THE IMPACTS OF DIGITAL CONTENT PIRACY AND COPYRIGHT PROTECTION POLICIES WHEN CONSUMERS ARE LOSS AVERSE

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Abstract. Recent technological advances in digitization and online communications have enabled unauthorized reproduction and illegal file-sharing. However, controversies still exist over the impacts of digital content piracy and copyright protection policies. Using a game-theoretic framework, we examine the impacts of digital content piracy and copyright protection policies on product quality, firm profitability, consumer surplus, and social welfare when consumers exhibit loss aversion in the quality dimension. Specifically, consumers are initially uncertain about the product quality and will form an expectation, but once they buy the licensed product or use piracy, they know the actual product quality and compare it with their expectation. When consumers are loss averse, consumer propensity to an option is more negatively affected by product quality above the expectation than positively affected by product quality below the expectation. Our analysis shows that although piracy exerts a negative cannibalization effect in the absence of loss aversion, it can exert an additional positive information effect when the degree of loss aversion on the licensed product is higher than the degree of loss aversion on piracy. We find that when the information effect dominates the cannibalization effect, piracy can lead to a win-win situation for firm profitability and consumer surplus. Moreover, under certain circumstances, anti-protection policies can simultaneously raise product quality, firm profitability and consumer surplus. The rationale behind the positive impacts of piracy and anti-protection policies is rooted in the influences of loss aversion behavior on consumer purchase decisions. The results show that it is essential to quantify the degree of consumer loss aversion for firms in formulating pricing and quality strategies and for policymakers to develop copyright protection policies.

1. Introduction. The unauthorized reproduction of digital content products (e.g., software, movies, games, videos, e-books, music, etc.) and massive pirated file-sharing has emerged as a major concern for society. Many industry analysts regard piracy as one of the critical threats to firm profitability and product innovation.

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Although piracy is illegal in many countries, using and disseminating piracy may be legitimate and socially accepted in terms of norms and beliefs for some groups. Feige [9], Jenkin et al. [21], and Webb et al. [47] define the informal economy as the set of illegal yet legitimate activities through which actors recognize and exploit opportunities. Digital content piracy represents a large realm within the informal economy, and it is vital to explore the rationales behind the social acceptability of piracy [32].

In order to explain why some groups consider piracy to be legitimate/socially acceptable acts and oppose governments enforcing stringent copyright protection policies, researchers have investigated whether piracy will exert positive impacts and when they occur. For example, piracy may raise a consumer base and increase firm profitability in the presence of positive demand-side externalities, such as the network effect and the word-of-mouth effect [7, 11, 15, 40, 41, 44]. In the absence of positive demand-side externalities, Jain [20], Lahiri and Dey [31], Guo and Meng [13], and Kim et al. [27] reveal the positive impacts of piracy or anti-protection policies by considering competitive producers, heterogeneous consumers, consumer search behavior and distribution supply chain, respectively.

A common postulate in previous research is that consumers grasp precise product quality information when deciding to make a purchase. However, digital content producers are unlikely to disclose the actual product quality to consumers, such as providing a free trial version. It is estimated that only 93% of web-based software companies offer a free trial or demo version of their software [28]. Moreover, digital content producers may only offer consumers a free “demo” version with limited functionality or content [6]. Consequently, the assumption that consumers grasp actual product quality information is sometimes violated. That is, consumers can be uncertain about product quality when making purchase decisions.

Since the seminal work by Kahneman and Tversky [23], it has been well established that consumer propensity to buy is often influenced by their reference points and characterized by loss aversion. In the digital content market, consumers who are initially uncertain about product quality will feel a sense of loss or gain after determining whether the actual quality is lower or higher than the reference points. When consumers are loss averse, consumer propensity to buy is more negatively affected by product quality above the reference point, compared to being positively affected by product quality below the reference point [50].

However, piracy can be viewed as a product sampling mechanism [5, 46], providing consumers with referable information on the quality of the licensed digital content product. In turn, consumers who have used piracy can be free from potential losses caused by uncertain information. It seems that piracy may raise consumer willingness to buy and stimulate consumer demand. Hence, it is worth exploring whether piracy and anti-protection policies can exert positive impacts when consumers are loss averse. Motivated by the above inference, we incorporate consumer loss aversion into a model of the pirated market, seeking to examine the impacts of digital content piracy and copyright protection policies.

To this end, we first construct a model of the pirated market wherein a digital content producer directly sells its licensed product to consumers who are loss averse in the quality dimension. The producer can invest in product quality to improve the technical performance of the digital content. We conceptualize the quality of the licensed product as the linear combination of basic content quality and improved
technology quality. The quality of piracy is assumed to be equivalent to the content quality of the licensed product. The consumers initially know the technology quality (e.g., via advertisements) but are uncertain about the content quality. They have a common belief in the distribution of the basic content quality and take the expectation as the reference point. Once consumers have used piracy, they know the actual quality and are not loss averse. Using a game-theoretic framework wherein consumers are loss averse, we address the following questions:

1. How does piracy impact the digital content producer’s pricing and quality strategies?
2. How does piracy impact the digital content producer’s profit, consumer surplus, and social welfare?
3. Can piracy lead to a win-win situation for both firm profitability and consumer surplus? If yes, when and why?

Answering these questions is of great significance. First, it has important implications for digital content producers who do not provide free trial versions or simply offer a “demo” with limited functions or content to redesign production and pricing strategies. Second, these answers can also help policymakers develop appropriate copyright protection policies, especially when consumers’ loss aversion behavior is non-negligible.

Our research provides several main insights and managerial implications. For question (1): We show that piracy can increase (decrease) the price of the licensed product when the degree of loss aversion on the licensed product is relatively high (low). Our analysis shows that although piracy exerts a negative cannibalization effect in the absence of loss aversion, it can exert an additional positive information effect when the degree of loss aversion on the licensed product is higher than the degree of loss aversion on piracy. This information effect leads consumers who initially do not buy the licensed product to decide to purchase the product once determining the product quality through piracy. In particular, when the degree of loss aversion on the licensed product is sufficiently high, the information effect dominates the cannibalization effect. In this situation, consumer propensity to buy in the pirated market can be higher than in the market without piracy, enabling the producer to raise the pricing power. However, piracy does not impact the technology quality. This is because the marginal return of the producer’s investment in quality remains the same even if piracy exists. In other words, the positive role of the technology quality in enhancing consumer propensity to buy is not changed by piracy.

These results suggest that the digital content producer facing competition with piracy does not need to decrease its product price or change its investment in quality when consumers are loss averse. In particular, when the degree of loss aversion on the licensed product is sufficiently high, the producer should set a higher price in the pirated market than in the market without piracy. It is essential for digital content producers to quantify the degree of consumer loss aversion when formulating pricing and quality strategies.

For question (2): We find that piracy can increase (decrease) the profit of the digital content producer when the degree of loss aversion on the licensed product is relatively high (low). The producer can benefit from the enhanced pricing power led by the information effect of piracy. In turn, consumers can benefit from the producer’s weakened pricing power led by the cannibalization effect of piracy. Additionally, we contribute a new rationale behind the positive impacts of piracy on
social welfare, where the information effect of piracy can eliminate inefficient loss aversion.

These findings indicate that the digital content producer who does not offer a free trial version of its product can expect its profit to be raised by piracy when the degree of loss aversion on the licensed product is sufficiently high. Policymakers should also be cautious of eliminating piracy, considering that consumers uncertain about product quality are characterized by loss aversion. In particular, they should support piracy rather than oppose it when the degree of loss aversion on the licensed product is higher than the degree of loss aversion on piracy.

For question (3): We unexpectedly find that the producer does not always need to gain higher profitability at the expense of consumer surplus when consumers are loss averse. When the degree of loss aversion on the licensed product is sufficiently high, the information effect of piracy leads the producer achieve higher pricing power and profit; meanwhile, the competition between the licensed product and piracy always leads to more consumer surplus. Eventually, piracy can lead to a win-win situation for both firm profitability and consumer surplus.

Furthermore, we examine a model extension wherein the producer ex-ante does not know whether piracy exists but knows the possibility of its existence. We conceptualize the level of copyright protection policies as the possibility that piracy does not exist and explore the impacts of copyright protection policies when consumers are loss averse.

