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Regulating Digital Piracy Consumption

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Abstract

Regulators across the globe have imposed penalties on consumers for digital piracy consumption. Contrary to expectations, however, digital piracy consumption has continued to grow. The authors develop a simple model of competition between a copyright holder and a pirate firm to offer a plausible account for this observation as well as actionable guidelines for optimal regulation design. The core of this idea is to endogenize the pirate firm's strategic investment in antitracking technologies that help consumers evade a regulator's penalty. The authors find that as the penalty rises, piracy consumption can surprisingly increase after decreasing first; relatedly, the copyright holder and the society may suffer from tighter regulation. Depending on the cost of antitracking technologies of the pirate firm, the regulator optimally sets the penalty to operate in two different regimes. When the technology is available at a low cost, the regulator can achieve the goals of maximizing social welfare and minimizing piracy consumption simultaneously by setting a moderate penalty that maximizes consumers' expected penalty and tolerates some level of piracy consumption. In contrast, when the technology is costly, the regulator should set a relatively high penalty to completely impede piracy supply. Additionally, the authors show that supply-side regulation does not substitute away demand-side regulation, and educating consumers about copyright protection may unintentionally lead to an increase in piracy consumption. Last, the authors identify complex nonmonotonic long-run effects of piracy consumption regulation on the copyright holder's incentives for content creation and copyright protection.

Keywords

digital piracy, regulation, copyright protection

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Digital piracy refers to the act of illegally downloading and distributing copyrighted digital material over the internet. Digital piracy is a serious problem that has witnessed an unprecedented rise over the years (Brown and Holt 2021). According to Blackburn, Eisenach, and Harrison (2019), digital piracy annually eroded \$29.2 billion–\$71 billion in revenue and drained 230,000–560,000 jobs from the U.S. economy. A report by an antipiracy solution provider (MUSO 2022) estimates that piracy websites attracted 182 billion visits globally in 2021—a 15.2% increase from 2020.

Pirated digital content is commonly downloaded by piracy users for no monetary cost through peer-to-peer networks (such as torrent) using notorious piracy websites. Pirate Bay is one such example, consistently topping the list of the most visited piracy websites among torrenting users in recent years. In response to digital piracy consumption, regulators across the globe have enacted or strengthened regulations by penalizing users who download pirated digital content, with the aim of curbing these activities. For instance, in 2008, the United States issued the PRO-IP Act, which boosted civil penalties for copyright infringement from \$500–\$100,000 to \$1,000–\$200,000. Likewise, in 2021, France replaced the 13-year-old antipiracy agency HADOPI (High Authority for the Distribution of Works and the Protection of Rights on the Internet) with a new regulatory body named ARCOM (Regulatory Authority for Audiovisual and Digital Communication), aimed at producing tighter regulation and stronger protection of access to digital content. These demand-side regulations are unique to digital content, as digital consumption can be traced by regulators much more easily than physical transactions.

Given the high penalty invoked by the preceding regulations, one might naturally intuit that piracy users would be reluctant to visit Pirate Bay. Contrary to the intuition, however, user visits to Pirate Bay, as measured by Google Trends, have actually risen since the inception of these regulations, as shown

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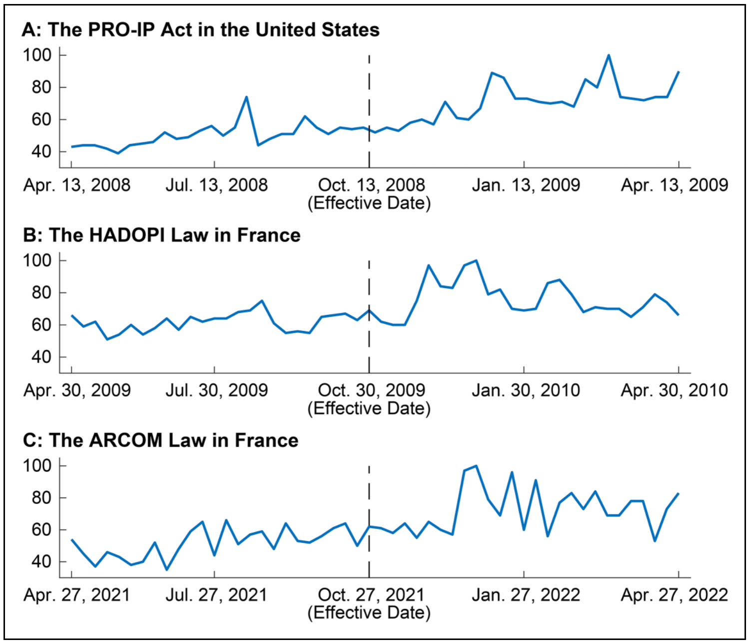

Figure 1. Pirate Bay's Google Trends Before and After Enforcement of New Antipiracy Laws.

in Figure 1.[1] Similar trends have also been observed with respect to other leading piracy websites (specifically, Torrentz and IsoHunt around 2008 and 2009, and YTS and 1337x around 2021). Indeed, Dejean, Pénard, and Suire (2010) evaluate the impact of the HADOPI law on piracy consumption and find that piracy consumption actually rose by 3% since the inception of the regulation.[2] In this article, we aim to offer a plausible account for this seeming inefficacy of demand-side piracy regulation and to provide actionable guidelines for regulators to optimally design regulations against digital piracy.

Most piracy websites, including Pirate Bay, make money from advertising revenue, which is positively associated with the traffic volume of piracy users. Pirate Bay thus suffers when its users avoid surfing its website out of concern about high regulatory penalties. To counter this user reluctance, Pirate Bay constantly invests in new technologies or exerts efforts that help piracy users evade regulators' attempts to track their footage on its website. Table 1 details a set of Pirate Bay's antitracking actions in recent years.[3] Pirate Bay's antitracking actions are also apparent from its recent home page in Figure 2, which enables its visitors to hide their IP addresses by using a VPN service to evade penalty. These countermeasures offer piracy users a sense of security with respect to their ability to avoid penalties, which may explain why they are willing to visit Pirate Bay in greater numbers since the inception of the regulations in Figure 1. From a different angle, the invention of secure torrenting technologies on piracy websites appears effective in helping piracy users evade penalties, because only €87,000 in fines have been generated by the HADOPI law since its enactment (Maxwell 2020).

We formalize these observations by developing a simple vertical competition model. The model consists of a copyright holder that offers a high-quality digital product and strategically sets a price to fight piracy, and a pirate firm that offers a free, low-quality pirated version of the product and strategically

Table 1. Pirate Bay's Antitracking Actions.

Time	Actions
2008	Supported SSL encryption in response to Sweden's new wiretapping law
2008	Inserted "random IP addresses" automatically to pollute the evidence gathering of antipiracy outfits
2010	Offered the IPREDator VPN service that keeps piracy users anonymous and safe from being tracked by law enforcement
2012	Switched from torrents to untraceable magnet links, which makes it more difficult to determine who has downloaded a file using the website
2013	Released a free web browser, PirateBrowser, to circumvent internet censorship
2020	Used the IP address operated by an anonymous VPN service provider, OPVN, which does not store any logs

Sources: Dredge (2013), Janssen (2020), Lindvall (2009), Mitchell (2012), Schofield (2008), and Van der Sar (2008).

[1] There is no intention to infer any causal relationship from these time series; rather, they show that these digital piracy regulations are not effective (or not effective enough) to suppress the ongoing growth of piracy consumption. Google Trends, which measures the popularity of search queries on Google, has been used as a proxy for piracy consumption in the literature (e.g., Lu, Rajavi, and Dinner 2021).

[2] This study was originally written in French, and its main findings were summarized in English in a news report (Seibt 2022).

[3] Similar countermeasure actions have been taken by other piracy websites. For instance, Kickass Torrents forces SSL encryption for all visitors to avoid surveillance.

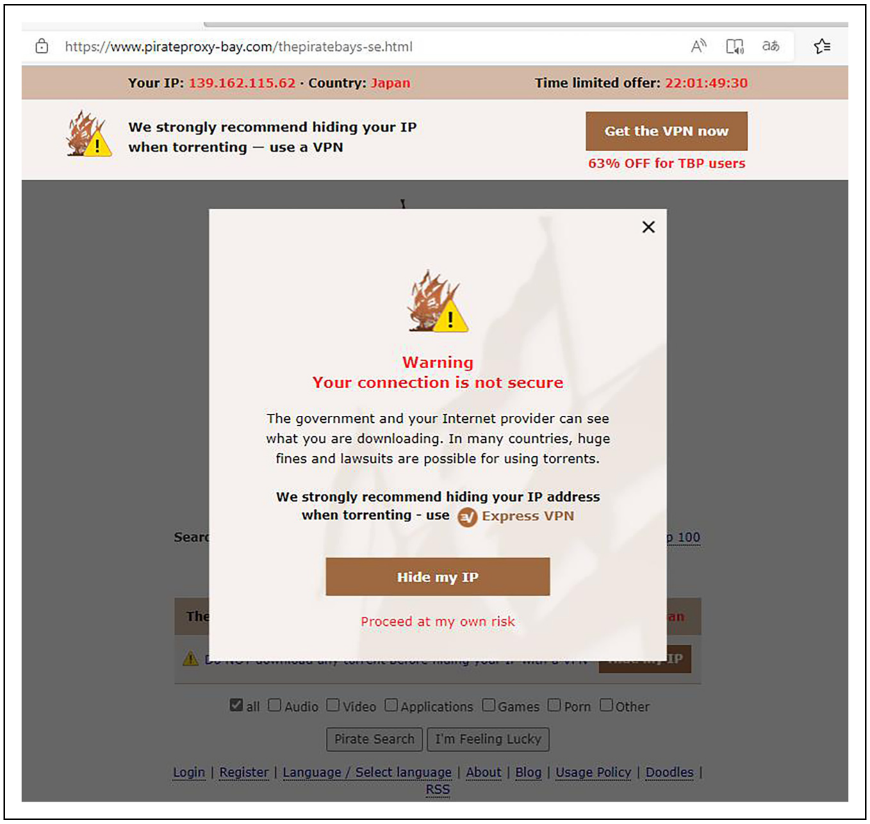

Figure 2. Pirate Bay's Home Page (Accessed March 9, 2023).

invests in antitracking technology to help consumers evade a regulator's penalty for piracy consumption. Consumers differ in their preference regarding product quality and choose between copyrighted products and pirated products subject to a potential penalty.

Our equilibrium analysis shows that when the pirate firm can develop antitracking technologies at a relatively low cost, piracy supply cannot be completely eliminated from the market no matter how high the penalty imposed on piracy users is, because the pirate firm will always participate in the market by investing in these technologies to help consumers evade the penalty. More importantly, we find that piracy consumption exhibits a U-shaped relationship with the penalty, where an increase in the penalty can surprisingly promote piracy consumption when the penalty is relatively high. The rise in piracy consumption is again driven by the pirate firm's endogenous investment in antitracking technologies, since the expected penalty for consumers' piracy consumption depends not only on the penalty set by the regulator but also on the likelihood of consumers being tracked—a factor controllable by the pirate firm via antitracking technologies. Hence, the higher the penalty, the more the pirate firm invests in antitracking technologies. Consumers' expected penalty consequently exhibits an inverse U-shaped relationship with the penalty. Put differently, we demonstrate that the pirate firm's strategic investment in antitracking technologies may dominate the direct effect of the penalty and thus result in a lower expected penalty for piracy users and more piracy consumption.

As a result, tighter regulation can make both the copyright holder and the society worse off due to the resulting increase in piracy consumption. We find that depending on the cost of antitracking technologies of the pirate firm, the regulator optimally sets the penalty to operate in two different regimes. On the one hand, when the technology is available at a low cost, the regulator can reach the goals of maximizing social welfare and minimizing piracy consumption simultaneously by setting a moderate penalty that maximizes consumers' expected penalty and tolerates some level of piracy consumption. On the other hand, when the technology is costly for the pirate firm to acquire, the regulator should set a relatively high penalty to completely impede the supply of piracy.

Besides demand-side regulation, we also examine alternative policy tools that combat piracy. We show that supply-side regulation does not substitute away demand-side regulation, because shutting down the pirate websites could reduce market competition and result in lower social welfare. Moreover, we find that educating consumers to adopt copyrighted products may inadvertently prompt more consumers to use pirated products.

Last, we extend the main model in several directions. First, we study how piracy consumption regulation impacts a copyright holder's incentives to create content by endogenizing its product quality. Second, we allow a copyright holder to take proactive steps to protect its copyrighted content by endogenizing the quality of pirated products. In these two extensions, we show that the penalty may produce complex nonmonotonic effects on the optimal quality of copyrighted products and pirated products respectively. Third, we show that using an internet service provider (ISP) as an inspector to enforce the penalty may not alleviate the piracy problem. Fourth, we demonstrate that our results can be extended to broader regulation contexts.

