Bundling a Partially Piratable Digital Good

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Abstract

This paper presents a model of how piracy affects a firm's profit in a market for a digital good which has a piratable and nonpiratable component. The firm can respond to piracy by bundling the components into a single good, or by pricing them separately. I find that the firm can earn higher profits from bundling the components when anti-piracy enforcement is high, the value of the piratable good is high, or the value of the nonpiratable component is low, and can earn higher profits from unbundling the components when anti-piracy enforcement is low, the value of the piratable good is low, or the value of the nonpiratable component is high.

1 Motivation and background

Piracy is defined as the unauthorized use or reproduction of another's work. Digital goods are usually non-rival by nature and have zero or close to zero marginal cost, because the code can often be copied with very little effort. Combined with nearly-costless distribution on the Internet, software piracy is potentially the most accessible form of piracy in history - anyone with a computer can be a pirate, and anyone with an Internet connection can distribute pirated goods to other consumers.

The literature in economics, information systems, and management science around digital piracy has tended to focus on piracy's effect on the firm's investment in product development, the consumer's choice of copying technology and the firm's investment in anti-copying technology, and the firm's profits. Some papers on the topic include [Belleflamme and Picard, 2007], [Sundararajan, 2005], and [Chellappa and Shivendu, 2005]. [Peitz and Waelbroeck, 2006] provides a review of the theoretical literature on digital piracy. The literature around bundling of digital goods as tended to focus on the music industry (e.g. [Zhu and MacQuarrie, 2003]) and the effects of bundling on competition between firms (e.g. [Bakos and Brynjolfsson, 2000]). As far as I am aware, this model is the first to combine piracy and bundling for digital goods and to use a Hotelling model to study digital piracy.

I abstract from the specifics consumer copying technology by assuming the pirated material exists and that consumers face a travel cost to acquire the pirated material.

The mirror of consumer copying technology is firms' investment in anti-copying technology. Firms often invest in digital rights management (DRM) technologies, which are intended to prevent copying. This tends to reduce (but not eliminate) access to the pirated good; the average individual may find it difficult to circumvent DRM technologies on their own, hackers who remove DRM from code and distribute it through websites and peer-to-peer networks make the good available regardless. I abstract from this and assume that a source of the piratable good exists without making any additional assumptions on the nature of the source. My model also does not consider the effects of piracy on future product investment by the firm (the investment margin), instead focusing on the effects of piracy on the firm's decision-making at the margin of producing an already-existing good (the production margin).

Firms that own or produce intellectual property (IP) tend to argue that piracy is an existential threat to their livelihoods, and that they would prefer perfect anti-piracy enforcement in general. Content-producers therefore invest in IP rights enforcement. This investment can take the form of lobbying efforts, hiring private investigators to identify individuals sharing content over peer-to-peer networks, lawsuits, and takedown notices to websites that host infringing content. I abstract from this by taking enforcement as exogenously given and common knowledge to consumers and the firm.

I find that whether the firm prefers to bundle or not will depend on the parameters of the model. The higher the value of the nonpiratable good to consumers, the more likely the firm is to prefer unbundling at all levels of enforcement. The higher the level of anti-piracy enforcement or the value of the piratable good to consumers, the less likely the firm is to prefer bundling.

The layout of this paper is as follows: in section 2 I describe the model and notation in more detail. In section 3 I solve for the equilibria under bundling and unbundling. In section 4 I compare the equilibria and present comparative statics. The main result, that the firm's profits may be higher with bundling than without, is here. Section 5 concludes, and the appendix lists figures and the full tables of derivatives used for the comparative statics.

2 Setting and notation

This model is a simple extension of the Hotelling model [Hotelling, 1929]. The firm, consumers, and source of the pirated good ("pirate source") are located on a line is normalized to length 1. The firm and the pirate source are located at opposite ends of the line, points 0 and 1 respectively. Consumers are uniformly distributed over the line with mass normalized to 1, and incur a travel cost of t to purchase from the firm or to pirate the good.

There are two goods in this model: a "piratable good" which is not excludable and has zero marginal cost, and a "nonpiratable good" which is excludable and has a marginal cost. In a digital goods setting, the piratable good can be thought of as the code for the good which can be costlessly copied and locally executed on any computer. The nonpiratable good is a service built around the code which can't be replicated by illegal suppliers like hackers or torrent sites, or protected by an authentication which can't be spoofed by consumers with illegal copies of the good. Such authentication is often possible when the consumer must establish a connection to the server before each use.