Our analysis of the model extension reveals many significant results and managerial implications. First, stricter copyright protection policies will decrease (increase) the technology quality, the price of the licensed product and the producer’s profit when the degree of loss aversion on the licensed product is relatively high (low), and the copyright protection level is relatively low (high). Note that the producer who ex-ante does not know whether piracy exists may set a relatively low price to gain sales from the whole market or set a relatively high price to gain sales from the partial market, which is composed of initial consumers who are not exposed to piracy or piracy users. When the degree of loss aversion on the licensed product is relatively high (low), and the copyright protection level is relatively low (high), the producer’s profit gained from the partial market composed of piracy users (initial consumers) is higher than that gained from the whole market. In this situation, stricter copyright protection will reduce (raise) the sales volume, leading to lower (higher) product quality, product price and firm profit.

These results forecast that the digital content producer should not always press governments for enhanced copyright protection when facing declining leverage of copyright protection policies. Moreover, the producer should not always abandon quality innovation and does not always need to sacrifice its pricing power or profit to counter anti-protection policies. In particular, when the degree of loss aversion on the licensed product is relatively high, and the copyright protection level is relatively low, the producer should raise its quality investment, set a higher price and expect a higher profit under anti-protection policies.

Second, since consumer surplus in the partial market is more than that in the partial market where piracy does not exist, stricter copyright protection can decrease consumer surplus. We also provide a new explanation for the positive impacts of anti-protection policies on social welfare, i.e., the enhanced information effect led by looser copyright protection policies can mitigate the inefficient loss aversion behavior, leading to more social welfare.
These findings suggest that policymakers should enhance their vigilance when striving for more comprehensive copyright protection policies and quantify the average degree of loss aversion on digital content products before designing copyright protection policies. In particular, they should enforce anti-protection policies when the degree of consumer loss aversion on the licensed product is sufficiently high.

Third, when the degree of loss aversion on the licensed product is relatively high and the copyright protection level is relatively low, anti-protection policies can increase both firm profitability and consumer surplus. Faced with anti-protection policies, the producer benefits from the enhanced information effect and consumers benefit from the intensified market competition.

The contributions of this paper are twofold. First, it contributes new rationales for the phenomenon that some groups in society consider piracy to be legitimate/socially acceptable acts and oppose governments enforcing stringent copyright protection policies. It is rooted in the influences of loss aversion behavior on consumer purchase decisions. Second, although research in marketing and psychology has shown that digital content piracy and consumer loss aversion are both prevailing, few studies have explored the interaction between the two phenomena. To the best of our knowledge, this paper is the first to examine the impacts of piracy and copyright protection policies by incorporating consumer loss aversion.

The rest of the paper is organized as follows. Section 2 discusses the relevant literature and scientific contribution of this paper. Section 3 first describes the basic model and then studies a benchmark case when consumers are not loss averse. Section 4 investigates the impacts of piracy when consumers are loss averse. Section 5 extends the basic model to explore the impacts of copyright protection policies. Section 6 concludes this paper and points out future research directions.

2. Literature review. This paper links two separate but emerging literature streams: digital content piracy, and consumer reference dependent and loss aversion.

In the digital content piracy literature, one rising theme investigates the positive impacts of piracy and explains the growing anti-protection trend. Some studies show that demand-side externalities enable digital content producers to benefit from piracy. In the presence of direct demand-side externalities (e.g., the network effect), consumer utility of buying the licensed product increases with the number of either pirated or licensed digital content users. Therefore, piracy can raise firm profitability when the network effect is sufficiently strong [7, 40, 44]. In the presence of indirect demand-side externalities (e.g., the word-of-mouth effect), digital content producers in the pirated market can be better off because piracy can promote product proliferation [11, 15, 41].

Other studies in this literature examine the positive impacts of piracy or copyright protection in the absence of demand-side externalities. Bae and Choi [2] model two types of costs associated with unauthorized copying, i.e., reproduction cost and degradation cost. They find that a lower reproduction cost can raise social welfare and a higher degradation cost induces a higher product quality. Jain [20] develops a duopoly model to investigate the impacts of piracy. He finds that the use of piracy by price-sensitive consumers can reduce the price competition between competitive digital content producers. Therefore, weaker copyright protection can sometimes raise the product quality, as well as increase firm profitability and social welfare. Lahiri and Dey [31] examine the impact of digital content piracy on product quality when consumers are heterogeneous in their preferences for quality. They find that
lower piracy enforcement can induce the digital content producer to invest more in product quality, which makes the licensed product highly differentiated in quality from piracy, and thus attracting more consumers to purchase the product. Tunca and Wu [45] reveal that in the presence of commercial piracy, the digital content producer can be better off under a lower detection rate for individual piracy. Guo and Meng [13] investigate the impact of copyright protection on firm profitability with endogenous consumer search behavior. They find that stricter copyright protection can raise consumers’ expectations of the product’s price and decrease consumers’ search willingness, negatively impacting firm profitability. Dey et al. [8] study the impacts of supply-side piracy enforcement and demand-side piracy enforcement, respectively. They show that supply-side piracy enforcement has a more desirable economic impact in the long run, while demand-side piracy enforcement may damage social welfare. Kim et al. [27] reveal the impacts of digital content piracy in a distribution supply chain. They explain that piracy can simultaneously benefit the digital content producer, the retailer, and consumers by mitigating double marginalization. Vernik et al. [46] point out that DRM restriction will reduce consumer valuation for the digital content product, leading to stronger downstream competition between download and traditional retailers. Therefore, the digital content producer can benefit from selling DRM-free albums. Wu et al. [49] examine the optimal DRM policy when consumers are heterogeneous in piracy cost sensitivity. They emphasize that implementing a DRM policy is a dominant strategy only if the level of DRM restriction is low.

This paper contributes to the literature on digital content piracy by providing an alternative rationale for the positive impacts of piracy and the growing anti-protection trend. We identify the conditions under which piracy and anti-protection policies can exert positive (negative) impacts on product quality, firm profitability, consumer welfare, and social welfare when consumers exhibit loss aversion in the quality dimension. Different from previous studies, the rationale for the positive impacts of piracy and anti-protection policies lies in the influences of loss aversion behavior on consumer purchase decisions.

Another relevant literature stream studies consumer reference dependence and loss aversion. According to prospect theory, the consumer value of an option is defined as losses or gains relative to a reference point [23]. A fundamental proposition of this theory is that consumers are more sensitive to losses than to gains, (i.e., consumers are loss averse). Some empirical research in the literature has presented evidence of consumer loss aversion [14, 25, 35, 42, 19, 18], while others have explored the factors that influence consumer reference point formation [14, 48, 4, 43, 24, 33, 10]. Other studies have also shown that consumer reference dependence can influence their purchase decisions in many ways [17], such as brand choice [25], purchase quantity [29], purchase timing [3], and search behavior [12].

One stream of analytical studies has examined the impacts of consumer reference dependence and loss aversion on firm strategy. Zhou [51] studies the implications of consumer reference dependence in market competition if consumers are loss averse and the product first reviewed is taken as the reference point. He shows that consumer loss aversion in the price dimension intensifies competition, whereas consumer loss aversion in the product attributes dimension (such as advertising and quality) softens it. Wang and Kuksov [30] examine how firms’ competitive strategy and profitability are affected by consumer loss aversion in the price dimension. They say that, counter-intuitively, consumer loss aversion does not necessarily lead
to lower prices or profits when firms compete over multiple periods and the consumer reference price in subsequent periods is affected by current prices. Amaldoss and He [1] analyze how consumer reference dependence affects price competition in a horizontally differentiated market where consumers’ tastes are diverse. They find that loss aversion on the price dimension always intensifies competition among low-valuation goods, whereas loss aversion on the taste dimension can sometimes soften competition. Orhun [39] investigate the impacts of consumer loss aversion on a firm’s product line strategy when the reference point is endogenous to the choice set. He points out three sharp predictions on optimal product line width and product positions, i.e., the compression effect, pooling effect, and augmentation effect, which differ from the results in previous studies that neglect consumer loss aversion. Narasimhan and Turut [38] explore the impacts of consumer reference-dependent preferences on a firm’s decision to differentiate or imitate. They show that, counter-intuitively, when consumer preferences are reference-dependent, the second mover prefers to imitate the first mover by adding the same feature even when there is no cost disadvantage to differentiate itself. Mehra et al. [36] examine how reference price effects affect firms’ product positioning and pricing strategies in a non-durable goods market (where consumers repeatedly purchase products from the same category). They empirically validate their findings, explaining that as the salience of reference price effects increase, product differentiation first decreases and then increases, and firm profits first decrease and then increase. Zhang and Li [50] investigate the implications of consumer loss aversion on firm profit, consumer surplus, and social welfare when firms endogenously make quality disclosure decisions. They find that consumer loss aversion leads symmetric firms to disclose quality more often and makes both firms in a competition better off, while at the same time decreasing consumer surplus and social welfare.