Our article contributes to the growing literature on digital piracy. Some research focuses on the ways in which copyright holders' initiated copyright protection may make them earn lower profit, including intensifying price competition (Jain 2008), reducing downstream competition (Vernik, Purohit, and Desai 2011), and discouraging consumer search (Guo and Meng 2015). Some other research looks at the impact of regulation on digital piracy. Copyright holders can be better off penalizing consumers for copyright infringement so as to diminish their adoption of pirated products (Dey, Kim, and Lahiri 2019; Lahiri and Dey 2013) or punishing pirate firms to deter their entry to the market (Dey, Kim, and Lahiri 2019). Moreover, Tunca and Wu (2013) show that penalizing users who produce pirated products for themselves may lower a copyright holder's profit because doing so will lend a commercial pirate firm a competitive advantage. Notably, the preceding studies do not model pirate firms' strategic decisions as we do, and thus our research offers original and novel insights to the digital piracy literature.

Broadly, our article also enriches the recent studies on dishonest behaviors and unintended consequences of regulations or the lack thereof across various contexts. Durbin and Iyer (2009) find that bribes can make a good adviser more likely to offer a truthful recommendation to a client. Wilbur and Zhu (2009) show that the revenue of a search engine may be high in the presence of click fraud. Zhu and Dukes (2015) present that media firms' competition makes consumers less informed about the truth of facts. Singh (2017) argues that lifting surveillance of corruptible agents may encourage them to recommend undesirable choices to their clients. Gao (2018) reveals that adopting anticounterfeiting technologies to deter counterfeiter entry may result in more counterfeit purchases. Iyer and Singh (2018) show that a firm may pursue product safety certification even when the firm and consumers do not have contrasting views regarding product safety. Dai and Singh (2020) find that a diagnostic expert with high ability does not seek testing for its client and only offers diagnosis. Wu and Geylani (2020) demonstrate that a high penalty imposed on firms for deceptive advertising may harm consumers. Gao and Wu (2023) point out that penalizing retailers for selling counterfeits may lead them to sell a large proportion of counterfeits. Wu, Gal-Or, and Geylani (2022) uncover that tighter regulation may make native ads more opaque and thus lower consumer surplus and social welfare. Zhou and Zou (2023) highlight that regulations prohibiting platforms from using price information for product recommendations may hurt consumers.

The remainder of the article is organized as follows. Next, we describe the model setup and then present the equilibrium analysis and results. We then discuss policy implications and consider several extensions before concluding the article. All proofs are relegated to the Web Appendix.

Model Setup

Consider a consumer market of size one served by two firms. A legal firm holds the copyright for a digital product with quality $v > 0$, and a pirate firm offers a pirated version of the product with quality βv, where $\beta \in (0, 1)$ can be seen as the copyright holder's copyright protection level, as copyrighted products are generally superior to their pirated counterparts (Guo and Meng 2015; Jain 2008).[4] Marginal production costs of the firms are set as zero due to the nature of digital products. The copyright holder charges price p_c for its copyrighted products. Consistent with common practice and the literature (Dey, Kim, and Lahiri 2019), we assume that the pirate firm offers its products for free to consumers and earns revenue kD_p from advertising, where $k > 0$ is the expected ad revenue per consumer and D_p is consumer demand for pirated products.[5]

To protect copyright and guard against piracy, a regulator of the market tries to keep track of piracy consumption and imposes penalty t on consumers who adopt pirated products and get tracked.[6] There are two types of consumers in the market (Chen and Png 2003; Jain 2008). Specifically, a fraction of them, $\gamma \in [0, 1)$, are ethical in that they have high moral standards and only consider copyrighted products; the remaining fraction, $1 - \gamma$, are unethical in that they choose between copyrighted and pirated products based on expected utility maximization. In response to regulation, the pirate firm invests in an antitracking technology or exerts an effort that entails a cost of $s(1 - x)^2/2$ and results in probability $x \in [0, 1]$ that a

[4] We will endogenize the copyright holder's product quality as well as the quality differential between copyrighted products and pirated products in two extensions respectively.

[5] This model specification captures the commonly observed practice that copyright holders and pirate firms typically adopt different revenue models. Piracy websites, such as Pirate Bay, are essentially online platforms that monetize visitor traffic through sponsored ads; copyright holders, like software developers, in general profit from selling their own products directly to consumers and do not accommodate ads from other firms. Nevertheless, we allow the pirate firm to adopt a pricing-based revenue model in an extension.

[6] We focus on demand-side regulation in this article. While the regulator can also rely on supply-side regulation to fight piracy, it involves other complexities. For example, piracy websites, such as Pirate Bay, could locate their servers anywhere globally and actively modify their domain names to evade detection. Thus, it is difficult to shut down piracy websites via supply-side regulation. Nevertheless, we incorporate supply-side regulation formally in the "Policy Implications" section. Additionally, as in Becker (1968) and Wu and Geylani (2020), a higher t could result from a higher punishment level and/or a higher enforcement level. In the "Extensions" section, we consider an ISP that acts as an intermediary between the regulator and consumers and can influence the enforcement level.

consumer will be tracked, where $s > 0$ is a cost parameter.[7] That is, without this investment, unethical consumers engaging in digital piracy face penalty t imposed by the regulator; by investing more, the pirate firm can reduce x, the likelihood of piracy users being tracked. As a result, xt measures the *expected penalty* for piracy consumption of unethical consumers.

Consumers' utilities from consuming a copyrighted product and a pirated one are, respectively,

$$\begin{aligned} u_c &= \theta v - p_c, \\ u_p &= \theta\beta v - xt, \end{aligned}$$

where θ measures consumers' preference for product quality and is assumed to follow a uniform distribution in [0, 1] across consumers. Consumers also have an outside option of consuming neither product, which is normalized to zero.

The timing of the game is as follows. At the first stage, the copyright holder sets the price, p_c; at the same time, the pirate firm determines the tracking probability, x. At the second stage, consumers make their product choice, and then the payoffs of all parties are realized.[8] To study the effects of piracy consumption regulation, we will first treat penalty t as exogenous in the analysis and then endogenize t by adding to the game a pre-stage wherein the regulator sets t first.

Prior to the model analysis, we make the following assumption to focus on the most meaningful parameter ranges.

Assumption 1. $\gamma < \frac{1-\beta}{\beta}$.

The assumption ensures that the fraction of ethical consumers is not too large; otherwise, the copyright holder may only serve ethical consumers, unethical consumers may only adopt pirated products, and, consequently, there would be no direct competition between the two firms.[9] Notice that γ is allowed to take the value of 0 under the assumption. Put differently, our results do not rely on the existence of ethical consumers in the market.

Equilibrium Analysis

We solve the game by backward induction. Given that the pirate firm's products are of lower quality and entail a potential penalty for piracy consumption, it may be unprofitable for the pirate firm to participate in the market when facing competition with the copyright holder. This implies that there are two subgames to study.

In Subgame I, both firms operate in the market. Let us first analyze the demand of unethical consumers who choose between the two products and the outside option based on expected utility maximization. Specifically, an unethical consumer buys a copyrighted product if and only if the following constraints are satisfied:

$$u_c \geq u_p \Leftrightarrow \theta \geq \frac{p_c - xt}{(1-\beta)v}, \text{ and } u_c \geq 0 \Leftrightarrow \theta \geq \frac{p_c}{v},$$

where the first constraint reflects the copyright holder's demand loss from unethical consumers due to the existence of pirated products. That is, the demand loss can be measured by the segment of unethical consumers with $\theta \in [p_c/v, (p_c - xt)/[(1-\beta)v])$ as they would purchase copyrighted products in the absence of pirated products.

Analogously, an unethical consumer adopts a pirated product if and only if

$$u_p > u_c \Leftrightarrow \theta < \frac{p_c - xt}{(1-\beta)v}, \text{ and } u_p \geq 0 \Leftrightarrow \theta \geq \frac{xt}{\beta v}.$$

Since

$$\frac{p_c - xt}{(1-\beta)v} > \frac{p_c}{v} \Leftrightarrow \frac{p_c - xt}{(1-\beta)v} > \frac{xt}{\beta v} \Leftrightarrow p_c > \frac{xt}{\beta},$$

there are two cases to consider depending on the comparison between p_c and xt/β, as shown in Figure 3. Note that when $p_c \leq xt/\beta$, pirated products generate no demand even when offered. Panel A of Figure 3 demonstrates the consumer market segmentation where patrons of piracy tend to have intermediate θ. To map this result to real-world observations, notice that θ can be reinterpreted as a measure of consumer income.[10] Demand for piracy emerges due to copyright streaming services owning content that is typically unavailable in other portals. Therefore, Panel A of Figure 3 implies that consumers with intermediate income are most interested in accessing content across platforms via piracy, because their income is not very low, so they are still willing to bear the risk of a potential piracy penalty, but not very high, so they are subject to budget constraints.

Furthermore, notice that ethical consumers' demand is always given by Panel B of Figure 3. Consequently, we can express consumer demand for copyrighted products and pirated products respectively as follows:

$$D_c^I(p_c, x) = \begin{cases} \gamma\left(1 - \frac{p_c}{v}\right) \\ +(1-\gamma)\left[1 - \frac{p_c - xt}{(1-\beta)v}\right] & \text{if } p_c > \frac{xt}{\beta}, \\ 1 - \frac{p_c}{v} & \text{otherwise;} \end{cases}$$

$$D_p^I(p_c, x) = \begin{cases} (1-\gamma)\left[\frac{p_c - xt}{(1-\beta)v} - \frac{xt}{\beta v}\right] & \text{if } p_c > \frac{xt}{\beta}, \\ 0 & \text{otherwise,} \end{cases}$$

[7] In an extension, we allow antitracking actions to be initiated by consumers instead of by the pirate firm.

[8] In an extension, we study two alternative timings of the game wherein the copyright holder moves either before or after the pirate firm, and we find that the equilibrium outcome does not change qualitatively.

[9] The analysis for sufficient large γ is provided in the "Policy Implications" section.

[10] Tirole (1988, p. 97) defines u(I) as consumers' utility over their income I and shows that $\theta = u'(I)^{-1}$, which increases with I due to concavity of $u(\cdot)$.

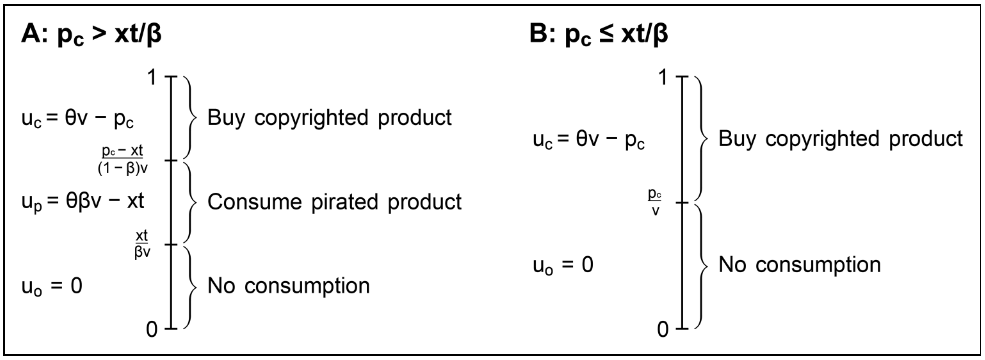

Figure 3. Demand Structure of Unethical Consumers in the Presence of Both Firms.

where the superscript "I" denotes Subgame I.

In Subgame II, only the copyright holder operates in the market. We have both types of consumer demand given by Panel B of Figure 3.