While the piratable good is available for free, piracy is illegal, and consumers who pirate run the risk of a prohibitively costly lawsuit for violating IP laws. However, it is not always possible to fully enforce IP laws. Sources of pirated content such as peer-to-peer networks and anonymous websites with search keywords are difficult to fully suppress, though IP rightsholders and law enforcement agencies make efforts to catch and prosecute pirates. I model enforcement as an exogenous probability θ with which the consumer will be sued for piracy and receive 0 utility from the pirated good. With probability $1-\theta$ the consumer will escape enforcement and receive the full utility of the pirated good.

When the goods are bundled, the firm sells them both at a single price in a single Hotelling line, and consumers choose between purchasing the bundled good from the firm or obtaining the piratable component for free at some risk of 0 utility. When the goods are unbundled, the firm sells them at different prices in separate Hotelling lines. In the market for the piratable good, the firm competes with the pirate source for the consumers. In the market for the nonpiratable good, the firm is a monopolist. In the unbundled case, I assume that consumers who have not purchased the piratable component can still use the nonpiratable component. This assumption removes network effects from the unbundled case, making the model easy to solve.

Pirated software suppliers in the real world are diverse agents with complex motives, with some pirate groups operating as profit-maximizing firms and selling the good to limited bandwidth consumers for a fraction of the retail price in areas with low levels of enforcement, others providing the good for free online for ideological reasons, and still others providing the good because they enjoy the challenge of breaking the DRM technology in place to prevent piracy. I take the existence of the pirate source as given and focus on the consumers' and firm's decisions from there. I don't model the pirate source as a separate agent.

Video games with singleplayer and multiplayer offerings are one example of excludable/nonexcludable bundling of digital goods. The singleplayer components of video games are relatively easy to pirate and run locally on a computer. The costs of running game servers, rebalancing gameplay, and providing customer support prevent the multiplayer offering from also being pirated. To be clear, the actual code which characterizes the multiplayer component can be copied as easily as the other code - the excludability comes from the costs of service acting as barriers to entry to the illegal suppliers, and from the server connection allowing the firm to exclude customers with illegal copies from playing on the official servers. Unbundling in this case would correspond to selling separate singleplayer and multiplayer versions of the same game separately. I am not aware of any games which are sold like this.

Commercial Linux software is another example. Commercial Linux distributors like RedHat bundle enterprise and troubleshooting services (nonpiratable) with a Linux distribution (piratable). In this type of example the "piracy" may not actually be illegal, as Linux is open-source and the distributor may or may not have a more restrictive license in place for their specific distribution. If free copying and use is legal then θ would be 0. But whatever the type of license, the code can still be costlessly copied and redistributed, so the issue of pricing a bundle that is only partially excludable remains. Unbundling in this case would correspond to selling a standalone Linux OS with no service and a pure service component for people who already have a Linux OS installed.

Digital music is a third example. While record companies (the music producers) rarely offer excludable services directly and prefer to rely on DRM technologies, third-parties such as Spotify bundle music and a player program (piratable) with access to large amounts of music. While the content that users gain access to is not nonpiratable per se, the service spares consumers the storage costs of holding the large amounts of music for instant playback, and offers consumers who have a lower willingness-to-pay for legal copies or high music demand with a cheaper legal source. The access to music is therefore a nonpiratable service in the sense discussed here. Since providers like Spotify do not actually provide downloadable DRM-free copies of music (the piratable good), services like Spotify are in a sense already selling the unbundled nonpiratable component.

Below is a list of notation I use in this paper:

1. v: value of piratable good
2. β: value of non-piratable good
3. t: travel cost
4. p: price
5. θ: probability of being sued for piracy (probability of enforcement)
6. $x(p)$: marginal consumer's demand
7. $\beta + v - p - tx(p)$: marginal consumer's surplus from legally purchasing the bundled good
8. $(1-\theta)(v-t(1-x(p)))$: marginal consumer's surplus from piracy
9. $\beta - p - tx(p)$: marginal consumer's surplus from legally purchasing the unbundled nonpiratable good

10. $v - p - tx(p)$: marginal consumer's surplus from legally purchasing the unbundled piratable good
11. c: marginal cost of nonpiratable good

Before proceeding, a few words on the interpretation of certain parameters are in order:

Value of the nonpiratable good: The parameter β in the value of the nonpiratable good captures consumers' preferences for the nonpiratable good. To keep the model simple, I assume away the network effects that are often present in nonpiratable digital goods such as multiplayer games and software with service.