In general, previous studies have examined the impacts of consumer reference dependence and loss aversion on consumer purchase decisions and firm strategy. However, few studies have discussed this in the pirated market. Recently, Martínez-Sánchez [34] analyze how consumer loss aversion affects the government’s and the incumbent’s strategies for preventing commercial piracy. Contrary to conventional knowledge, he finds that when consumers are loss averse, the government will not block the entry of a pirate, because socially, it is better to encourage the incumbent to establish a price low enough to deter the pirate from entering the market. Although this last paper is relevant to digital content piracy, our context is entirely different. First, in this paper, we focus on the individual piracy of digital content products, i.e., consumers making illegal copies independently, rather than relying on purchasing copies from commercial pirates. Second, we investigate how consumer loss aversion influences the role of piracy, rather than piracy-preventing strategies of firms and the government.

This paper contributes to the literature on consumer reference dependence and loss aversion by incorporating the existence of individual piracy, and investigates how the impacts of piracy change if consumers exhibit loss aversion. When consumers are not loss averse, piracy exerts a negative cannibalization effect, thus damaging firm profitability. When consumers are loss averse, we show that piracy may exert both a positive information effect and a negative cannibalization effect. Moreover, piracy can positively impact firm profitability, consumer surplus, and social welfare when the information effect dominates the cannibalization effect.
3. **Model setup and benchmark.** Consider a pirated market where a digital content producer directly sells its licensed product to consumers who exhibit loss aversion in the quality dimension. The producer can invest in product quality to improve the technical performances of the digital content. We conceptualize the quality of the licensed product as the linear combination of the basic content quality $v$ and the improved technology quality $q$. Following previous literature [31, 22, 37], we assume that the quality investment cost is a quadratic function of $q$, i.e., \( cq^2 \), where $c > 0$ is the exogenous marginal cost. The initial development cost for the basic content is assumed to be sunk. The fixed and marginal cost of selling the digital content product is normalized to 0.

The quality of piracy is equivalent to the basic content quality of the licensed product. It represents the reality that it is easy for potential consumers to copy the basic digital content from file-sharing networks, but it is normally difficult or unnecessary for them to improve the technical performances of piracy. For profitability considerations, digital content producers may not provide a free trial version for prospective consumers to personally perceive the basic content quality [28, 6, 50], but they can advertise the improved technical performance. Therefore, we assume that when consumers initially decide to buy the licensed product or use piracy, they know the actual technology quality $q$ but are uncertain about the content quality $v$. According to prospect theory [23], when a consumer faces uncertainty about the basic content quality $v$, he or she forms a reference point and feels a sense of losses or gains if the actual basic content quality is higher or lower than the reference point. Moreover, the consumer exhibits loss aversion; the disutility of losses has greater impacts on his or her decision of purchasing the licensed product or using piracy than the utility of gains [50, 26]. Once consumers have used piracy, they know the actual basic content quality and are not loss averse.

The mass of consumers is normalized to 1. The cost for consumers to use piracy is negligible. Each consumer desires at most one unit of either a licensed product or a free pirated version. Consumers initially have a common belief in the distribution of $v$. Let $f(v)$ be the probability density function of $v$, which is continuous and non-negative over $[0, 1]$. $F(v)$ is the cumulative distribution function, which is continuous and non-decreasing over $[0, 1]$, and simultaneously satisfies the conditions of $F(0) = 0$ and $F(1) = 1$. Therefore, the consumer’s overall expectation on the basic content quality is

$$\bar{v} = \int_0^1 vf(v) \, dv - \int_0^1 F(v) \, dv = 1 - \int_0^1 F(v) \, dv$$

Let $\Gamma(v)$ be a primitive function of $F(v)$, i.e., $F(v) \, dv = d\Gamma(v)$. Substituting $\Gamma(v)$ into equation (1), we get $\bar{v} = 1 - \Gamma(1)$. Following the literature on consumer loss aversion [50, 26, 16], we take the expectation $\bar{v}$ as consumer reference point. The net utility of consumers for the license product is the linear combination of intrinsic utility, gained utility, and lost utility. Intrinsic utility refers to the normal utility achieved when consumers know the actual quality. Gained (lost) utility refers

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1 Even though it is increasingly more accessible for prospective consumers to read online reviews and watch experience videos, they cannot personally use the digital content product, thus still remain uncertain about the basic content quality of the product.

2 We assume that consumers always have access to buy the licensed product regardless of whether they have used piracy.

3 $\Gamma(v)$ is continuous and non-decreasing, simultaneously satisfying the conditions $\Gamma(0) = 0$ of and $\Gamma(1) < 1$. 
to a positive (negative) utility arising when the actual quality is higher (lower) than the expectation. Therefore, the net utility of a consumer for the licensed product is

$$\bar{u}_l = \frac{v + q - p}{\text{Intrinsic utility}} + \max\{v - \bar{v}, 0\} + \lambda \min\{v - \bar{v}, 0\},$$

where \(\lambda > 1\) denotes the degree of loss aversion on the licensed product, and \(p\) denotes the price of the licensed product. A higher \(\lambda\) represents that the negative impact of potential losses on consumer propensity to buy the licensed product is much more than the positive impact of potential gains. Consequently, the consumer’s expected net utility for the licensed product is

$$E(\bar{u}_l) = \int_0^1 (v + q - p) f(v) \, dv + \int_{\bar{v}}^1 (v - \bar{v}) f(v) \, dv + \lambda \int_0^{\bar{v}} (v - \bar{v}) f(v) \, dv$$

Substituting \(\Gamma(v)\) into equation (2), we get

$$E(\bar{u}_l) = 1 + q - p - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))$$

(3)

Analogously, the net utility of a consumer for piracy is

$$\bar{u}_p = \frac{v}{\text{Intrinsic utility}} + \max\{v - \bar{v}, 0\} + \mu \min\{v - \bar{v}, 0\},$$

where \(\mu > 1\) denotes the degree of loss aversion on piracy, and a higher \(\mu\) represents that the negative impact of potential losses on consumer propensity to use piracy is much more than the positive impact of potential gains. Therefore, the consumer’s expected net utility for piracy is

$$E(\bar{u}_p) = \int_0^1 v f(v) \, dv + \int_{\bar{v}}^1 (v - \bar{v}) f(v) \, dv + \mu \int_0^{\bar{v}} (v - \bar{v}) f(v) \, dv$$

(4)

Substituting \(\Gamma(v)\) into equation (4), we get

$$E(\bar{u}_p) = 1 - \Gamma(1) - (\mu - 1) \Gamma(1 - \Gamma(1))$$

(5)

The producer and consumers make decisions to maximize their expected payoffs. The timing of events is as follows. In stage 1, the producer decides the technology quality \(q\). In stage 2, the producer sets the price of the licensed product \(p\). In stage 3, consumers make their decisions.

3.1. **Benchmark without consumer loss aversion.** We start from the benchmark where consumers are not loss averse, i.e., when \(\lambda = \mu = 1\). To examine the impacts of piracy, we first solve the equilibrium outcomes in the pirated markets and in the market without piracy, respectively.

Consumers make their decisions based on the corresponding individual rationality (IR) and incentive compatibility (IC) conditions. In the market without piracy, consumers purchase the licensed product if \(E(\bar{u}_l) \geq 0\) (IR-Licensed product); otherwise, they forgo their use. In the pirated market, consumers initially purchase the licensed product if \(E(\bar{u}_l) \geq 0\) (IR-Licensed product) and \(E(\bar{u}_l) \geq E(\bar{u}_p)\) (IC-Licensed product); use piracy if \(E(\bar{u}_p) \geq 0\) (IR-Piracy) and \(E(\bar{u}_p) \geq E(\bar{u}_l)\) (IC-Piracy); otherwise, they forgo their use. If consumers initially use piracy, they further decide whether to purchase the licensed product. In this situation, consumers
switch to purchase the licensed product if \( v + q - p \geq v \) (IC-Licensed product); keep using piracy if \( v > v + q - p \) (IC-Piracy)\(^4\).