So far, we have determined consumer demand for Subgame I and Subgame II. The remaining question is to identify the condition that delimits the two subgames. That is, when will the pirate firm participate in the market? In fact, when the pirate firm participates in the market and gets positive demand, its profit is

$$\Pi_p^I(p_c, x) = kD_p^I(p_c, x) - \frac{s}{2}(1-x)^2 \text{ for } p_c > \frac{xt}{\beta}.$$

By maximizing $\Pi_p^I(p_c, x)$ with respect to x, we have the optimal choice of x as

$$x^* = \max\left\{1 - \frac{(1-\gamma)kt}{\beta(1-\beta)sv}, 0\right\}. \quad (1)$$

Interestingly, the pirate firm's best response function, x*, does not depend on p_c.[11] Correspondingly, the pirate firm's maximum profit under x* is

$$\Pi_p^I(p_c, x^*) = \begin{cases} \dfrac{(1-\gamma)k}{(1-\beta)v}\left[p_c - \dfrac{t}{\beta} + \dfrac{(1-\gamma)kt^2}{2\beta^2(1-\beta)sv}\right] & \text{if } 0 \le t < T, \\ \dfrac{(1-\gamma)kp_c}{(1-\beta)v} - \dfrac{s}{2} & \text{otherwise;} \end{cases}$$

[11] The key driving forces behind the independence of x* and p_c are that (1) the pirate firm's demand is linear in x, which results from the uniform distribution of the consumer quality preference, and (2) the pirate firm's profit margin does not depend on p_c nor on x. Consequently, the marginal return from a lower x is a constant that does not depend on p_c. In other words, by investing in a better anti-tracking technology, the pirate firm gains some marginal consumers who would have chosen the copyrighted product in the absence of the investment, and the number and profitability of these marginal consumers do not depend on the current market share of the pirate firm and thus do not depend on the competing copyright holder's price, p_c.

where $T \equiv \frac{\beta(1-\beta)sv}{(1-\gamma)k}$. The pirate firm will participate in the market if and only if

$$\Pi_p^I(p_c, x^*) > 0 \Leftrightarrow p_c > \widetilde{p}_c \equiv \begin{cases} \dfrac{t}{\beta} - \dfrac{(1-\gamma)kt^2}{2\beta^2(1-\beta)sv} & \text{if } 0 \le t < T, \\ \dfrac{(1-\beta)sv}{2(1-\gamma)k} & \text{otherwise;} \end{cases}$$

To summarize Subgame I and Subgame II along with the pirate firm's participation constraint, we have consumer demand for two types of products as follows:

$$D_c(p_c, x) = \begin{cases} \gamma\left(1 - \dfrac{p_c}{v}\right) + (1-\gamma)\left[1 - \dfrac{p_c - xt}{(1-\beta)v}\right] & \text{if } p_c > \max\left\{\dfrac{xt}{\beta}, \widetilde{p}_c\right\}, \\ 1 - \dfrac{p_c}{v} & \text{otherwise;} \end{cases}$$

$$D_p(p_c, x) = \begin{cases} (1-\gamma)\left[\dfrac{p_c - xt}{(1-\beta)v} - \dfrac{xt}{\beta v}\right] & \text{if } p_c > \max\left\{\dfrac{xt}{\beta}, \widetilde{p}_c\right\}, \\ 0 & \text{otherwise.} \end{cases}$$

The copyright holder's profit and the pirate firm's profit are, respectively,

$$\begin{aligned} \Pi_c(p_c, x) &= p_c D_c(p_c, x), \\ \Pi_p(p_c, x) &= kD_p(p_c, x) - \frac{s}{2}(1-x)^2. \end{aligned}$$

Proposition 1 solves the equilibrium price and tracking probability by a set of equations as follows:

$$\begin{cases} p_c^* = \arg\max_{p_c} \Pi_c(p_c, x^*), \\ x^* = \arg\max_x \Pi_p(p_c^*, x), \end{cases}$$

where given p_c^* and x*, we can define the equilibrium demand $D_j^* \equiv D_j(p_c^*, x^*)$ and the equilibrium profit $\Pi_j^* \equiv \Pi_j(p_c^*, x^*)$ for $j \in \{c, p\}$. We will provide necessary derivations or elaborations that lead to each proposition in the main text but relegate complete proofs to the Web Appendix.

Proposition 1 (Equilibrium Characterization).

There exist thresholds $\underline{s}$ and $\bar{t}$ such that

i. if $0 < s < \underline{s}$ or if $s \geq \underline{s}$ and $0 \leq t < \bar{t}$, the pirate firm's equilibrium antitracking technology choice is

$$x^* = \max\left\{1 - \frac{(1-\gamma)kt}{\beta(1-\beta)sv}, 0\right\},$$

and the copyright holder's equilibrium price is

$$p_c^* = \frac{(1-\beta)v + (1-\gamma)x^*t}{2(1-\gamma\beta)};$$

ii. otherwise, if $s \geq \underline{s}$ and $t \geq \bar{t}$, the pirate firm does not participate in the market, and the copyright holder's equilibrium price is

$$p_c^* = \min\left\{\tilde{p}_c, \frac{v}{2}\right\}.$$

Proposition 1 implies that when the technology cost is relatively low with $0 < s < \underline{s}$ or the penalty is relatively low with $0 \leq t < \bar{t}$, the copyright holder and the pirate firm can coexist in the market where ethical consumers buy copyrighted products, and for unethical consumers, the equilibrium consumer segmentation is shown by Panel A in Figure 3: those with relatively high preference for quality buy copyrighted products and those with intermediate preference go for pirated products. The equilibrium x^* is exactly given by Equation 1. In contrast, when both s and t are relatively high, the pirate firm is driven out of the market and, consequently, no piracy is supplied.

Effects of Regulation

In this section, we examine the effects of piracy consumption regulation on the equilibrium outcome in a series of propositions. To begin with, we are interested in how penalty t influences the pirate firm's antitracking technology choice and consumers' expected penalty. Proposition 2 states the results. By Proposition 1, when $s \geq \underline{s}$, we restrict ourselves to $0 \leq t < \bar{t}$, because otherwise, x^* is not well defined.

Proposition 2 (Effect of Penalty on Antitracking Technology Choice and Expected Penalty).

i. a. If $0 < s < \underline{s}$, x^* decreases with t for $0 \leq t < T$ and stays at zero for $t \geq T$;
   b. otherwise, if $s \geq \underline{s}$, x^* decreases with t for $0 \leq t < \bar{t}$.

ii. There exists a threshold $\bar{s}$ that does not depend on t such that
   a. if $0 < s < \underline{s}$, x^*t increases with t for $0 \leq t < \underline{t}$, decreases with t for $\underline{t} \leq t < T$, and stays at zero for $t \geq T$;
   b. if $\underline{s} \leq s < \bar{s}$, x^*t increases with t for $0 \leq t < \underline{t}$ and decreases with t for $\underline{t} \leq t < \bar{t}$;
   c. otherwise, if $s \geq \bar{s}$, x^*t increases with t for $0 \leq t < \bar{t}$.

The relationship between x^* and t has a clear intuition—as penalty t increases, the pirate firm reduces x^* to keep its products still attractive for unethical consumers, whose consumption utility of pirated products, u_p, depends on the whole term of x^*t, the expected penalty. In particular, when $0 < s < \underline{s}$ and $t \geq T$, the pirate firm chooses $x^* = 0$, which leads to an expected penalty of zero as a result.

To see the relationship between x^*t and t, given that x^*t is the determinant of consumer utility and choice, it is worthwhile to take a closer examination by decomposing the marginal effect of t on x^*t into two parts:

$$\begin{aligned}\frac{d(x^*t)}{dt} &= \underbrace{x^*}_{\text{direct effect}} + \underbrace{\frac{dx^*}{dt} \times t}_{\text{strategic effect}} \\ &= \underbrace{1 - \frac{(1-\gamma)kt}{\beta(1-\beta)sv}}_{\text{direct effect}} + \underbrace{\left[-\frac{(1-\gamma)k}{\beta(1-\beta)sv} \times t\right]}_{\text{strategic effect}}. \qquad (2)\end{aligned}$$

Here, we focus on the situation where $x^* > 0$; otherwise, the expected penalty will never change even if the regulator further increases the penalty. The first part in Equation 2 is the positive direct effect. The second part is the negative strategic effect and comes from the pirate firm's strategic investment in improving its antitracking technology in response to tighter regulation. It is somewhat surprising that the strategic effect can dominate the direct effect when s is relatively low and t is relatively high. In fact, one may interpret penalty t as a form of tax on piracy consumption, and further intuit that while the pirate firm has an incentive to compensate consumers by reducing x^* to mitigate the adverse effect of piracy tax, the compensation is a second-order effect that will never override the first-order effect of taxation per se. However, it turns out that this intuition is incorrect, as shown in Figure 4. This is because the pirate firm's compensation for consumers is not a simple monetary transfer; instead, the effective tax on consumers is the expected penalty, x^*t, which is jointly determined by the regulator and the pirate firm that bears a technology development cost of $s(1-x^*)^2/2$. Since the pirate firm's marginal benefit of reducing x^*, $(1-\gamma)kt/[\beta(1-\beta)v]$, increases with t, the pirate firm has strong incentives to lower x when the penalty is high. As a result, the strategic effect can override the direct effect under a high penalty.

As illustrated in Figure 4, under a relatively low s and a relatively high t, as t increases further, the pirate firm has an incentive to decrease x^*t by investing in antitracking technologies that reduce x^*, because a decreased x^*t benefits not only piracy users but also the pirate firm itself. Notice that the decreasing relationship between x^* and t is quite general and does not depend on the copyright holder's pricing strategy, as shown by Equation 1; nor does it depend on the uniform distribution of consumer preference for quality.[12] We can also explain the decreasing relationship between x^*t and t from Equation 2, where the direct effect decreases with t and increases with s while the strategic effect increases with t and decreases with s (in magnitude); as a result, the latter can dominate the former when t is relatively high and s is relatively low.

[12] One can further show that as long as the distribution function is convex, x^* decreases with t.

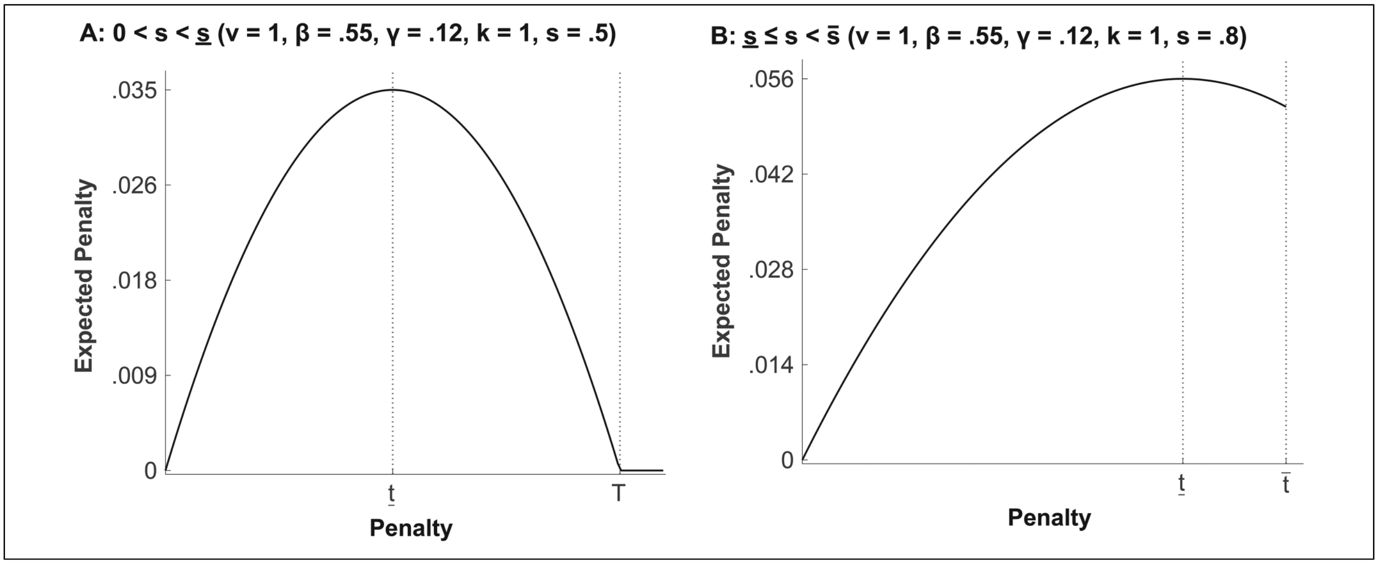

Figure 4. Effect of Penalty on Expected Penalty.

For simplicity, we do not plot the case with $s \geq \bar{s}$ in Figure 4 and other figures in the following analysis, as it can be seen as a degenerate case of $\underline{s} \leq s < \bar{s}$, where the interval of $[\underline{t}, \bar{t}]$ shrinks to an empty set.

Next, we investigate the impact of regulation on piracy consumption. Proposition 3 and Figure 5 reveal rich nonmonotonic relationships between piracy consumption and the penalty. These U-shaped relationships between D_p^* and t follow directly from the inverse U-shaped relationship between x*t and t. The abrupt drop to zero of D_p^* at $t = \bar{t}$ when $s \geq \underline{s}$ is due to the pirate firm's participation constraint—for $t \geq \bar{t}$, piracy is no longer supplied. In short, Proposition 3 uncovers that when technology cost s is not high enough (i.e., $0 < s < \bar{s}$), tighter regulation may backfire by promoting more piracy consumption at a relatively high penalty.

Proposition 3 (Effect of Penalty on Piracy Consumption).

i. If $0 < s < \underline{s}$, D_p^* decreases with t for $0 \leq t < \underline{t}$, increases with t for $\underline{t} \leq t < T$, and is invariant in t for $t \geq T$.
ii. If $\underline{s} \leq s < \bar{s}$, D_p^* decreases with t for $0 \leq t < \underline{t}$, increases with t for $\underline{t} \leq t < \bar{t}$, and stays at zero for $t \geq \bar{t}$.
iii. Otherwise, if $s \geq \bar{s}$, D_p^* decreases with t for $0 \leq t < \bar{t}$ and stays at zero for $t \geq \bar{t}$.