Surplus from piracy: The consumer's surplus from piracy is $\theta u(\text{lawsuit}) + (1-\theta)(v - t(1 - x(p)))$. The idea is that with some probability θ, the consumer will be sued for piracy. I normalize $u(\text{lawsuit})$ to 0.

Travel cost: In this setting we can interpret t as representing some aspect of the experience of downloading the digital good from the firm or from the illegal source - smaller t corresponds to a more user-friendly experience. We could use a directional travel cost, for example t^F to get to the firm and t^T to get to the illegal source in the bundled case, where $t^F \neq t^T$, and then separate travel costs in each market in the unbundled case. This doesn't change the key results discussed here, so I use a common travel cost t to keep the exposition simple.

Marginal cost: I assume that the piratable good has zero marginal cost, and that the nonpiratable good has a constant marginal cost of c. In the unbundled case, the firm only incurs this cost when it sells the nonpiratable good. In the bundled case, the firm incurs this cost for every consumer who purchases the bundled good.

Unless otherwise mentioned, I assume that $\beta > c$ and $v > t$.

3 Bundled and Unbundled Equilibria

When the goods are bundled

When the goods are bundled, the marginal consumer is indifferent between the bundled good at a price p and the piratable component for free but at a risk θ. This gives us the following demand:

$$\begin{aligned}\beta + v - p - tx(p) &= (1-\theta)v - t(1-x(p)) \\ \implies x(p) &= \frac{\beta + \theta v - p + t(1-\theta)}{t(2-\theta)}\end{aligned}$$

The firm solves

$$\max_p \quad (p-c)x(p)$$

The demand, price, and profit are:

$$\begin{aligned}x =& \frac{\beta + \theta v + t(1-\theta) - c}{2t(2-\theta)} \\ p =& \frac{\beta + \theta v + t(1-\theta) + c}{2} \\ \pi^B =& \frac{(\beta + \theta v + t(1-\theta) - c)^2}{4t(2-\theta)}\end{aligned}$$

When the goods are unbundled

When the goods are unbundled, there are two marginal consumers: one in the market for the piratable good, and one in the market for the nonpiratable good. The first marginal consumer is indifferent between the piratable good at a price p^v and the piratable component for free but at a risk θ, while the second marginal consumer is indifferent between the nonpiratable good at a price p^β and no purchase (0 utility). This gives us the following demands:

$$\begin{aligned}v - p^v - tx^v(p^v) &= (1-\theta)(v - t(1 - x^v(p^v))) \\ \implies x^v(p^v) &= \frac{\theta v - p^v + t(1-\theta)}{t(2-\theta)} \\ \beta - p^\beta - tx^\beta(p^\beta) &= 0 \\ \implies x^\beta(p^\beta) &= \frac{\beta - p^\beta}{t}\end{aligned}$$

The firm solves

$$\max_{p^v, p^\beta} \quad (p^v)x^v(p^v) + (p^\beta - c)x^\beta(p^\beta)$$

The demands, prices, and profit are:

$$\begin{aligned}
x^v &= \frac{\theta v + t(1-\theta) - c}{2t(2-\theta)}, \quad p^v = \frac{\theta v + t(1-\theta) + c}{2} \\
x^\beta &= \frac{\beta - c}{2t}, \qquad\qquad\qquad\quad p^\beta = \frac{\beta + c}{2} \\
\pi^U &= \pi^v + \pi^\beta = \frac{(\theta v + t(1-\theta))^2}{4t(2-\theta)} + \frac{(\beta - c)^2}{2t}
\end{aligned}$$

Since the products are unbundled and we assume that consumers can buy either product without need of the other, the firm's problem is just to maximize the sum of profits in each market.

4 Analysis

Now that we have the equilibria in both cases, we can investigate how bundling affects the demands, prices, and profits.

Bundled vs Unbundled

When is it better to bundle or unbundle? I assume that $\beta > c$ and $v > t$ here.

$$\pi^B > \pi^U$$
$$\implies (\beta + \theta v + t(1-\theta) - c)^2 > (\theta v + t(1-\theta))^2 + 2(2-\theta)(\beta - c)^2$$

Given strictly positive parameter values, $\theta < 1$, and $\beta > c$, this inequality will hold if:

$$\beta < \frac{2t(1-\theta) + 2\theta v + c(3-2\theta)}{3-2\theta}$$

In words: bundling will be preferable to unbundling when the value of the nonpiratable good is not too large relative to the value of the nonpiratable good, the risk of getting sued, and the travel cost. As $\theta \to 1$, the effect of the travel cost disappears and the value of the nonpiratable good minus its cost must be greater than twice the value of the piratable good for unbundling to yield higher profits than bundling ($\beta \geq 2v+c$). Figure 1 plots the profits under bundling and unbundling as functions of θ and β to show this. Figure 1 also shows a case when $\beta < c$ and unbundled profits are better than bundled profits at the lower end of β in the bottom panel.