According to the IR and IC conditions, the demand for the licensed product in the market with and without piracy are respectively

\[
D^b_{w(n)} = \begin{cases} 
1, & \text{if } p \leq q \\
0, & \text{otherwise}
\end{cases}
\]

and

\[
D^b_n = \begin{cases} 
1, & \text{if } p \leq q + 1 - \Gamma(1) \\
0, & \text{otherwise}
\end{cases}
\]

The producer’s profit is \( \pi = pD^b_{w(n)} - cq^2/2 \). Using backward induction, we can derive the equilibrium outcomes when consumers are not loss averse.

**Theorem 1.** When consumers are not loss averse, (i) in the market without piracy, the technology quality, price of the licensed product, and profit of the producer in equilibrium are respectively

\[
q^b_n = \frac{1}{c}, \quad p^b_n = \frac{1}{c} + 1 - \Gamma(1) \quad \text{and} \quad \pi^b_n = \frac{1}{2c} + 1 - \Gamma(1);
\]

(ii) in the pirated market, the technology quality, price of the licensed product, and profit of the producer in equilibrium are respectively

\[
q^b_w = \frac{1}{c}, \quad p^b_w = \frac{1}{c} \quad \text{and} \quad \pi^b_w = \frac{1}{2c}.
\]

By comparing the equilibrium outcomes in part (i) and part (ii) of Theorem 1, we can analyze the impacts of piracy when consumers are not loss averse. Note that the marginal return of the producer’s investment in technology quality maintains even if piracy exists. That is, the positive role of the technology quality in enhancing consumer propensity to buy is not changed by piracy. Therefore, piracy has no impact on the technology quality of the product. Next, we study the impacts of piracy on the price of the licensed product and the producer’s profit when consumers are not loss averse.

**Proposition 1.** When consumers are not loss averse, piracy will decrease both the price of the licensed product and the profit of the producer, i.e., when \( \lambda = \mu = 1 \), \( p^b_w < p^b_n \) and \( \pi^b_w < \pi^b_n \).

The results of Proposition 1 are consistent with the conventional belief that piracy harms firm pricing power and profitability. When consumers are not loss averse, whether consumers know the actual basic content quality does not influence their decisions. That is, once consumers initially use piracy, they keep using it. The threat of piracy pushes the producer to set a lower price in the pirated market than in the market without piracy, and thus the producer’s profit is damaged by piracy, which we refer to as the “cannibalization effect” of piracy.

Next, we study the impacts of piracy on consumer surplus and social welfare when consumers are loss averse. In the market without piracy, the producer acts as a monopoly and extracts total consumer surplus. Therefore, we get \( CS^b_n = 0 \) and \( SW^b_n = \pi^b_n \). However, the producer in the pirated market must decrease its...
marginal profit to attract consumers to buy. In this situation, consumer surplus derives from the competition between the licensed product and piracy. Therefore, piracy increases consumer surplus at the cost of the producer’s profit, but keeps social welfare the same, i.e., \( CS^b_w > CS^b_n \) and \( SW^b_w = SW^b_n \).

4. Impacts of piracy under consumer loss aversion. This section re-examines the impacts of piracy when consumers are loss averse. According to the IR and IC conditions, the demand for the licensed product in the market with and without piracy are, respectively

\[
D_w = \begin{cases} 
1 & \text{if } \mu > \xi \text{ and } p \leq q + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) \\
1 & \text{if } \lambda \leq \mu \leq \xi \text{ and } p \leq q - (\lambda - \mu) \Gamma(1 - \Gamma(1)) \\
1 & \text{if } \mu \leq \xi, \mu < \lambda \text{ and } p \leq q \\
0 & \text{otherwise}
\end{cases}
\]

and \( D_n = \begin{cases} 
1 & \text{if } p \leq q + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) \\
0 & \text{otherwise}
\end{cases} \),

where we define \( \xi = 1 + \frac{1 - \Gamma(1)}{\Gamma(1 - \Gamma(1))} \) for ease of illustration. The producer’s profit is \( \pi = pD_{w(n)} - cq^2/2 \). Using backward induction, we can derive the equilibrium outcomes when consumers are loss averse.

**Theorem 2.** When consumers are loss averse, (i) in the market without piracy, technology quality, price of the licensed product, and profit of the producer in equilibrium are respectively

\[
q_n = \frac{1}{c}, \quad p_n = \frac{1}{c} + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) \quad \text{and} \quad \pi_n = \frac{1}{2c} + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1));
\]

(ii) in the pirated market, the technology quality, price of the licensed product, and profit of the producer in equilibrium are respectively

\[
q_w = \frac{1}{c}, \quad p_w = \begin{cases} 
\frac{1}{c} + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) & \text{when } \mu > \xi \\
\frac{1}{c} - (\lambda - \mu) \Gamma(1 - \Gamma(1)) & \text{when } \lambda \leq \mu \leq \xi \\
\frac{1}{c} & \text{when } \mu \leq \xi \text{ and } \lambda > \mu
\end{cases}
\]

and \( \pi_w = \begin{cases} 
\frac{1}{2c} + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) & \text{when } \mu > \xi \\
\frac{1}{2c} - (\lambda - \mu) \Gamma(1 - \Gamma(1)) & \text{when } \lambda \leq \mu \leq \xi \\
\frac{1}{2c} & \text{when } \mu \leq \xi \text{ and } \lambda > \mu
\end{cases} \).

By comparing the equilibrium outcomes in part (i) and part (ii) of Theorem 2, we can analyze the impacts of piracy when consumers are loss averse. As the same with the benchmark, the technology quality is not impacted by piracy. When \( \mu > \xi \), consumers never consider using piracy, so the producer can act as a monopoly and its decisions and profit are not impacted by piracy. Therefore, we focus on the case when \( \mu \leq \xi \) in the following analysis. We next study how piracy affects the producer’s pricing strategy and profit, seeing Proposition 2.

**Proposition 2.** When consumers are loss averse, (i) piracy will increase the price of the licensed product and the profit of the producer, i.e., \( p_w > p_n \) and \( \pi_w > \pi_n \), when \( \mu \leq \xi \) and \( \lambda > \xi \);
(ii) piracy will decrease the price of the licensed product and the profit of the producer, i.e., \( p_w < p_n \) and \( \pi_w < \pi_n \), when \( \mu < \xi \) and \( \lambda < \xi \); (iii) otherwise, piracy will not impact the price of the licensed product or the producer’s profit.

Proposition 2 conveys a contrary insight to conventional wisdom, i.e., piracy is not always harmful to the producer’s pricing power and profit. To see the rationale, note that when \( \mu \leq \xi \), in the pirated market, the sales of the licensed product may come from initial consumers who are unaware of the actual quality, or piracy users who have known the actual quality.

When the degree of loss aversion on the licensed product is lower than the degree of loss aversion on piracy, initial consumers’ propensity to buy is higher than that of piracy users. If consumers cannot afford the licensed product initially, they cannot afford it even when they have used piracy. Therefore, the producer can only gain sales from the initial consumers. To this end, the producer will decrease the price of the licensed product. As with the benchmark, the “cannibalization effect” of piracy leads the producer’s pricing power and profit in the pirated market to be lower than that in the market without piracy when \( \lambda < \mu \).

However, when the degree of loss aversion on the licensed product is higher than the degree of loss aversion on piracy, initial consumers’ propensity to buy is lower than that of piracy users. Consumers initially do not buy since they cannot bear the potentially significant losses. However, once the initial consumers have used piracy, they know the actual quality and decide to buy, which we refer to as the “information effect” of piracy. Under this effect, the producer’s sales gained from piracy users are higher than that gained from initial consumers. Therefore, it is in the producer’s interest to strategically set a relatively high price to induce initial consumers to use piracy. In particular, when the degree of loss aversion on the licensed product is sufficiently high, the information effect dominates the cannibalization effect, and thus piracy users’ propensity to buy is higher than initial consumers’ propensity to buy in the market without piracy. Therefore, when \( \lambda > \xi \), the price of the product is raised by piracy and the producer is better off in the pirated market.

Proposition 2 has proven that when consumers are loss averse, piracy may lead to higher firm profitability under certain circumstances. However, can piracy lead to a win-win situation for firm profitability and consumer surplus? In the next proposition, we investigate the impacts of piracy on consumer surplus and social welfare when consumers are loss averse.