Furthermore, we study how regulation affects the copyright holder's price and profit, which are summarized in Proposition 4 and illustrated in Figures 6 and 7. When $0 < s < \underline{s}$, the copyright holder's equilibrium price and profit exhibit an inverse U-shaped relationship with t for $0 \leq t < T$ and are invariant in t for $t \geq T$, which can also be explained by the inverse U-shaped relationship between x*t and t for $0 \leq t < T$ and invariance between x*t and t for $t \geq T$ as shown in Proposition 2. The similar inverse U-shaped relationship exhibits for $0 \leq t < \bar{t}$ when $\underline{s} \leq s < \bar{s}$. When $s \geq \underline{s}$, it is interesting to see that the copyright holder drops its price discretely at $t = \bar{t}$ so as to edge the pirate firm out of the market. As t further increases, the maximum price the copyright holder can charge while still keeping the pirate firm out of the market will rise; as t gets sufficiently high, it is possible for the copyright holder to freely exercise its monopoly power in the market by pricing at v/2 and gain monopoly profit.

In summary, Proposition 4 shows that the copyright holder can use different pricing strategies to combat piracy, and tighter regulation can help the copyright holder for a relatively high or low penalty but hurt at an intermediate penalty.

Proposition 4 (Effect of Penalty on Copyright Holder's Price and Profit).

i. If $0 < s < \underline{s}$, p_c^* increases with t for $0 \leq t < \underline{t}$, decreases with t for $\underline{t} \leq t < T$, and is invariant in t for $t \geq T$.
ii. If $\underline{s} \leq s < \bar{s}$, p_c^* increases with t for $0 \leq t < \underline{t}$, decreases with t for $\underline{t} \leq t < \bar{t}$, drops directly at $t = \bar{t}$, increases with t for $\bar{t} \leq t < T$, and is invariant in t for $t \geq T$.
iii. Otherwise, if $s \geq \bar{s}$, p_c^* increases with t for $0 \leq t < \bar{t}$, drops discretely at $t = \bar{t}$, increases with t for $\bar{t} \leq t < T$, and is invariant in t for $t \geq T$.

The relationship between Π_c^* and t is the same as between p_c^* and t except that Π_c^* is continuous in t with no drop at $t = \bar{t}$ if $s \geq \underline{s}$.

Last, we analyze the effect of regulation on consumer surplus and social welfare in Propositions 5 and 6. We consider two measures in calculating consumer surplus and social welfare. First, in calculating consumer surplus (CS) and social welfare (SW), we exclude consumer surplus from pirated products, as well as penalty fees. This reflects the idea that the regulator should not design policies aiming to maximize consumer surplus gains from consuming illegal products. Second, we also calculate total consumer surplus (TCS) and total social welfare

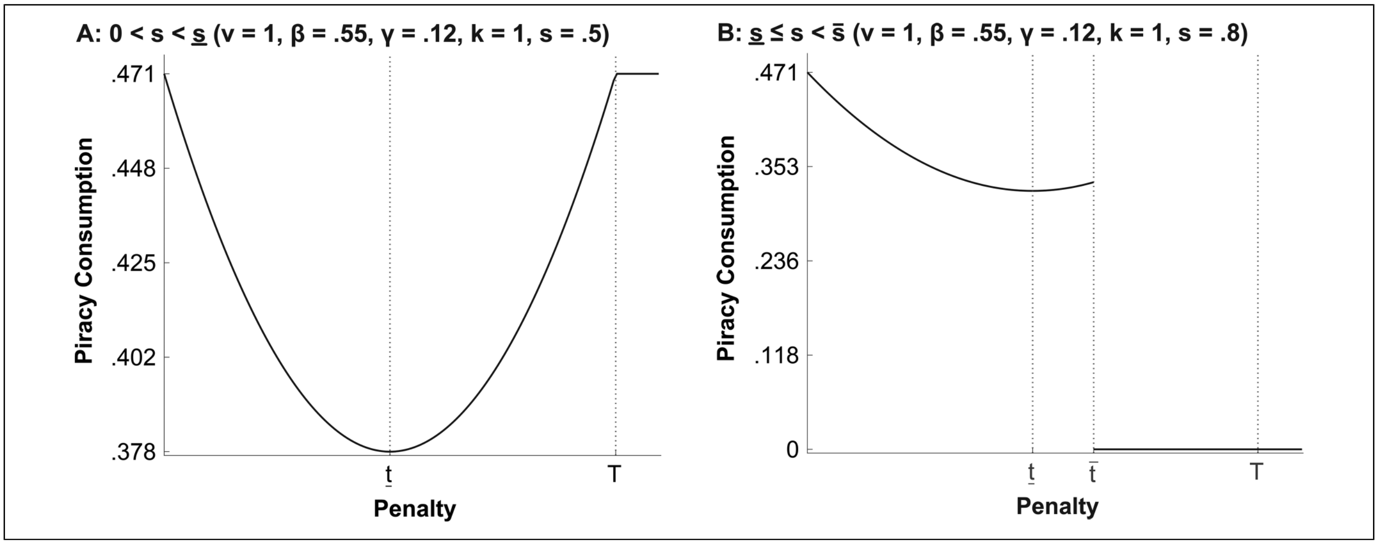

Figure 5. Effect of Penalty on Piracy Consumption.

(TSW), which further include consumer surplus from consuming pirated products and penalty fees.

Proposition 5 (Effect of Penalty on Consumer Surplus and Total Consumer Surplus).

i. a. If $0 < s < \underline{s}$, CS exhibits a nonmonotonic relationship with t in general for $0 \le t < T$ and is invariant in t for $t \ge T$.
   b. Otherwise, if $s \ge \underline{s}$, CS exhibits a nonmonotonic relationship with t in general for $0 \le t < \bar{t}$, jumps discretely at $t = \bar{t}$, decreases with t for $\bar{t} \le t < T$, and is invariant in t for $t \ge T$.

ii. a. If $0 < s < \underline{s}$, TCS decreases with t for $0 \le t < \underline{t}$, increases with t for $\underline{t} \le t < T$, and is invariant in t for $t \ge T$.
   b. If $\underline{s} \le s < \bar{s}$, TCS decreases with t for $0 \le t < \underline{t}$ and increases with t for $\underline{t} \le t < \bar{t}$, (TCS = CS for $t \ge \bar{t}$).
   c. Otherwise, if $s \ge \bar{s}$, TCS decreases with t for $0 \le t < \bar{t}$ (TCS = CS for $t \ge \bar{t}$).

CS is calculated by integrating over all consumers who buy copyrighted products, where the surplus for each consumer equals the consumer's valuation of a copyrighted product minus price p_c^*. A higher expected penalty has two opposing effects on CS: (1) it makes pirated products less attractive and thus increases consumer demand for copyrighted products, and (2) it induces the copyright holder to charge a higher price. These two opposing effects result in a nonmonotonic relationship between CS and x*t. Furthermore, as shown by Proposition 2, the expected penalty, x*t, has a nonmonotonic relationship with penalty t. Consequently, the relationship between CS and t, as a combination of the relationship between CS and x*t and that between x*t and t, exhibits a complex nonmonotonic pattern for $0 < s < \underline{s}$ and $0 \le t < T$, or for $s \ge \underline{s}$ and $0 \le t < \bar{t}$. This is illustrated by Panels A and B in Figure 8. We further zoom into CS in the range of $0 \le t \le \bar{t}$ as shown by a box in Panel B. In contrast, when $s \ge \underline{s}$, the copyright holder reduces its price discontinuously at $t = \bar{t}$ so as to drive the pirate firm out of the market, which improves CS since more consumers obtain copyrighted products at a lower price. For $t \ge \bar{t}$, all consumers buy copyrighted products. Raising penalty t leads to a higher p_c^* (that is, the first effect is muted), which results in lower CS, as shown in Figure 8, Panel B.

TCS comprises CS and the surplus of unethical consumers who adopt pirated products, the latter of which equals their valuation of pirated products minus the expected penalty. When $0 < s < \underline{s}$ or when $s \ge \underline{s}$ and $0 \le t < \bar{t}$, an increase in the expected penalty increases p_c^* and decreases consumers' total demand for copyrighted products and pirated products. As a result, TCS decreases as the expected penalty increases. Therefore, the U-shaped relationship between TCS and the penalty directly follows the inverse U-shaped relationship between the expected penalty and t. When $s \ge \underline{s}$ and $t \ge \bar{t}$, pirated products are not supplied and TCS is equal to CS.

Proposition 6 (Effect of Penalty on Social Welfare and Total Social Welfare).

i. a. If $0 < s < \underline{s}$, SW increases with t for $0 \le t < \underline{t}$, decreases with t for $\underline{t} \le t < T$, and is invariant in t for $t \ge T$.
   b. If $\underline{s} \le s < \bar{s}$, SW increases with t for $0 \le t < \underline{t}$, decreases with t for $\underline{t} \le t < \bar{t}$, jumps discretely at $t = \bar{t}$, decreases with t for $\bar{t} \le t < T$, and is invariant in t for $t \ge T$.
   c. Otherwise, if $s \ge \bar{s}$, SW increases with t for $0 \le t < \bar{t}$, jumps discretely at $t = \bar{t}$, decreases with t for $\bar{t} \le t < T$, and is invariant in t for $t \ge T$.

ii. a. If $0 < s < \underline{s}$, TSW increases with t for $0 \le t < \underline{t}$, decreases with t for $\underline{t} \le t < T$, and is invariant in t for $t \ge T$.
   b. Otherwise, if $s \ge \underline{s}$, TSW exhibits a nonmonotonic relationship with t in general for $0 \le t < \bar{t}$ (TSW = SW for $t \ge \bar{t}$).

SW comprises CS and the copyright holder's profit. When $0 < s < \underline{s}$, as the expected penalty rises, more consumers buy

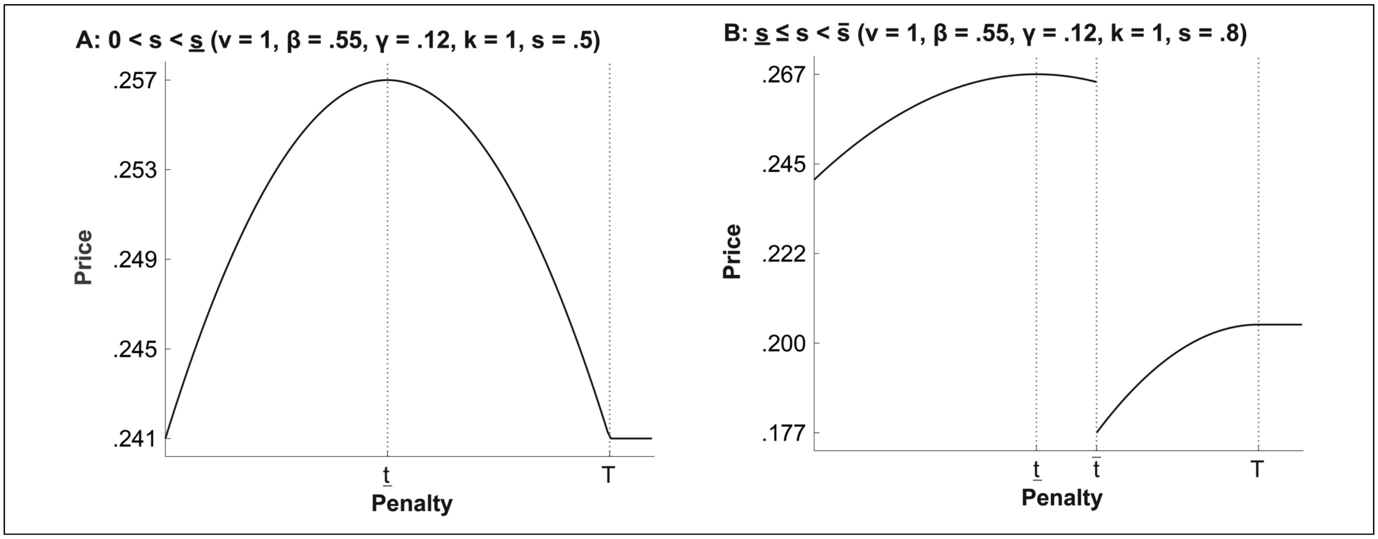

Figure 6. Effect of Penalty on Copyright Holder's Price.