Comparative statics

Tables 1 and 2 list the signs of the derivatives of demand, price, investment, and profit with respect to the parameters of each model assuming positive parameter values - the columns are the variables being differentiated, and the rows are the variables they are differentiated with respect to. The signs of many of these derivatives are ambiguous without parameter restrictions. The tables below show the signs of the derivatives assuming that v, t, θ, and β are all positive, and $v > t$, $\beta > c$, $\theta < 1$. Even with these parameter restrictions, the derivatives of profit when the goods are bundled and profits from the piratable good are difficult to sign. $\frac{\partial x}{\partial v}$, $\frac{\partial x}{\partial \beta}$, $\frac{\partial \pi}{\partial v}$, and $\frac{\partial \pi}{\partial \beta}$ in table 1will be positive if $\theta < 2t$.

Table 1: Statics when bundled

	x	p	π
v	?	$+$	?
β	?	$+$	?
t	$-$	$+$	?
θ	$+$	$+$	?

Table 2: Statics when unbundled

	x^v	x^β	p^v	p^β	π^v	π^β
v	?	0	$+$	0	$+$	0
β	0	$+$	0	$+$	0	$+$
t	$-$	$-$	$+$	0	?	$-$
θ	$+$	0	$-$	0	?	0

The full derivatives are in tables 3 and 4 in the appendix.

5 Conclusion

Bundling is common for some digital goods, such as video games, and less common for others, such as digital music. Which is better for the firm depends on how the consumers value the piratable and nonpiratable components and the level of anti-piracy enforcement in effect.

This model is a simple variation of a Hotelling model which offers a tractable and extensible framework to analyze questions of digital piracy and bundling. Although I only consider the case of a single firm, extending this model as a spokes model would allow for analysis of multiproduct monopolies and inter-firm competition. Letting the value of the nonpiratable good depend on demand for the bundle or the piratable good would allow analysis that incorporates network effects and dependence between products, although the Bertrand-Nash solution concept used here may no longer work. Empirical investigation of bundling behavior by firms in digital goods markets subject to piracy will help uncover the scope conditions under which this model is applicable.

When the goods are bundled, the firm's profits become a complicated function of the parameters of the model, and it is not clear that higher anti-piracy enforcement is always better. The entry of the pirate source is like the entry of a competitor firm in a spokes model; although the pirate source doesn't charge a price, the risk of getting sued can be viewed as analogous to a price for the pirated good. A result first discovered by [Chen and Riordan, 2007] indicates that if the price effects of entry of the pirate source outweigh the output effects of entry, a firm selling a bundled digital good may make higher profits with imperfect anti-piracy enforcement ($\theta < 1$). This is an interesting question for future investigation with many policy implications.

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6 Appendix

The Mathematica notebook and R script used to analyze this model can be found at

https://github.com/akhilrao/akhilrao.github.io/tree/master/public/micro3model

Table 3: Statics when bundled

	x	p	π
v	$\frac{\theta}{2(2t-\theta)}$	$\frac{\theta}{2}$	$\frac{\theta(\beta+t+\theta(v-t)-c)}{2(2t-\theta)}$
β	$\frac{1}{2(2t-\theta)}$	$\frac{1}{2}$	$\frac{\beta+t+\theta(v-t)-c}{2(2t-\theta)}$
t	$\frac{2(c-\beta)-\theta(1+2v-\theta)}{2(\theta-2t)^2}$	$\frac{1-\theta}{2}$	$\frac{(c-\beta-t-\theta(v-t))(\beta-t+\theta(v+t)+\theta(1-\theta))}{2(\theta-2t)^2}$
θ	$\frac{\beta+2t(v-t)+t-c}{2(\theta-2t)^2}$	$\frac{v-t}{2}$	$\frac{(c-\beta-t-\theta(v-t))(\beta-t+\theta(v+t)+\theta(1-\theta))}{4(\theta-2t)^2}$