**Proposition 3.** When consumers are loss averse, (i) piracy will increase consumer surplus, i.e., \( CS_w > CS_n \), when \( \mu < \xi \) or \( \lambda > \mu = \xi \); otherwise, piracy will not impact consumer surplus; (ii) piracy will increase social welfare, i.e., \( SW_w > SW_n \), when \( \mu \leq \xi \) and \( \lambda > \mu \); otherwise, piracy will not impact social welfare; (iii) piracy can lead to a win-win situation for firm profitability and consumer surplus when \( \mu \leq \xi < \lambda \).

---

6When \( \lambda < \mu \), the reservation price that initial consumers have for the licensed product is higher than the reservation price that piracy users have.

7When \( \lambda > \mu \), the reservation price that initial consumers have for the licensed product is lower than the reservation price that piracy users have.

8When \( \lambda > \xi \), the reservation price that piracy users have for the licensed product is higher than the reservation price that initial consumers have in the market without piracy.
Part (i) and (ii) of Proposition 3 analyze the impacts of piracy on consumer surplus and social welfare when consumers are loss averse, respectively. When the degree of loss aversion on the licensed product is not higher than the degree of loss aversion on piracy, i.e., when 
\[ \lambda \leq \mu < \xi \]
the cannibalization effect of piracy puts downward pressure on the producer’s marginal profit but raise equal-sized consumer surplus. In this situation, piracy does not influence social welfare. In particular, we contribute a new rationale behind the positive impacts of piracy on social welfare. When the degree of loss aversion on the licensed product is higher than the degree of loss aversion on piracy, i.e., when \( \mu \leq \xi \) and \( \lambda > \mu \), piracy increases social welfare by eliminating inefficient loss aversion behavior.

Unlike the benchmark, where the producer’s profit increases at the cost of consumer surplus, part (iii) of Proposition 3 indicates that the producer does not always need to gain higher profitability at the expense of consumer surplus when consumers are loss averse. When the degree of loss aversion on the licensed product is sufficiently high, i.e., when \( \lambda > \xi \), the information effect of piracy leads the producer achieve higher pricing power and profit; meanwhile, the competition between the licensed product and piracy always leads to more consumer surplus. Eventually, piracy can lead to a win-win situation for both firm profitability and consumer surplus.

5. Model extension: Impacts of copyright protection policies under consumer loss aversion. The above results about the impacts of piracy are obtained under the assumption that the producer ex-ante knows whether piracy exists. In this section, we extend the model by assuming that the producer ex-ante does not know whether piracy exists but knows the possibility that piracy exists. We conceptualize the exogenous copyright protection level, \( \alpha \in (0, 1) \), as the possibility that piracy does not exist. Here, we intend to investigate the impacts of copyright protection policies when consumers are loss averse.

To solve the equilibrium solutions, we first derive the reservation prices that consumers have for the licensed product. If piracy does not exist, the reservation price that initial consumers have for the licensed product is
\[
R^i_n = q + 1 - \Gamma (1) - (\lambda - 1) \Gamma (1 - \Gamma (1))
\]
where we use the superscript \( i \) to denote initial consumers. When \( p > R^i_n \), they forgo their use. If piracy exists, the reservation price that initial consumers have for the licensed product is
\[
R^i_w = \min \{ q - (\lambda - \mu) \Gamma (1 - \Gamma (1)) , q + 1 - \Gamma (1) - (\lambda - 1) \Gamma (1 - \Gamma (1)) \}
\]
If \( p > R^i_w \) and \( \mu \leq \xi \), consumers become piracy users. If \( p > R^i_w \) and \( \mu > \xi \), they forgo their use. The reservation price that piracy users have for the licensed product is
\[
R^p_w = q,
\]
where we use the superscript \( p \) to denote piracy users\(^9\). If \( p \leq R^p_w \), they switch to buy the licensed product. If \( p > R^p_w \), they keep using piracy. Considering the ranges of \( R^i_n, R^i_w \), and \( R^p_w \), the equilibrium outcomes are respectively solved in the following four cases, i.e., (a) \( \mu > \xi \), (b) \( \lambda \leq \mu \leq \xi \), (c) \( \mu < \lambda \leq \xi \), and (d) \( \mu \leq \xi < \lambda \). Theorem 3 characterizes the equilibrium outcome under copyright protection policies.

\(^9\)Note that \( q > R^i_w \) must be satisfied for the existence of piracy users.
Theorem 3. When consumers are loss averse, under copyright protection policies, the technology quality, price of the licensed product, and profit of the producer in equilibrium are respectively

\[
q^* = \begin{cases} 
\frac{\alpha}{1-\alpha} & \text{when } \lambda \leq \mu \leq \xi \text{ and } \alpha > \hat{\alpha} \text{ or when } \mu < \lambda \leq \xi \text{ and } \alpha > \hat{\alpha} \\
\frac{1}{1-c} & \text{when } \mu \leq \xi < \lambda \text{ and } \alpha < \hat{\alpha} \\
\frac{1}{1-\alpha} & \text{otherwise}
\end{cases}
\]

\[
p^* = \begin{cases} 
\frac{1}{c(1-c)} + 1 - (\lambda - 1) \Gamma(1 - \Gamma(1)) - \Gamma(1) & \text{when } \mu > \xi \\
\frac{\alpha}{c} + 1 - (\lambda - 1) \Gamma(1 - \Gamma(1)) - \Gamma(1) & \text{when } \lambda \leq \mu \leq \xi \text{ and } \alpha > \hat{\alpha} \\
\frac{1}{c} - (\lambda - \mu) \Gamma(1 - \Gamma(1)) & \text{when } \lambda \leq \mu \leq \xi \text{ and } \alpha < \hat{\alpha} \\
\frac{1}{1-c} & \text{when } \mu < \lambda \leq \xi \text{ and } \alpha > \hat{\alpha} \\
\frac{1}{1-c} & \text{when } \mu \leq \lambda < \xi \text{ and } \alpha < \hat{\alpha}
\end{cases}
\]

\[
\pi^* = \begin{cases} 
\frac{\lambda^2}{2c} + 1 - (\lambda - 1) \Gamma(1 - \Gamma(1)) - \Gamma(1) & \text{when } \mu > \xi \\
\frac{\lambda^2}{2c} + [1 - (\lambda - 1) \Gamma(1 - \Gamma(1)) - \Gamma(1)] \alpha & \text{when } \lambda \leq \mu \leq \xi \text{ and } \alpha > \hat{\alpha} \\
\frac{1}{2c} - (\lambda - \mu) \Gamma(1 - \Gamma(1)) & \text{when } \lambda \leq \mu \leq \xi \text{ and } \alpha < \hat{\alpha} \\
\frac{1}{2c} & \text{when } \mu < \lambda \leq \xi \text{ and } \alpha < \hat{\alpha}
\end{cases}
\]

where \( \hat{\alpha} = -\Lambda + \sqrt{1 + \Lambda^2 - 2c(\lambda - \mu) \Gamma(1 - \Gamma(1))} \), \( \hat{\alpha} = -\Lambda + \sqrt{1 + \Lambda^2} \) and \( \hat{\alpha} = 1 - \sqrt{1 + 2\sqrt{\Lambda}} \). Here, we define \( \Lambda = e \left[1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))\right] \) for ease of illustration.

Conventional wisdom posits that stricter copyright protection policies will promote quality improvement, increase firm profitability and enhance social welfare. However, in view of the information effect of piracy, can anti-protection policies exert some positive impacts? The next proposition shows the impacts of copyright protection policies on the producer’s quality and pricing strategies and its profit when consumers are loss averse.

Proposition 4. When consumers are loss averse, (i) stricter copyright protection policies will decrease the technology quality, price of the licensed product, and profit of the producer, i.e., \( \frac{\partial q^*}{\partial \alpha} < 0, \frac{\partial p^*}{\partial \alpha} < 0 \) and \( \frac{\partial \pi^*}{\partial \alpha} < 0 \), when \( \mu \leq \xi < \lambda \) and \( \alpha < \hat{\alpha} \); (ii) stricter copyright protection policies will increase the technology quality, price of the licensed product, and profit of the producer, i.e., \( \frac{\partial q^*}{\partial \alpha} > 0, \frac{\partial p^*}{\partial \alpha} > 0 \) and \( \frac{\partial \pi^*}{\partial \alpha} > 0 \), when \( \lambda \leq \mu \leq \xi \) and \( \alpha > \hat{\alpha} \) or when \( \mu < \lambda \leq \xi \) and \( \alpha > \hat{\alpha} \); (iii) otherwise, the copyright protection level will not impact the technology quality, price of the licensed product, or profit of the producer.