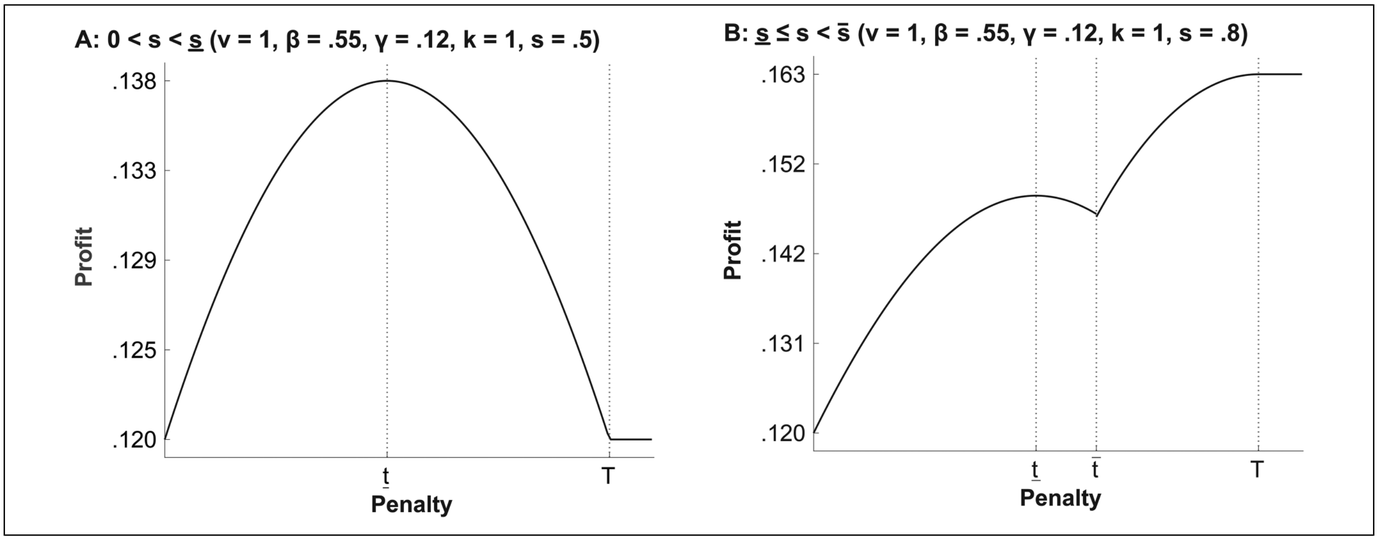

Figure 7. Effect of Penalty on Copyright Holder's Profit.

copyrighted products and the copyright holder's profit grows, which in turn improves SW. This implies that the pattern of SW follows that of the expected penalty, peaking at $t = \underline{t}$. When $s \geq \underline{s}$, analogously, the relationship between SW and t follows that between x*t and t for $0 \leq t < \bar{t}$. However, the copyright holder discretely drops its price at $t = \bar{t}$, which leads to a discontinuous jump in SW. At this point, SW is maximized since copyrighted products are provided at a lower price. When $t \geq \bar{t}$, only copyrighted products exist in the market, and thus a higher price due to an increase in the penalty will harm SW.

TSW comprises TCS, the copyright holder's profit, and penalty fees. When $0 < s < \underline{s}$ or when $s \geq \underline{s}$ and $0 \leq t < \bar{t}$, as the expected penalty increases, although the sum of the consumer surplus from consuming copyrighted products and the copyright holder's profit increases, fewer unethical consumers adopt pirated products, causing a reduction in the sum of the consumer surplus from consuming pirated products and penalty fees. We find that the former positive effect can be dominated by the latter negative effect only if $s \geq \underline{s}$. As a result, when $0 < s < \underline{s}$, TSW and the expected penalty exhibit the same pattern with t for $t \geq 0$. However, when $s \geq \underline{s}$, combined with the nonmonotonic relationship between x*t and t, TSW has a complex relationship with t for $0 \leq t < \bar{t}$. Furthermore, when $s \geq \underline{s}$ and $t \geq \bar{t}$, TSW coincides with SW because there is no piracy supply (Figure 9).

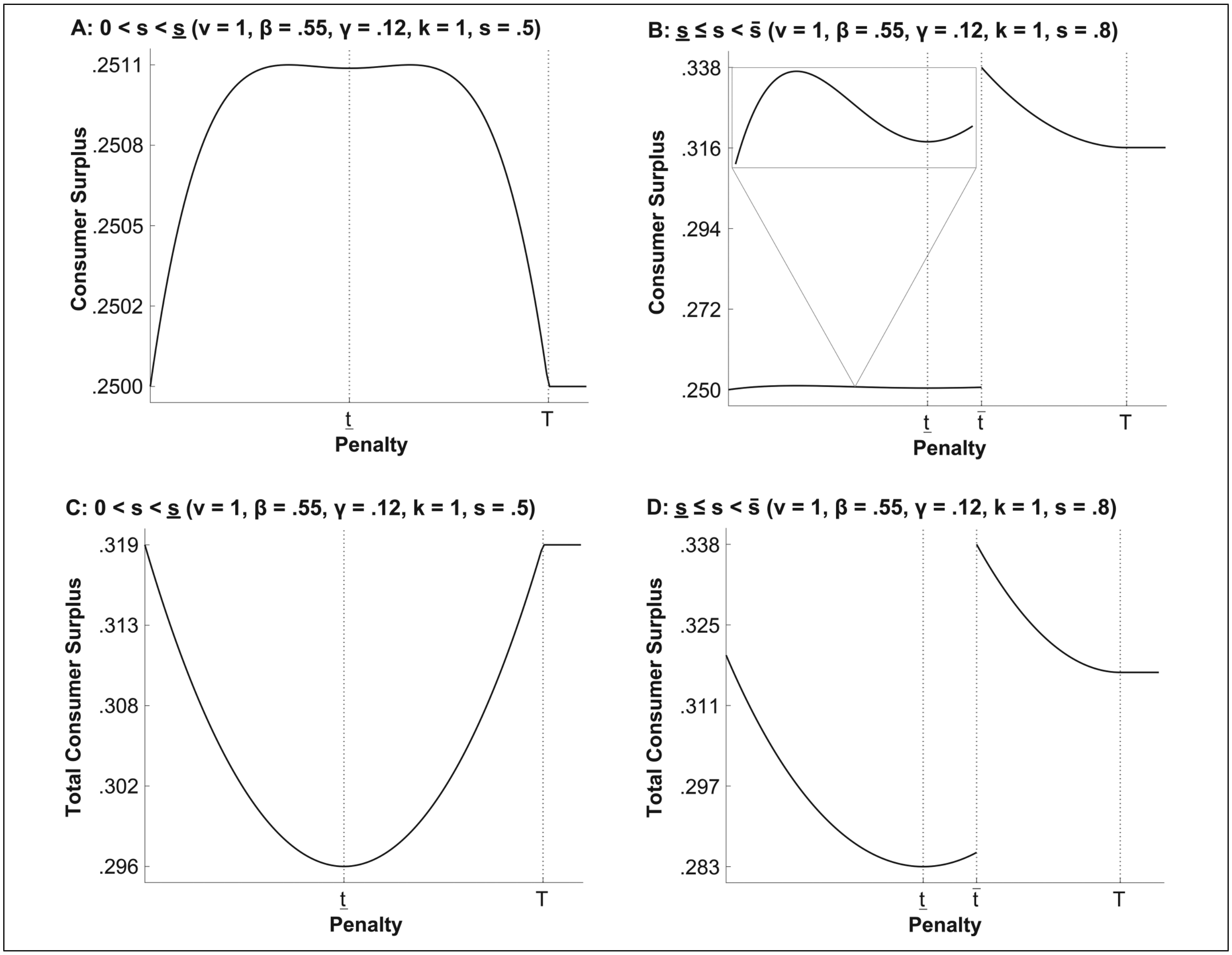

Figure 8. Effect of Penalty on Consumer Surplus and Total Consumer Surplus.

Policy Implications

After solving the equilibrium and identifying the effects of regulation, we analyze a series of policy tools that could help the regulator combat piracy. We start by solving the welfare-maximizing regulation.

Optimal Regulation

Proposition 7 (Optimal Regulation).

i. a. If $0 < s < \underline{s}$, SW is maximized at $t = \underline{t}$.
   b. Otherwise, if $s \geq \underline{s}$, SW is maximized at $t = \bar{t}$.
ii. a. If $0 < s < \underline{s}$, TSW is maximized at $t = \underline{t}$.
   b. If $\underline{s} \leq s < s^+$, TSW is maximized at $t = \bar{t}$, where $s^+ > \bar{s}$.
   c. Otherwise, if $s \geq s^+$, TSW is maximized at $t = t^+$, where $0 < t^+ < \bar{t}$.

Proposition 7 directly follows from Proposition 6. Let us start with the scenario where the regulator wants to maximize SW. When the pirate firm can develop antitracking technologies at a relatively low cost with $0 < s < \underline{s}$. SW is maximized at the moderate penalty $t = \underline{t}$, where the expected penalty hits the maximum (Proposition 2) and piracy consumption touches the minimum but cannot be completely eliminated (Proposition 3). The reason is that a penalty higher than $\underline{t}$ will encourage more consumer adoption of pirated products and thus hurt the copyright holder due to the pirate firm's strategic investment in antitracking technologies. Therefore, a moderate penalty that maximizes the expected penalty can simultaneously maximize SW and minimize piracy consumption. This suggests the following actionable guideline for policy making in this scenario: To achieve the social optimum, the regulator should simply resort to maximizing the expected penalty when setting the penalty. In contrast, we also find that when $s \geq \underline{s}$, SW peaks at the high penalty $t = \bar{t}$ that edges the pirate firm out of the market.

Next, we consider the scenario where the regulator tries to maximize TSW including the consumer surplus from pirated products and penalty fees. The optimal penalty that maximizes TSW is the

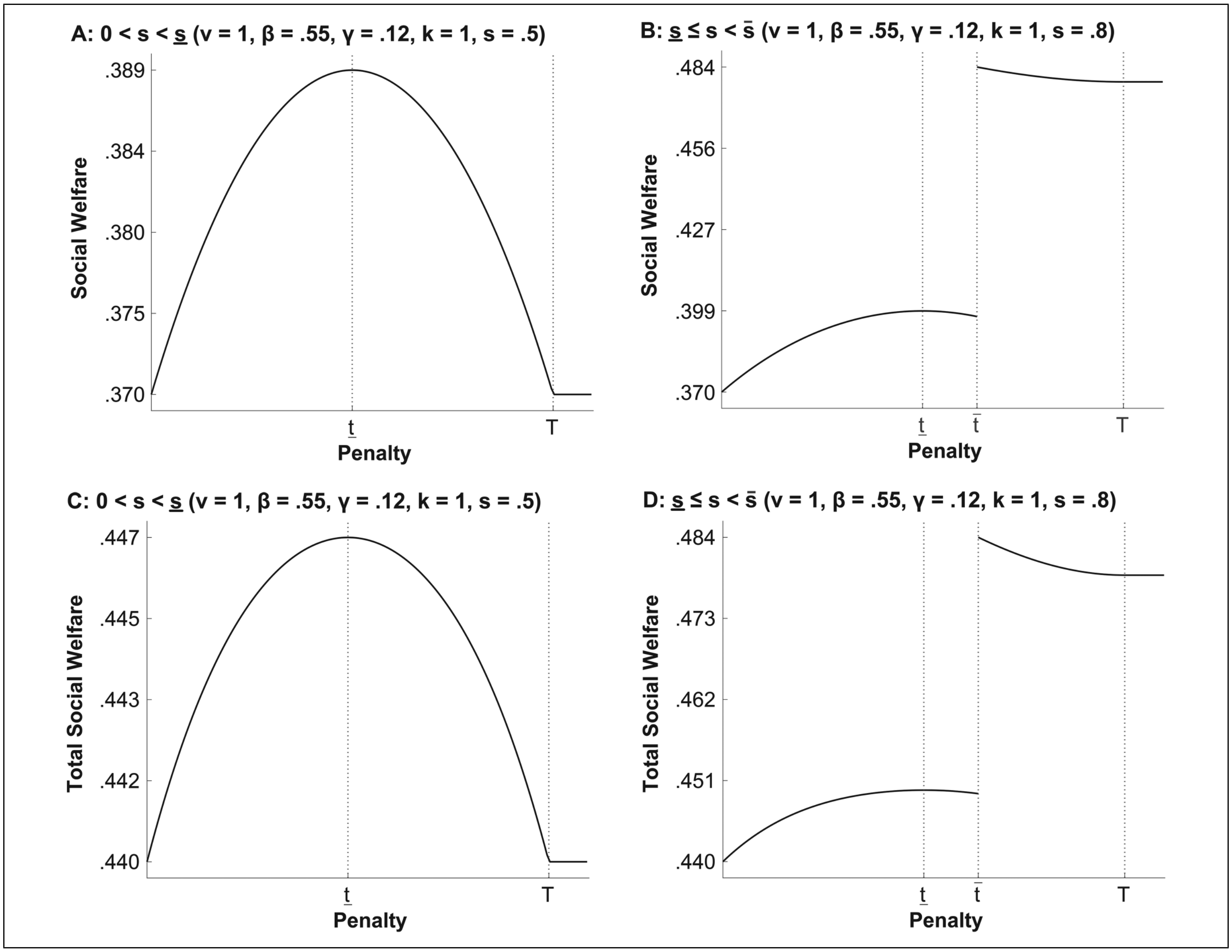

Figure 9. Effect of Penalty on Social Welfare and Total Social Welfare.

same as that maximizing SW, except for the case when $s \geq s^+$. As shown in Figure 10, when $s > s^+$, TSW increases with t for $0 \leq t < t^+$, then decreases with $t^+ \leq t < \bar{t}$, and reaches the maximum at $t = t^+$. In comparison, SW increases monotonically with t for $0 \leq t < \bar{t}$. The difference comes from the consumer surplus from pirated products and penalty fees, which decrease with the expected penalty and thus decrease with t given $s > s^+$. Consequently, the global maximizer of TSW could be either $t = t^+$ or $t = \bar{t}$ as shown in Figure 10. At $t = \bar{t}$, the copyright holder will set a low price to force the pirate firm out of the market, and this task is easier to achieve when the antitracking technology is costly. As a result, copyrighted products' price at $t = \bar{t}$ increases with s, and hence TSW at this point becomes lower under a higher s. Therefore, when $s \geq s^+$, TSW at $t = t^+$ can exceed TSW at $t = \bar{t}$.

