and 6

Proof of Proposition 2

For pure component, it’s easy to have demands \(d_1^* = \frac{1}{2}, \ d_2^* = \frac{1-c}{2}\), and profit \(\pi^* = \frac{1+(1-c)^2}{4}\) when we substitute \(p_1^* = \frac{1}{2}\) and \(p_2^* = \frac{1+c}{2}\).

For pure bundling, the bundle’s demand is \(d_B = \begin{cases} 
1 - \frac{1}{2}p_B^2, & \text{if } c < p_B < 1 \\
\frac{1}{2}(2 - p_B)^2, & \text{if } 1 < p_B < 2
\end{cases}\), and the bundle’s profit is \(\pi = (p_B - c)d_B\). By the substitution of the bundle’s optimal price \(p_B^* = \begin{cases} 
\frac{c+\sqrt{c^2+6}}{3}, & 0 < c < \frac{1}{2} \\
\frac{3+2c}{3}, & \frac{1}{2} < c < 1
\end{cases}\), we have the bundle’s optimal demand and optimal profit as follows:

1. When \(0 < c < \frac{1}{2}\), the bundle’s optimal equilibrium demand and optimal profit are \(d_B^* = \frac{6-c^2-c\sqrt{c^2+6}}{9}\) and \(\pi = \frac{1}{27}(c^3 + c^2\sqrt{c^2+6} - 18c + 6\sqrt{c^2+6})\).
2. When \(\frac{1}{2} < c < 1\), the bundle’s optimal equilibrium demand and profit are \(d_B^* = \frac{2(2-c)^2}{9}\), \(\pi = \frac{2(2-c)^2}{27}\).

For mixed bundling, the demand functions for product 1, product 2, and the bundle are as follows:

\[
\begin{align*}
    d_1 &= (1 - p_1)(p_B - p_1) \\
    d_2 &= (1 - p_2)(p_B - p_2) \\
    d_B &= (1 - p_B + p_1)(1 - p_B + p_2) - \frac{1}{2}(p_1 + p_2 - p_B)^2
\end{align*}
\]

The software vendor’s profit function is \(\pi = p_1d_1 + (p_2 - c)d_2 + (p_B - c)d_B\). By substituting the optimal prices \(p_1^* = \frac{1}{48}(3c + 38 - \sqrt{9c^2 + 292c + 36})\), \(p_2^* = \frac{24c}{3}\), and \(p_B^* = \frac{224+11c}{24}\), we have the optimal profit as \(\pi^* = p_1^*(1 - p_1^*)(p_B^* - p_1^*) + (\frac{24c}{3})^2 + (p_B^* - c)((1 - p_B^* + p_1^*)(1 - p_B^* + p_2^*) - \frac{1}{2}(p_1^* + p_2^* - p_B^*)^2\).

By using numerical simulation, we find that mixed bundling is the optimal selling strategy for all infrastructure costs.

Propositions 3, 4, 5 and 6

Based on the model setup, we conducted numerical analyses using a variation of parameter values to represent all possible scenarios. Our propositions are consistent under all these scenarios. The code is available upon request.