Contrary to the conventional wisdom, proposition 4 indicates that stricter copyright protection does not necessarily positively impact product quality, firm pricing power and profitability. Under certain circumstances, stricter copyright protection policies will prevent quality improvement and harm the producer’s pricing power and profit. Note that when \( \mu > \xi \) consumers never consider using piracy. The copyright protection level thus will not impact the producer’s decisions and profit. Therefore, we focus on the case when \( \mu \leq \xi \) in the following analysis.
When the degree of loss aversion on the licensed product is relatively low and the price of the licensed product is relatively high, i.e., when \( \lambda < \xi \) and \( \max\{R_{iw}, R_{pw}\} < p \leq R_{in} \), consumers who are not exposed to piracy initially buy the licensed product, but consumers exposed to piracy initially use piracy and continue to use it. In this situation, the producer can simply gain sales from the partial market where piracy does not exist. When the degree of loss aversion on the licensed product and the price of the licensed product are both relatively low, i.e., when \( \lambda < \xi \) and \( p \leq \max\{R_{iw}, R_{pw}\} < R_{in} \), consumers buy the licensed product regardless of whether piracy exists. In this situation, the producer can gain sales from the whole market. Since stricter copyright protection increases the consumer base of the partial market without piracy, when the copyright protection level is relatively high, the producer’s profit from the partial market is higher than that from the whole market. Specifically, when \( \alpha > \hat{\alpha} \) and \( \lambda \leq \mu \leq \xi \) or when \( \alpha > \hat{\alpha} \) and \( \mu < \lambda \leq \xi \), it is in the producer’s interest to set a relatively high price and gain the profit from the partial market without piracy. Under such circumstances, stricter copyright protection raises the sales volume, thus increasing the marginal return of the quality investment. Holding the marginal cost of the quality investment fixed, stricter copyright protection increases the producer’s incentive to invest in technology quality and raises its pricing power, thus increasing the producer’s profit. Otherwise, when the copyright protection level is relatively low, i.e., when \( \alpha \leq \hat{\alpha} \) and \( \lambda \leq \mu \leq \xi \) or when \( \alpha \leq \hat{\alpha} \) and \( \mu < \lambda \leq \xi \), the producer optimally sets a relatively low price to gain the profit from the whole market, and thus the copyright protection level does not influence the producer’s decisions and profit.

When the degree of loss aversion on the licensed product and the price of the licensed product are both relatively high, i.e., \( \lambda > \xi \) and \( R_{in} < p \leq R_{nw} \), consumers initially do not buy the licensed product even if they are not exposed to piracy. However, consumers who are exposed to piracy initially use it and then switch to buy the licensed product. In this situation, the producer can only gain sales from the partial market where piracy exists. When the degree of loss aversion on the licensed product is relatively high and the price of the licensed product is relatively low, i.e., \( \lambda > \xi \) and \( p \leq R_{in} \), consumers buy the licensed product regardless of whether piracy exists. In this situation, the producer can gain sales from the whole market. Since stricter copyright protection decreases the consumer base of the partial market with piracy, when the copyright protection level is relatively low, the producer’s profit from the partial market is higher than that from the whole market. Therefore, when \( \alpha < \hat{\alpha} \), it is in the producer’s interest to set a relatively high price and gain the profit from the partial market with piracy. Under this circumstance, stricter copyright protection leads to a lower sales volume, thus decreasing the marginal return of the quality investment. Holding the marginal cost of the quality investment fixed, stricter copyright protection decreases the producer’s incentive to invest in technology quality and weakens its pricing power, thus decreasing the producer’s profit. Otherwise, when the copyright protection level is relatively high, i.e., when \( \alpha \geq \hat{\alpha} \), the producer optimally sets a relatively low price to gain the profit from the whole market, and thus the copyright protection level does not influence the producer’s decisions and profit.

In brief, the rationale behind the positive impacts of anti-protection policies is as follows: When the degree of loss aversion on the licensed product is relatively high, consumers initially do not buy the licensed product even if piracy does not exist. However, the information effect of piracy can increase consumer propensity to buy
and induce piracy users to switch to buy. Anti-protection policies can increase the probability of consumers being exposed to piracy, thus raising consumer demand for the licensed product. This increased consumer demand enables the producer in the market under loose copyright protection policies to improve product quality, gain higher pricing power, and benefit from anti-protection policies.

Proposition 4 has shown that when consumers are loss averse, the producer facing anti-protection policies may be better off under certain circumstances. However, can anti-protection policies lead to a win-win situation for firm profitability and consumer surplus? In the final proposition, we investigate the impacts of copyright protection policies on consumer surplus and social welfare when consumers are loss averse.

Proposition 5. When consumers are loss averse, (i) stricter copyright protection policies will decrease consumer surplus, i.e.,

\[
\frac{dCS^*}{d\alpha} < 0 \quad \text{when} \quad \begin{cases} 
\lambda \leq \mu \leq \xi \text{ and } \alpha > \hat{\alpha} \\
\mu \leq \xi \text{ and } \lambda > \mu
\end{cases}
\]

Otherwise, the copyright protection level will not impact consumer surplus;

(ii) stricter copyright protection policies will decrease (increase) social welfare, i.e.,

\[
\frac{dSW^*}{d\alpha} < 0 \quad \text{when} \quad \begin{cases} 
\begin{align*}
\mu < \lambda &\leq \xi, \quad \alpha > \hat{\alpha} \quad \text{and} \quad c > \frac{\alpha}{(\lambda-\mu)\Gamma(1-\Gamma(1))} \\
\mu \leq \xi &< \lambda
\end{align*}
\end{cases}
\]

\[
\frac{dSW^*}{d\alpha} > 0 \quad \text{when} \quad \begin{cases} 
\begin{align*}
\mu < \lambda &\leq \xi, \quad \alpha > \hat{\alpha} \quad \text{and} \quad c < \frac{\alpha}{(\lambda-\mu)\Gamma(1-\Gamma(1))} \\
\lambda \leq \mu &\leq \xi \quad \text{and} \quad \alpha > \hat{\alpha}
\end{align*}
\end{cases}
\]

Otherwise, the copyright protection level will not impact social welfare;

(iii) anti-protection policies can lead to a win-win situation for firm profitability and consumer surplus when \(\mu \leq \xi < \lambda\) and \(\alpha < \hat{\alpha}\).

Part (i) of Proposition 5 points out the impacts of copyright protection policies on consumer surplus. Specifically, when \(\alpha \leq \hat{\alpha}\) and \(\lambda \leq \mu \leq \xi\), since consumers initially buy the licensed product regardless of whether piracy exists, the copyright protection level does not impact consumer surplus. When \(\alpha > \hat{\alpha}\) and \(\lambda \leq \mu \leq \xi\), or when \(\alpha > \hat{\alpha}\) and \(\mu \leq \lambda \leq \xi\), or when \(\alpha < \hat{\alpha}\) and \(\mu \leq \xi < \lambda\), consumer surplus only derives from the partial market where piracy exists, and thus consumer surplus decreases with the copyright protection level. When \(\alpha \leq \hat{\alpha}\) and \(\mu < \lambda \leq \xi\), or when \(\alpha \geq \hat{\alpha}\) and \(\mu \leq \xi < \lambda\), consumer surplus in the partial market where consumers initially use piracy and then switch to buy is higher than that in the partial market where piracy does not exist. Therefore, consumer surplus can be worse off by stricter copyright protection policies.

Part (ii) of Proposition 5 shows the impacts of copyright protection policies on social welfare. Specifically, when \(\alpha > \hat{\alpha}\) and \(\lambda \leq \mu \leq \xi\), or when \(\alpha < \hat{\alpha}\), \(\mu < \lambda \leq \xi\) and \(c < \frac{\alpha}{(\lambda-\mu)\Gamma(1-\Gamma(1))}\), the increase of the producer’s profit is larger than the decrease of consumer welfare under stricter copyright protection polices, and thus social welfare increases with the copyright protection level. When \(\alpha > \hat{\alpha}\), \(\mu < \lambda \leq \xi\) and \(c \geq \frac{\alpha}{(\lambda-\mu)\Gamma(1-\Gamma(1))}\), the increase of the producer’s profit is smaller than the decrease of consumer welfare under stricter copyright protection, and thus social welfare decreases with the copyright protection level. When \(\mu \leq \xi < \lambda\), the enhanced information effect led by looser copyright protection can mitigate the inefficient loss aversion behavior, leading to more social welfare. In this case, if \(\alpha \geq \hat{\alpha}\), stricter copyright protection decreases consumer surplus but does not
impact the producer’s profit; otherwise, faced with anti-protection policies, the producer benefits from the enhanced information effect and consumers benefit from the intensified market competition. As shown in part (iii) of Proposition 5, when \( \mu \leq \xi < \lambda \) and \( \alpha < \tilde{\alpha} \), stricter copyright protection simultaneously decreases consumer surplus and the producer’s profit.