Supply-Side Regulation

In practice, regulators can also explore supply-side regulations to combat piracy. Will supply-side regulations completely replace the role of demand-side regulations? As we have argued previously, this is unlikely, as it may prove challenging to rely on supply-side regulations solely to completely shut down piracy websites, which have the ability to globally host their servers and constantly alter their domain names to avoid detection. We formally examine the role of supply-side regulation and its relationship with demand-side regulation next.

Specifically, we extend the main model by allowing the regulator to exert an effort of $d \cdot y^2/2$ to raid and take down the pirate firm with probability $y \in [0, 1]$, where $d > 0$ is a cost parameter. As a result, given the regulator's supply-side investment, with probability y, the copyright holder serves as the monopoly in the market, and with the complementary probability of $1 - y$, the market remains the same as in the main model.

If social welfare is the regulator's target, it will choose t and y to maximize $ySW^M + (1 - y)SW - d \cdot y^2/2$, where SW^M is social welfare when the copyright holder monopolizes the market. In contrast, if the regulator seeks to maximize total social welfare, its objective becomes $yTSW^M + (1 - y)TSW - d \cdot y^2/2$, where, by definition, $TSW^M = SW^M$.

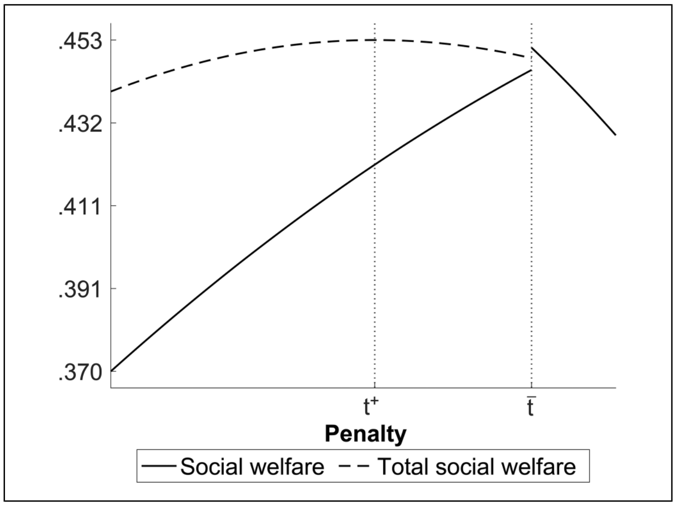

Figure 10. Effect of Penalty on Social Welfare and Total Social Welfare for $s \geq s^+$ ($v = 1$, $\beta = .55$, $\gamma = .12$, $k = 1$, $s = 260$).

Solving the regulator's joint maximization problem, we obtain the optimal supply-side regulation y^* and optimal demand-side regulation t^* by the following proposition.

Proposition 8.

i. When the regulator aims to maximize SW,
  a. if $0 < s < \min\{\hat{s}, \underline{s}\}$, $y^* = \min\left\{\frac{SW^M - SW|_{t=\underline{t}}}{d}, 1\right\}$ and $t^* = \underline{t}$;
  b. if $\min\{\hat{s}, \underline{s}\} \leq s \leq \underline{s}$; $y^* = 0$ and $t^* = \underline{t}$;
  c. otherwise, if $s \geq \underline{s}$, $y^* = 0$ and $t^* = \bar{t}$.
ii. When the regulator aims to maximize TSW, $y^* = 0$ and the optimal demand-side regulation t^* is the same as in Proposition 7.

Proposition 8 implies that even if the regulator has access to supply-side regulation, it does not use it unless s is low. The intuition is that using supply-side regulation to shut down the pirate firm softens market competition and thus hurts SW. When $SW^M < SW$ ($TSW^M < TSW$), the regulator will optimally choose $y^* = 0$ to maximize (total) social welfare. An active supply-side regulation is implemented only when s is sufficiently low such that $0 < s < \min\{\hat{s}, \underline{s}\}$, in which case so much piracy is supplied in the market that too many consumers switch from the copyright holder to the pirate firm, which reduces SW. In a nutshell, Proposition 8 suggests that supply-side regulation may be useful when the antitracking technology is available at a sufficiently low cost, but it does not substitute for the role of demand-side regulation even when it is being actively used.

Educating Consumers About Copyright Protection

Will educating instead of penalizing consumers help suppress privacy consumption? This is the question we try to answer in this section by investigating the effect of γ on piracy consumption. The premise is that by educating the public about the rationale and importance of copyright protection, the regulator could potentially raise the fraction of ethical consumers in the population. To this end, we need to expand our main analysis by relaxing Assumption 1 and extending the support of γ from $[0, (1 - \beta)/\beta)$ to the full range of $[0, 1]$. The following proposition characterizes how γ impacts piracy consumption.[13]

Proposition 9 (Effect of Fraction of Ethical Consumers on Piracy Consumption).

Given $0 < t < \hat{t}$, there exists a threshold $\tilde{\gamma}$ such that D_p^* jumps discretely at $\gamma = \tilde{\gamma}$ and decreases with γ for $\tilde{\gamma} < \gamma < 1$.

The condition of $0 < t < \hat{t}$ in Proposition 9 ensures that the penalty is not prohibitively high so that the pirate firm remains active in the market. The proposition shows that a higher γ could increase piracy consumption. This is also illustrated in Figure 11. The intuition is that as the fraction of ethical consumers in the market increases, the copyright holder may find it more profitable to give up all unethical consumers and serve only ethical consumers by setting the monopoly price. As a result, this would lead to an increase in piracy consumption from unethical consumers because all of them now turn to pirated products. Moreover, it can be verified that this result does not depend on whether the tracking probability x is exogenous or endogenous. In summary, it seems that educating consumers about ethical and legal usage of copyrighted products could inadvertently increase piracy consumption, and thus cannot replace the role of punitive regulation on piracy consumption. We only point out this possibility in theory, and measuring the actual effect of piracy education on piracy consumption would require a careful empirical examination.

Extensions

Alternative Timings of the Game

This extension considers two alternative timings of the game. First, when the copyright holder sets p_c before the pirate firm sets x, we find that the equilibrium outcome is exactly the same as in the main model. This is because the pirate firm's optimal choice x^* does not depend on the copyright holder's price p_c, as shown by Equation 1. Second, when the pirate firm sets x before the copyright holder sets p_c, Proposition 10 states that our main findings are robust.

Proposition 10.

There exist thresholds $\underline{s}^{at}$ and $\bar{s}^{at}$ such that

i. if $0 < s < \underline{s}^{at}$, x^*t increases with t for $0 \leq t < \underline{t}^{at}$, decreases with t for $\underline{t}^{at} \leq t < T^{at}$, and is invariant in t for $t \geq T^{at}$, while D_p^* decreases with t for $0 \leq t < \underline{t}^{at}$, increases with t for $\underline{t}^{at} \leq t < T^{at}$, and is invariant in t for $t \geq T^{at}$;[14]

[13] We assume that the pirate firm moves after the copyright holder to preclude the mixed-strategy equilibrium due to the simultaneous move of the two firms for large γ. As shown subsequently by an extension, the sequential move produces the same equilibrium outcome as the simultaneous move for the main model under Assumption 1.

[14] The superscript "at" stands for "alternative timing," and it signifies thresholds in this extension. For convenience, we omit the superscript for all equilibrium variables in the "Extensions" section.

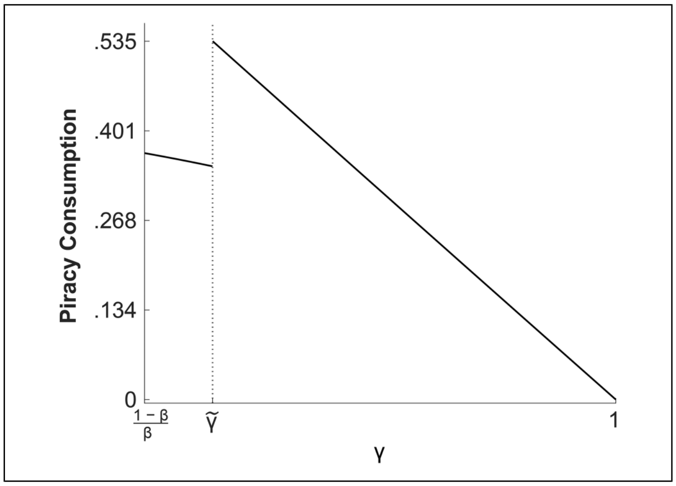

Figure 11. Effect of Fraction of Ethical Consumers on Piracy Consumption ($v = 1$, $\beta = .75$, $t = .05$, $k = 1$, $s = .5$).

ii. if $\underline{s}^{at} \leq s < \bar{s}^{at}$, x^*t increases with t for $0 \leq t < \underline{t}^{at}$ and decreases with t for $\underline{t}^{at} \leq t < \bar{t}^{at}$, while D_p^* decreases with t for $0 \leq t < \underline{t}^{at}$ and increases with t for $\underline{t}^{at} \leq t < \bar{t}^{at}$;

iii. otherwise, if $s \geq \bar{s}^{at}$, x^*t increases with t for $0 \leq t < \bar{t}^{at}$, while D_p^* decreases with t for $0 \leq t < \bar{t}^{at}$.

Endogenous Quality of Copyrighted Products

In this extension, we consider the copyright holder to be the digital content creator and explore the impact of regulation on its incentives to invest in quality improvement for its products (content creativity). Specifically, we add to the game a pre-stage wherein the copyright holder decides on quality v of its products, which entails a cost of $mv^2/2$. The copyright holder's profit is $\Phi_c(v) = \Pi_c^*(v) - mv^2/2$, where $m > 0$ is assumed to be sufficiently high so that $\Phi_c(v)$ is concave in v. The optimal quality v^* is determined by the first-order optimality condition, $\Phi_c'(v)|_{v=v^*} = 0$.

Using the implicit function theorem, we have

$$\frac{dv^*}{dt} = -\frac{\partial \Phi_c'(v)/\partial t}{\Phi''_c(v)}\bigg|_{v=v^*},$$

which is in the same sign as $\partial \Phi_c'(v)/\partial t$, as $\Phi_c''(v) < 0$ by concavity of $\Phi_c(v)$. It is more convenient to explicitly signify the dependence of $\Phi_c(v)$ on t by introducing $\phi_c(v, t) = \Phi_c(v)$; furthermore, we can isolate the impact of t on $\phi_c(v, t)$ through x^* by introducing $\tilde{\phi}_c(v, t, x^*(v, t)) = \phi_c(v, t) = \Phi_c(v)$. Then, we have

$$\begin{aligned} \frac{dv^*}{dt} \propto \frac{\partial \Phi_c'(v)}{\partial t} &= \frac{\partial^2 \phi_c}{\partial v \partial t} = \frac{\partial^2 \tilde{\phi}_c}{\partial v \partial t} + \frac{\partial^2 \tilde{\phi}_c}{\partial v \partial x^*}\frac{\partial x^*}{\partial t} \\ &+ \left(\frac{\partial^2 \tilde{\phi}_c}{\partial x^* \partial t} + \frac{\partial^2 \tilde{\phi}_c}{\partial x^{*2}}\frac{\partial x^*}{\partial t}\right)\frac{\partial x^*}{\partial v} + \frac{\partial \tilde{\phi}_c}{\partial x^*}\frac{\partial^2 x^*}{\partial v \partial t} \end{aligned}. \tag{3}$$

The first term on the right-hand side in Equation 3 is a direct effect under exogenous x, which can be shown to be negative (see details in the Web Appendix). That is, raising the penalty induces lower product quality because the copyright holder faces weaker competition from the pirate firm and thus has fewer incentives to differentiate its products from pirated products. The remaining terms consist of an indirect effect due to endogenous x, which can be shown to be positive for $0 \leq t < T$ when $0 < s < \underline{s}$, and for $0 \leq t < \bar{t}$ when $s \geq \underline{s}$. Intuitively, the pirate firm's investment in anti-tracking technologies intensifies competition and thus prompts the copyright holder to invest more in quality improvement.