Table 4: Statics when unbundled

	x^v	x^β	p^v	p^β	π^v	π^β
v	$\frac{\theta}{2t(2-\theta)}$	0	$\frac{\theta}{2}$	0	$\frac{\theta(t(1-\theta)+v\theta)}{2t(2-\theta)}$	0
β	0	$\frac{1}{2t}$	0	$\frac{1}{2}$	0	$\frac{\beta-c}{2t}$
t	$\frac{v\theta}{2t^2(\theta-2)}$	$\frac{c-\beta}{2t^2}$	$\frac{1-\theta}{2}$	0	$-\frac{v^2\theta^2-t^2(\theta-1)^2}{4t^2(2-\theta)}$	$-\frac{(c-\beta)^2}{4t^2}$
θ	$\frac{2v-t}{2t(\theta-2)^2}$	0	$-\frac{v-t}{2}$	0	$\frac{v^2\theta(4-\theta)-2tv(\theta^2+2-4\theta)+t^2(\theta^2+3-4\theta)}{4t(\theta-2)^2}$	0

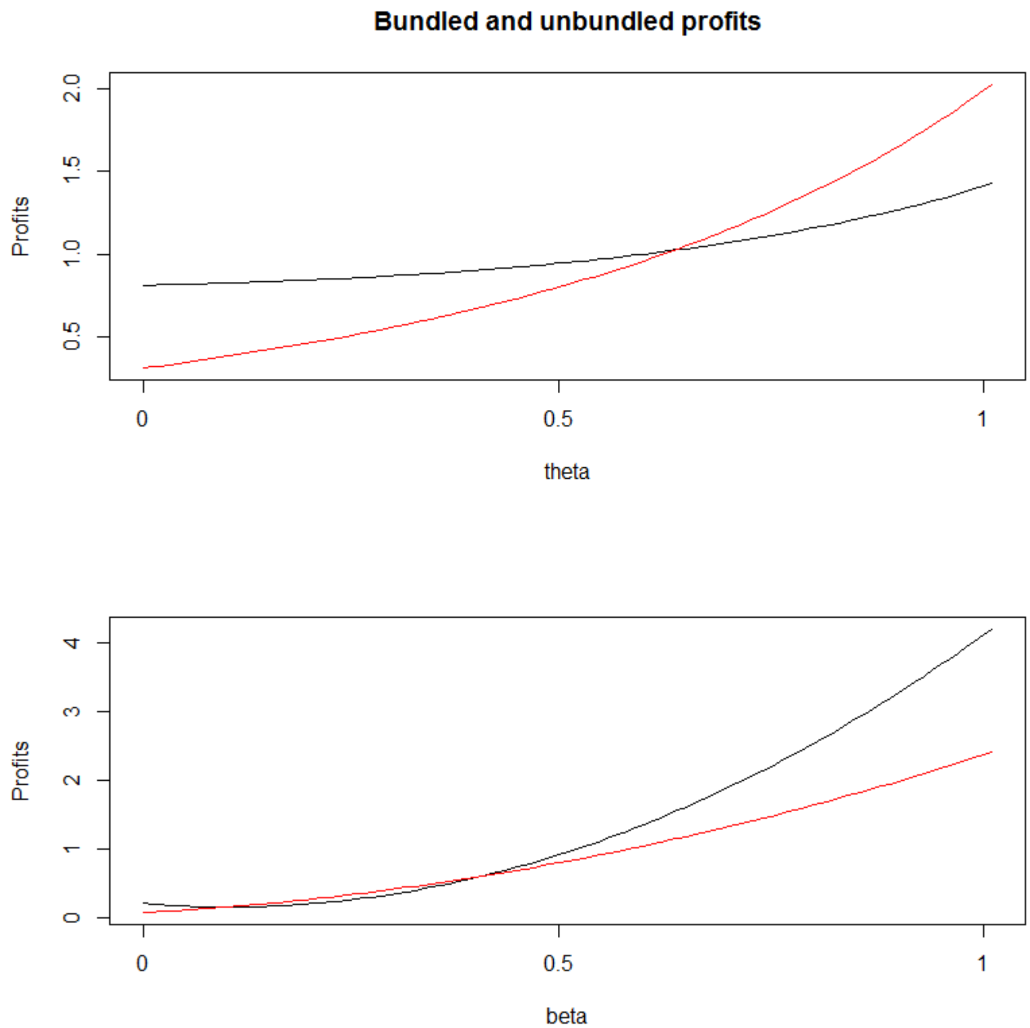

Figure 1: π^B and π^U as functions of θ and β. Specific parameter values are $v = 0.5$, $t = 0.1$, $c = 0.1$, $\beta = 0.5$ (upper plot), and $\theta = 0.05$ (lower plot). Red is profits with bundling (π^B), and black is profits without bundling (π^U).