6. **Concluding remarks.** This paper is motivated by the existing controversies on digital content piracy and copyright protection policies. Intuitively, piracy can cause severe losses for digital content producers, consumers, and society in many ways. Therefore, policymakers are often encouraged by the public to enforce stringent copyright protection policies. However, piracy as a representative informal economy is socially accepted under certain circumstances. This paper re-examines the impacts of piracy and copyright protection policies when consumers are loss averse. Loss aversion is a well-established phenomenon when consumers face uncertainty about product information, which often occurs in the digital content market. The central issue we address is the impacts of piracy and copyright protection policies on product quality, firm profitability, consumer surplus, and social welfare, and we identify the conditions under which piracy or anti-protection policies exert positive impacts on these factors.

The rationale for the positive impacts of piracy and anti-protection policies in this paper differs from previous studies and hinges on the influences of consumer loss aversion on their purchase decisions. When consumers are not loss averse, intuitively, piracy exerts a negative cannibalization effect on the producer’s profit. However, when consumers exhibit loss aversion, we show that piracy, revealing the content quality of the licensed product, can sometimes raise consumer propensity to buy, which we refer to as the information effect of piracy. Therefore, consumers who initially do not accept the licensed product may buy it once they have used piracy. This positive information effect on consumer purchase propensity may dominate the negative cannibalization effect on the producer’s marginal profit, constituting a force toward increasing the producers’ pricing power and profitability. We unexpectedly find that piracy can lead to a win-win situation for both firm profitability and consumer surplus when the degree of loss aversion on the licensed product is sufficiently high. This information effect of piracy can eliminate inefficient loss aversion, thus improving social welfare. Furthermore, we show that anti-protection policies can enhance this information effect and boost consumer demand for the licensed product, thus inducing the producer to invest more in product quality. This increased product quality enables the producer to gain higher pricing power and profitability. When the degree of loss aversion on the licensed product is sufficiently high, the enhanced information effect induced by looser copyright protection can mitigate inefficient loss aversion. Therefore, faced with anti-protection policies, the digital content producer, consumers, and even society can be better off.

This paper points to several directions for future research. First, we examine the impacts of piracy and copyright protection policies by assuming that consumers who exhibit loss aversion take their common expectation as the reference point. Since the formation of reference points is usually context-dependent, it is highly desirable to examine how different assumptions of reference points could lead to different market implications [51]. For example, with the prevalence of online trading, reference points may depend on customers’ online reviews and shared experience videos. Second, this paper investigates how piracy and copyright protection policies affect
the producer’s quality and pricing strategy. Future research could examine the producer’s other strategies when consumers are loss averse. For instance, if the producer offers a free trial version, the actual product quality is available to consumers without using piracy. Thus, it would be interesting to explore how piracy impacts the digital content producer’s trial version strategy when consumers exhibit loss aversion. Third, our model assumes a monopolistic digital content producer who directly sells its product to consumers. Future research could relax this assumption to see if the main results are robust with competing producers or distribution supply chains. Finally, this paper makes several testable predictions about the impacts of piracy and copyright protection policies within different ranges of the loss aversion degree. It would be helpful to validate these predictions when secondary or experimental data becomes available.

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Therefore, the equilibrium outcomes are the same as those in stage 1. In stage 1, the producer sets the technology quality \( q \) to maximize its profit \( \pi(q) \). Therefore, we can derive that \( p_n^b = q + 1 - \Gamma(1) \) and \( \pi_n^b = \frac{1}{c} + 1 - \Gamma(1) \).

Next, we solve the equilibrium outcomes in the market with piracy. In stage 2, the producer sets the price of the licensed product \( p \) to maximize its profit \( \pi(p) \). We can easily derive that \( p_n^b = q + \frac{1}{c} + 1 - \Gamma(1) \) and \( \pi_n^b = \frac{1}{c} + 1 - \Gamma(1) \).

Therefore, we obtain the results in Proposition 1.

**Appendix B. Proof of Theorem 2 and Proposition 2.** We first solve the equilibrium outcomes in the market without piracy. In stage 2, the producer sets the price of the licensed product \( p \) to maximize its profit \( \pi = p - \frac{c}{2}q^2 \), which must satisfy the condition of \( p \leq q + 1 - \Gamma(1) \). We can easily derive that \( p_n^b = q + 1 - \Gamma(1) \). In stage 1, the producer sets the technology quality \( q \) to maximize its profit \( \pi = q + 1 - \Gamma(1) - \frac{c}{2}q^2 \). Since \( \frac{\partial^2 \pi}{\partial q^2} < 0 \) and \( \frac{\partial \pi}{\partial q} = 1 - cq \), the first-order condition results in \( q_n^b = \frac{1}{c} \). Therefore, we can derive that \( p_n^b = \frac{1}{c} + 1 - \Gamma(1) \) and \( \pi_n^b = \frac{1}{c} + 1 - \Gamma(1) \).

Next, we solve the equilibrium outcomes in the market with piracy. In stage 2, the producer sets the price of the licensed product \( p \) to maximize its profit \( \pi = p - \frac{c}{2}q^2 \), which must satisfy the condition of \( p \leq q \). We can derive that \( p_n^b = q \). In stage 1, the producer sets the technology quality \( q \) to maximize its profit \( \pi = q - \frac{c}{2}q^2 \). Since \( \frac{\partial^2 \pi}{\partial q^2} < 0 \) and \( \frac{\partial \pi}{\partial q} = 1 - cq \), the first-order condition results in \( q_n^b = \frac{1}{c} \). Therefore, we have \( p_n^b = \frac{1}{c} \) and \( \pi_n^b = \frac{1}{c} + 1 - \Gamma(1) \) and \( \pi_n^b = \frac{1}{c} + 1 - \Gamma(1) \). Therefore, we can derive that \( p_n^b = \frac{1}{c} + 1 - \Gamma(1) \) and \( \pi_n^b = \frac{1}{c} + 1 - \Gamma(1) \). Therefore, we obtain the results in Proposition 1.

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**Appendix A. Proof of Theorem 1 and Proposition 1.** We first solve the equilibrium outcomes in the market without piracy. In stage 2, the producer sets the price of the licensed product \( p \) to maximize its profit \( \pi = p - \frac{c}{2}q^2 \), which must satisfy the condition of \( p \leq q + 1 - \Gamma(1) \). We can easily derive that \( p_n^b = q + 1 - \Gamma(1) \). In stage 1, the producer sets the technology quality \( q \) to maximize its profit \( \pi = q + 1 - \Gamma(1) - \frac{c}{2}q^2 \). Since \( \frac{\partial^2 \pi}{\partial q^2} < 0 \) and \( \frac{\partial \pi}{\partial q} = 1 - cq \), the first-order condition results in \( q_n^b = \frac{1}{c} \). Therefore, we can derive that \( p_n^b = \frac{1}{c} + 1 - \Gamma(1) \) and \( \pi_n^b = \frac{1}{c} + 1 - \Gamma(1) \). Therefore, we obtain the results in Proposition 1.

**Case 1.** when \( \mu > \xi \). In this case, \( E(\bar{u}_p) < 0 \), so consumers never use piracy. When \( E(\bar{u}_p) \geq 0 \), i.e., \( p \leq q + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) \), consumers initially buy the licensed product. Therefore, the equilibrium outcomes are the same as those
in the market without piracy, and part (iii) of Proposition 2 can also be partially proved.

**Case 2.** when \( \mu \leq \xi \). In this case, \( E(\bar{u}_p) \geq 0 \). Thus, if \( E(\bar{u}_i) \geq E(\bar{u}_p) \), i.e., \( p \leq q - (\lambda - \mu) \Gamma (1 - \Gamma (1)) \), consumers initially buy the licensed product. If \( p > q - (\lambda - \mu) \Gamma (1 - \Gamma (1)) \), consumers use piracy. Next, we divide this case into the following two sub-cases.