In Figure 12, we show that the indirect effect can dominate the direct effect such that v^* increases with penalty t. Moreover, Panel A in Figure 12 illustrates that when t is sufficiently high, v^* is determined as if there is no regulation in the market because the pirate firm always sets $x^* = 0$, given that the copyright holder's equilibrium profit is the function of x^*t. Last, the right panel in Figure 12 also reveals that v^* first drops discretely at $t = \bar{t}$ and then increases with t. The drop is explained by the copyright holder's strategic use of a low price to force the pirate firm out of the market, whereas the subsequent increasing relationship is due to stronger protection of monopoly profit with a higher penalty. Note that $\Pi_c^*(v)$ is invariant in t for $t \geq T$, so v^* stays the same for $t \geq T$.

Endogenous Copyright Protection

In this extension, we add to the game a pre-stage wherein the copyright holder engages in copyright protection by influencing the quality of pirated products. In other words, we allow the copyright holder to control β. The lower the β, the stronger the copyright protection. To this end, we specify the copyright holder's profit as $\Phi_c(\beta) = \Pi_c^*(\beta) - h(1-\beta)^2/2$, where $h > 0$ is assumed to be sufficiently high so that $\Phi_c(\beta)$ is concave in β. The optimal copyright protection β^* is determined by the first-order optimality condition, $\Phi_c'(\beta)|_{\beta=\beta^*} = 0$. By the implicit function theorem, we have

$$\frac{d\beta^*}{dt} = -\frac{\partial \Phi_c'(\beta)/\partial t}{\Phi''_c(\beta)}\bigg|_{\beta=\beta*},$$

which has the same sign with $\partial \Phi_c'(\beta)/\partial t$ because $\Phi_c''(\beta) < 0$ by concavity of $\Phi_c(\beta)$. To separate the impact of t on $\Phi_c(\beta)$ through x^*, we introduce $\tilde{\phi}_c(\beta, t, x^*(\beta, t)) = \phi_c(\beta, t) = \Phi_c(\beta)$. Then, we have

$$\begin{aligned} \frac{d\beta^*}{dt} \propto \frac{\partial \Phi_c'(\beta)}{\partial t} &= \frac{\partial^2 \phi_c}{\partial \beta \partial t} = \frac{\partial^2 \tilde{\phi}_c}{\partial \beta \partial t} + \frac{\partial^2 \tilde{\phi}_c}{\partial \beta \partial x^*}\frac{\partial x^*}{\partial t} + \\ &\left(\frac{\partial^2 \tilde{\phi}_c}{\partial x^* \partial t} + \frac{\partial^2 \tilde{\phi}_c}{\partial x^{*2}}\frac{\partial x^*}{\partial t}\right)\frac{\partial x^*}{\partial \beta} + \frac{\partial^2 \tilde{\phi}_c}{\partial x^*}\frac{\partial^2 x^*}{\partial \beta \partial t}, \end{aligned} \tag{4}$$

where the first term on the right-hand side in Equation 4 is a direct positive effect under exogenous x. That is, tighter regulation results in weaker copyright protection, since the copyright holder faces weak competition from the pirate firm. The remaining three terms consist of an indirect effect under

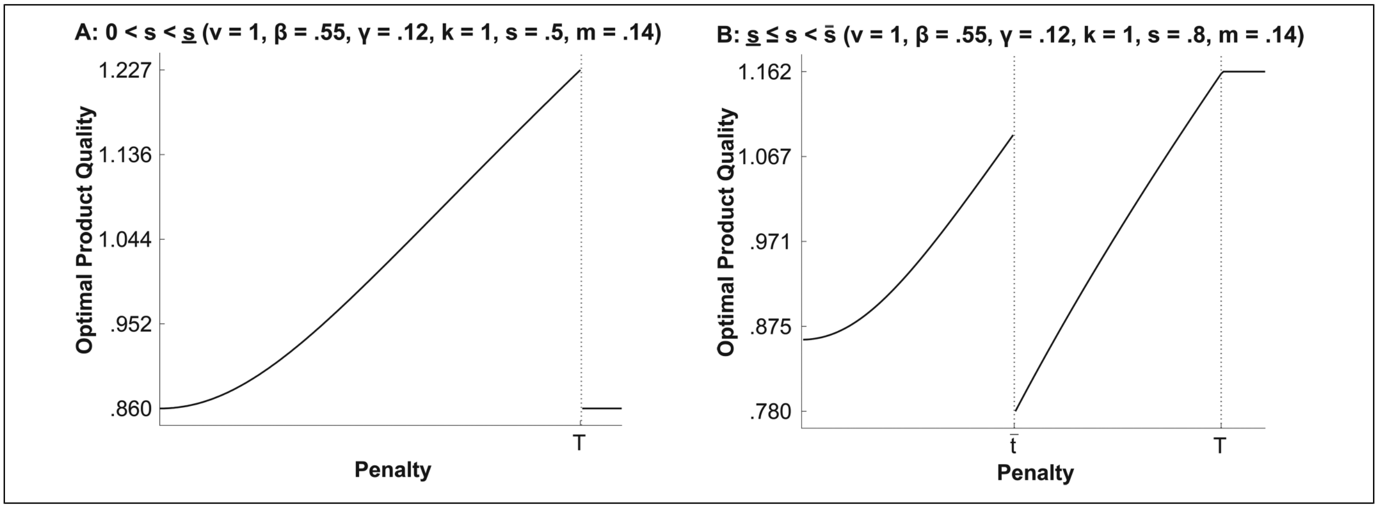

Figure 12. Effect of Penalty on Optimal Product Quality.

endogenous x, with the first term being negative. Intuitively, when penalty t is high, the pirate firm has an incentive to reduce x^* to compete with the copyright holder. To avoid intense competition, the copyright holder may reduce β to enlarge vertical differentiation between the two firms to mitigate this incentive.

The direct effect or the indirect effect can dominate, so β^* can increase or decrease with t, as shown in Figure 13, Panels A and B. The two panels also demonstrate that β^* is identical when $t = 0$ and when t is sufficiently high since $x^* t = 0$ for both cases. Moreover, Panels C and D of Figure 13 illustrate that β^* can jump (drop) discretely at $t = \bar{t}$ and then decrease (increase) with t for the case of high s. That is, to drive the pirate firm out of the market, the copyright holder can choose a combination of a higher $\tilde{p}_c$ and a lower β or a combination of a lower $\tilde{p}_c$ and a higher β, depending on which one is more cost-effective. Furthermore, β^* is constant for $t \geq T$ because $\Pi_c^*(\beta)$ is invariant in t for $t \geq T$.

Figure 14 illustrates that piracy consumption can increase with the penalty when the copyright holder endogenously determines β. On the one hand, as in the main model, an increase in t directly induces the pirate firm to reduce x to help piracy users evade the penalty. On the other hand, an increase in t also affects β^*, which can indirectly mitigate the pirate firm's incentives to reduce x. It turns out that the direct effect can dominate the indirect effect. Consequently, our main results can qualitatively remain to hold in this extension.

Using an Internet Service Provider as Inspector to Enforce Penalty

In practice, regulators may not have direct access to piracy consumption records, and they may have to rely on an internet service provider (ISP) to garner the relevant information and carry out punishment. In this case, the ISP can be viewed as an intermediary between the regulator and consumers. How will the existence of such an intermediary impact piracy demand regulation? We aim to look into this question here.

If a complete contract between the regulator and the ISP is available such that they are able to share all the relevant information about piracy users' activities and cooperate to jointly devise penalties based on the information, the two parties can be treated as an integrated agent. Our main model applies to this case directly without the need for any modification. However, it is possible that the ISP may be unable to track or share piracy users' activities with the regulator due to users' privacy control; moreover, the ISP may have no right to penalize consumers for piracy consumption by throttling their internet connection speed, because this can be seen as violation of network neutrality. In this case, we may end up with an incomplete contract between the regulator and the ISP. Thus, we study a setup in which the regulator places joint liability on the ISP to enforce the penalty for piracy consumption by punishing the ISP based on its enforcement level.

Specifically, we add to the game a pre-stage in which an ISP serves as an inspector that maintains an enforcement level of $z \in [0, 1]$ to monitor piracy users' activities with a cost $r \cdot z^2/2$, where $r > 0$ is a cost parameter. The enforcement level z together with the pirate firm's antitracking technology choice x determine the probability that a piracy user is tracked, which is parameterized as $z \cdot x$. In line with the incomplete-contract literature (Iyer and Villas-Boas 2003), we assume a linear contract, where the regulator monitors the ISP's enforcement level and penalizes the ISP l for lack of enforcement. Then, the ISP's objective is to choose enforcement level z so as to maximize its profit Π_I as follows:

$$\Pi_I = \Pi_I^0 - l(1 - z) - \frac{r}{2} z^2,$$

where Π_I^0 is the ISP's baseline profit. The maximization problem yields $z^* = \min\{l/r, 1\}$. The following proposition shows that our main result is robust for any $l > 0$.

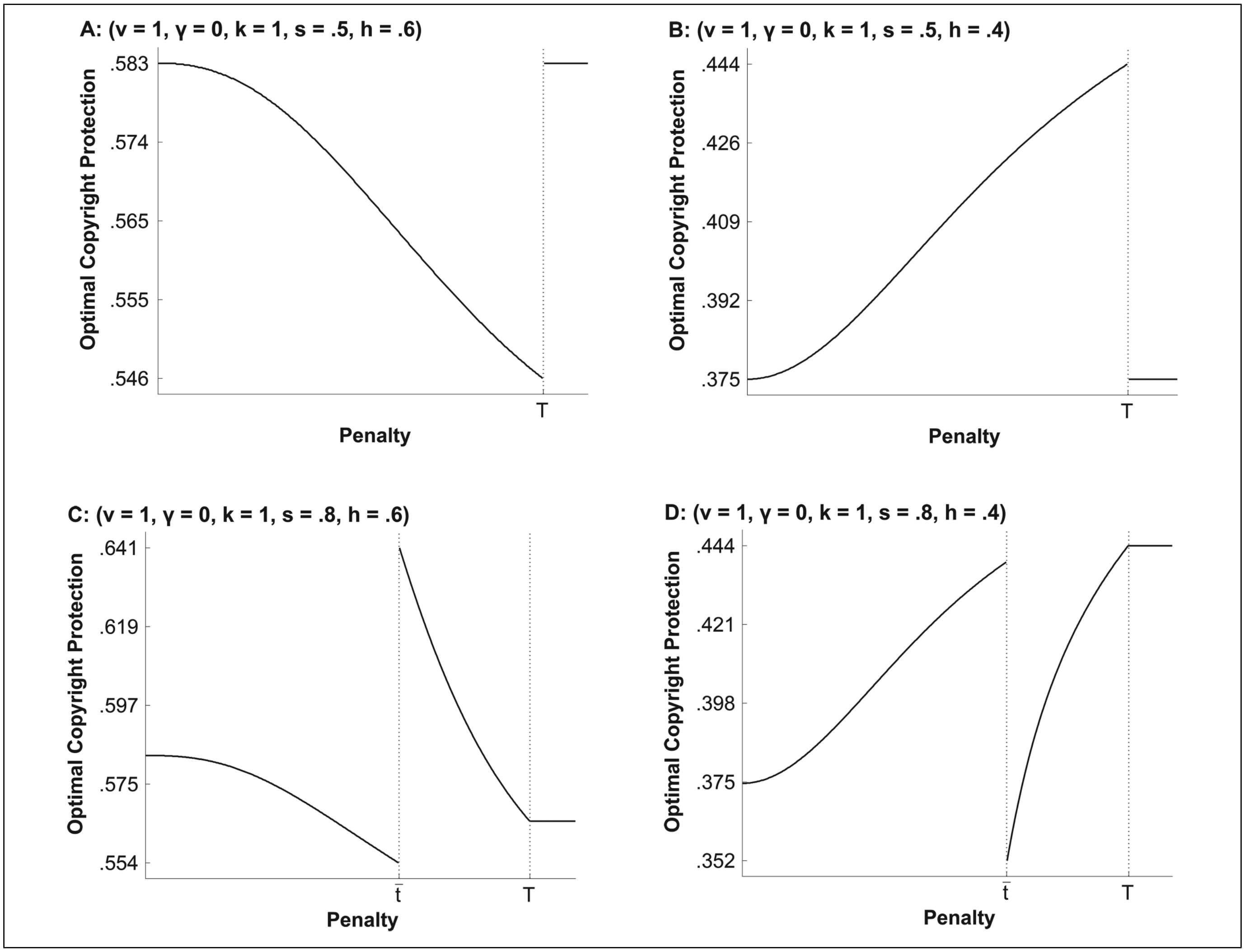

Figure 13. Effect of Penalty on Optimal Copyright Protection.

Proposition 11.

i. If $0 < l < r$, the effects of t on x^*t and D_p^* qualitatively follow the same relationship as in the main model, except that the thresholds on t depend on l and r.
ii. If $l \geq r$, the equilibrium degenerates to that in the main model.

It is not surprising to find that for a sufficiently high punishment l, the ISP will choose $z^* = 1$ so that we end up with the main model. Furthermore, Proposition 11 shows that even with relatively low l, as long as being positive, our main result still holds qualitatively. This is important, because in practice there could exist restrictions on l. For example, the ISP's participation constraint $\Pi_I|_{z=z^*} \geq 0$ would imply an upper bound on l.

Consumer-Initiated Antitracking Actions

Next, we consider an extension where antitracking actions are initiated by consumers instead of by the pirate firm. Then, consumers' utility from consuming a pirated product is $u_p = \theta\beta v - xt - s(1-x)^2/2$, and the pirate firm's profit is $\Pi_p = kD_p$. Proposition 12 states that piracy consumption always decreases with t.

Proposition 12.

There exists a threshold $\bar{s}^{ca}$ such that

i. if $0 < s < \bar{s}^{ca}$, D_p^* decreases with t for $0 \leq t < s$ and is invariant in t for $t \geq s$;[15]
ii. otherwise, if $s \geq \bar{s}^{ca}$, D_p^* decreases with t for $0 \leq t < \bar{t}^{ca}$ and stays at zero for $t \geq \bar{t}^{ca}$.

To understand this, note that total piracy cost for piracy consumption is the sum of the expected penalty x^*t and the cost of taking antitracking actions $s(1-x^*)^2/2$. Although consumers can reduce x^* when penalty t increases, total piracy cost is nondecreasing in t. Consequently, raising the penalty (weakly) diminishes piracy consumption.

[15] The superscript "ca" stands for "consumer-initiated antitracking," and it signifies thresholds in this extension.

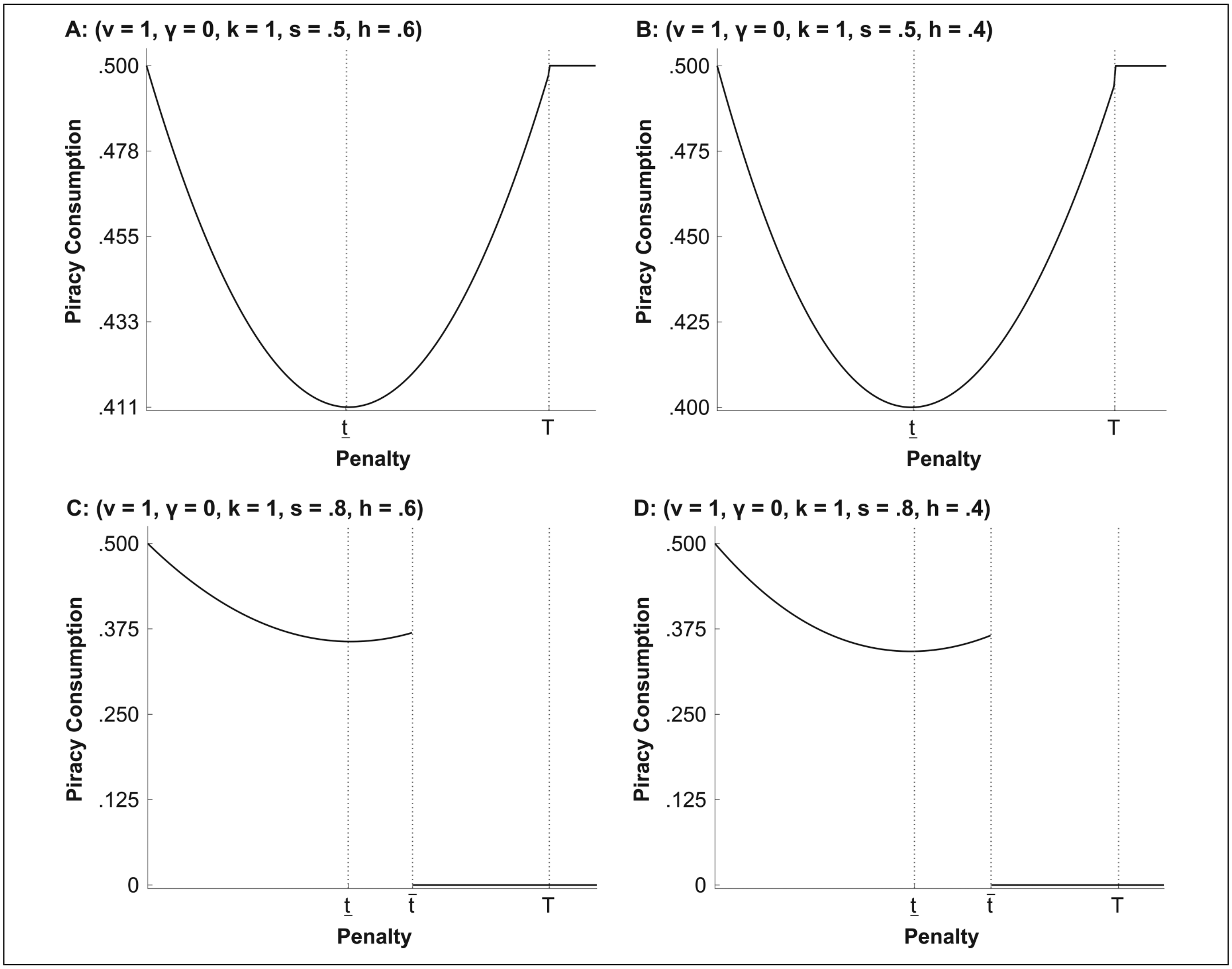

Figure 14. Effect of Penalty on Piracy Consumption Under Optimal β^*.

Pricing-Based Revenue for the Pirate Firm

This extension considers a pricing-based revenue model for the pirate firm. Formally, the pirate firm sells pirated products at price p_p. Then the pirate firm's profit is $\Pi_p = p_p D_p - s(1-x)^2/2$. We characterize the equilibrium in the Web Appendix and present the impact of t on the equilibrium outcome by the following proposition.

Proposition 13.

There exists a threshold $\bar{s}^{pb}$ such that

i. if $0 < s < \bar{s}^{pb}$, x^*t and $x^*t + p_p^*$ increase with t for $0 \le t < \underline{t}^{pb}$ and decrease with t for $\underline{t}^{pb} \le t < \bar{t}^{pb}$, while p_p^* and D_p^* decrease with t for $0 \le t < \underline{t}^{pb}$ and increase with t for $\underline{t}^{pb} \le t < \bar{t}^{pb}$;[16]

ii. otherwise, if $s \ge \bar{s}^{pb}$, x^*t and $x^*t + p_p^*$ increase with t for $0 \le t < \bar{t}^{pb}$, while p_p^* and D_p^* decrease with t for $0 \le t < \bar{t}^{pb}$.

Proposition 13 shows that the results of this extension are similar to those of the main model. To understand this, note that total expected cost for piracy consumption is the sum of price p_p^* and the expected penalty x^*t. The pirate firm's equilibrium price, p_p^*, exhibits a U-shaped relationship with t, just the opposite of the expected penalty. Intuitively, when the expected penalty is high (low), the pirate firm should set a low (high) price to compensate consumers. However, because the dependence of p_p^* on t is a strategic effect derived from the relationship between x^*t and t, the total effect is still governed by this relationship, as shown in Figure 15.

In particular, we would like to highlight that Proposition 13 can shed light on regulations of other criminal activities, such as

[16] The superscript "pb" stands for "pricing-based revenue," and it signifies thresholds in this extension.

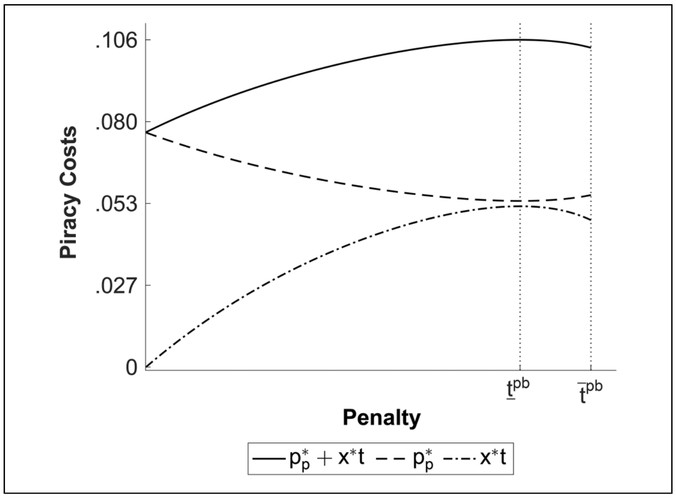

Figure 15. Effect of Penalty on Cost of Piracy Consumption (for $0 < s < \bar{s}^{pb}$) ($v = 1$, $\beta = .55$, $\gamma = .12$, $s = .04$).

drug sales, prostitution, and tax evasion. This is because illegal firms engaging in these activities make money from pricing and selling their products or services, and also have strong incentives to help their consumers escape the penalty for the consumption of illegal offerings. Therefore, the message of our article can be applied to broader contexts: tighter regulation may beget more consumption of illegal offerings, regardless of whether illegal firms earn revenue from advertisements or sales.

Conclusions

Regulation of piracy consumption is a unique feature of digital piracy, because piracy users' activities can be relatively easy to track in comparison to those for physical goods. Consequently, regulators around the world have been passing new laws to track and penalize piracy consumption.

Through a simple model, we show that a high penalty from the regulator may not only be ineffective in impeding piracy consumption, but also, in a worse situation, inadvertently promote piracy consumption by spurring the pirate firm's investment in antitracking technologies. This adverse situation can happen when the pirate firm can access or develop antitracking technologies at less cost and the penalty is relatively high. Based on our analysis, we devise the optimal piracy consumption regulation that depends on the cost of antitracking technologies of the pirate firm. Specifically, when the cost is low, the regulator can minimize piracy consumption and maximize social welfare simultaneously by setting a moderate penalty that maximizes consumers' expected penalty and tolerates some level of piracy consumption. In contrast, when the cost is high, the regulator at optimum chooses a relatively high penalty that completely thwarts piracy supply. Our model also produces additional policy implications. First, supply-side regulation that raids and takes down piracy websites does not replace demand-side regulation, as it may reduce market competition. Second, educating consumers about copyright protection may unintentionally encourage more consumers to adopt pirated products.

Next, we make two remarks on the applicability of our study. First, in reality, the existence of pirated products can increase consumer awareness of copyrighted products and thus boost their demand. Mortimer, Nosko, and Sorensen (2012) document that in the context of music, while piracy displaces CD sales, it increases concert revenue for less well-known artists. Intuitively, this type of positive demand spillover does not diminish the pirate firm's strategic reactions to regulation, and thus we expect our main result that a high penalty can increase piracy consumption to continue to hold. Moreover, with such positive demand spillover, the copyright holder is more willing to accommodate the coexistence of the pirate firm in the market. Therefore, we expect the regulator to have a higher tolerance for piracy when devising the regulation to maximize social welfare. Second, our results cannot be bluntly applied to understand the counterfeit context, because consuming counterfeits (think of knockoff Louis Vuitton handbags) is generally not illegal. Counterfeit users may not know that the product in use is counterfeit or can always claim that it is authentic even if they know that it is counterfeit. In contrast, the digital piracy context has less ambiguity about piracy users who knowingly commit the wrongdoing.

Last, we highlight three directions for future research. First, to capture supply-side regulation, we assume that the regulator directly controls the probability of taking down the pirate firm. One can also allow the regulator to impose penalties on the pirate firm, so the pirate firm may have incentives to make its identity less traceable. Second, in the current model, a copyrighted product is sold at a positive price. In practice, many digital content providers, such as Spotify, adopt the freemium model, where consumers use the basic product for free but have to bear with advertisements between content. This makes pirated products less attractive for consumers who mind less spending time watching advertisements, which in turn could alleviate the piracy problem. Third, the implementation of demand-side piracy regulation in practice can be hindered by other complex considerations. For example, some unethical consumers are minors, college students, and people in disadvantaged groups. The issue is further complicated by data privacy regulations (e.g., General Data Protection Regulation in the European Union) as well as voluntary tracking opt-out provided by tech companies.

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