**Sub-case 2.1.** when \( \lambda \leq \mu \leq \xi \). In this sub-case, if \( p > q - (\lambda - \mu) \Gamma (1 - \Gamma (1)) \), the piracy users are unwilling to switch to buy the licensed product. To guarantee the demand of the licensed product is positive, the condition of \( p \leq q - (\lambda - \mu) \Gamma (1 - \Gamma (1)) \) must be satisfied. In stage 2, the producer sets the price \( p \) of the licensed product \( p \) to maximize its profit \( \pi = p - \bar{c}q^2 \). Obviously, \( p_w = q - (\lambda - \mu) \Gamma (1 - \Gamma (1)) \). In stage 1, the producer sets the technology quality \( q \) to maximize the profit \( \pi = q - (\lambda - \mu) \Gamma (1 - \Gamma (1)) - \frac{\epsilon q^2}{2} \). Since \( \frac{\partial \pi}{\partial q} = 1 - cq \), the first-order condition results in \( q_w = \frac{1}{c} \). Therefore, we can derive that \( p_w = \frac{1}{c} - (\lambda - \mu) \Gamma (1 - \Gamma (1)) \) and \( \pi_n = \frac{1}{2c} - (\lambda - \mu) \Gamma (1 - \Gamma (1)) \).

Comparing the equilibrium outcomes in the market with and without piracy when \( \lambda \leq \mu \leq \xi \), we find that \( q_w = q_n \), \( p_w \leq p_n \) and \( \pi_w \leq \pi_n \). Therefore, a portion of part (ii) and a portion of part (iii) of Proposition 2 can be proved.

**Sub-case 2.2.** when \( \mu < \xi \) and \( \lambda > \mu \). In this sub-case, if \( p \leq q \), the piracy users switch to buy the licensed product. In stage 2, the producer sets the price \( p \) of the licensed product \( p \) to maximize its profit \( \pi = p - \bar{c}q^2 \). Since \( q - (\lambda - \mu) \Gamma (1 - \Gamma (1)) < q \), we have \( p_w = q \). In stage 1, the producer sets the technology quality \( q \) to maximize the profit \( \pi = q - \frac{\epsilon q^2}{2} \). Since \( \frac{\partial \pi}{\partial q} < 0 \) and \( \frac{\partial \pi}{\partial q} = 1 - cq \), the first-order condition results in \( q_w = \frac{1}{c} \). Therefore, we can derive that \( p_w = \frac{1}{c} \) and \( \pi_n = \frac{1}{2c} \).

Comparing the equilibrium outcomes in the market with and without piracy, we find that \( q_w = q_n \), \( p_w > (\lambda - 1) \Gamma (1 - \Gamma (1)) \) and \( \pi_w > (\lambda - 1) \Gamma (1 - \Gamma (1)) \). Therefore, part (i) and a portion of part (ii) of Proposition 2 can be proved.

**Appendix C. Proof of Proposition 3.** In the market without piracy, the producer extracts total consumer surplus, and thus we have

\[
CS_n = 0 \text{ and } SW_n = \pi_n = \frac{1}{2c} + 1 - \Gamma (1) - (\lambda - 1) \Gamma (1 - \Gamma (1)).
\]

In the market with piracy, we derive consumer surplus and social welfare in the following cases, respectively. When \( \mu > \xi \), we have

\[
CS_w = 0 \text{ and } SW_w = \pi_w = \frac{1}{2c} + 1 - \Gamma (1) - (\lambda - 1) \Gamma (1 - \Gamma (1)).
\]

In this situation, piracy does not influence consumer surplus and social welfare. When \( \lambda \leq \mu \leq \xi \), we have

\[
CS_w = 1 + q - p - \Gamma (1) - (\lambda - 1) \Gamma (1 - \Gamma (1)) - 1 - \Gamma (1) - (\mu - 1) \Gamma (1 - \Gamma (1)) \quad \text{and}
\]

\[
SW_w = 1 + q - \Gamma (1) - (\lambda - 1) \Gamma (1 - \Gamma (1)) = \frac{1}{2c} + 1 - \Gamma (1) - (\lambda - 1) \Gamma (1 - \Gamma (1))
\]

and

\[
SW_w = 1 + q - \Gamma (1) - (\lambda - 1) \Gamma (1 - \Gamma (1)) = \frac{1}{2c} + 1 - \Gamma (1) - (\lambda - 1) \Gamma (1 - \Gamma (1))
\].
In this situation, \(CS_w \geq CS_n\) (when \(\mu = \xi\), \(CS_w = CS_n\)) and \(SW_w = SW_n\). When \(\mu \leq \xi, \lambda > \mu\), we have
\[
CS_w = \bar{v} + q - p = 1 - \Gamma(1) \quad \text{and} \quad
SW_w = v + q = \frac{1}{2c} + 1 - \Gamma(1).
\]
In this situation, \(CS_w > CS_n\) and \(SW_w > SW_n\). Combining the results in the above cases, we can obtain part (i) and part (ii) of Proposition 3. Obviously, when \(\mu \leq \xi < \lambda\), we have \(\pi_w > \pi_n, CS_w > CS_n\) and \(SW_w > SW_n\), and thus part (iii) of Proposition 3 can be proved.

**Appendix D. Proof of Theorem 3 and Proposition 4.** We first derive the equilibrium outcomes in the following cases, respectively. Then we conduct static analysis on the equilibrium outcomes in every case.

**Case (a).** when \(\mu > \xi\). In this case, since \(R^*_w = R^*_n = q + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))\), the copyright protection level does not impact the equilibrium outcomes. The equilibrium outcomes in case (a) are detailed in Lemma 1.

**Lemma 1.** When \(\mu > \xi\), the technology quality, price of the licensed product, and profit of the producer in equilibrium are respectively
\[
q^* = \frac{1}{c}, \quad p^* = \frac{1}{c} + 1 - (\lambda - 1) \Gamma(1 - \Gamma(1)) - \Gamma(1)\quad \text{and} \quad 
\pi^* = 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) + \frac{1}{2c}.
\]

**Case (b).** when \(\lambda \leq \mu \leq \xi\). In this case, \(R^*_w \leq R^*_n = q - (\lambda - \mu) \Gamma(1 - \Gamma(1))\). When \(R^*_w < p \leq R^*_n\), if piracy exist, consumers initially use piracy and keep using it; if piracy does not exist, they initially buy the licensed product. When \(p \leq R^*_w\), consumers initially buy the licensed product regardless of whether piracy exists. The equilibrium outcomes in case (b) are detailed in Lemma 2.

**Lemma 2.** When \(\lambda \leq \mu \leq \xi\), the technology quality, price of the licensed product, and profit of the producer in equilibrium are respectively
\[
q^* = \left\{ \begin{array}{ll} \frac{\alpha}{2c} & \text{when } \alpha > \hat{\alpha} \\ \frac{1}{c} & \text{otherwise} \end{array} \right.,
\]
\[
p^* = \left\{ \begin{array}{ll} \frac{\alpha}{2} + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) & \text{when } \alpha > \hat{\alpha} \\ \frac{1}{c} - (\lambda - \mu) \Gamma(1 - \Gamma(1)) & \text{otherwise} \end{array} \right.,
\]
\[
\pi^* = \left\{ \begin{array}{ll} \frac{\alpha^2}{2c} + \left[1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))\right] \alpha & \text{when } \alpha > \hat{\alpha} \\ \frac{1}{2c} - (\lambda - \mu) \Gamma(1 - \Gamma(1)) & \text{otherwise} \end{array} \right.,
\]
where \(\hat{\alpha}\) satisfies
\[
\frac{1}{2c} \hat{\alpha}^2 + (1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))) \hat{\alpha} + (\lambda - \mu) \Gamma(1 - \Gamma(1)) - \frac{1}{2c} = 0.
\]
For ease of illustration, we define \(A = c \left[1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))\right]\). Solving the above function, we get \(\hat{\alpha} = -A + \sqrt{1 + A^2 - 2c(\lambda - \mu) \Gamma(1 - \Gamma(1))}\), satisfying \(\hat{\alpha} \in (0, 1)\).
When $\alpha > \hat{\alpha}$, the equilibrium outcomes are
\[
q^* = \frac{c}{\alpha}, \quad p^* = \frac{c}{\alpha} + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) \quad \text{and}
\]
\[
\pi^* = \frac{\alpha^2}{2c} + [1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))] \alpha.
\]
Under this circumstance, we have $\frac{d\pi}{d\alpha} > 0$, $\frac{dq}{d\alpha} > 0$ and $\frac{dp}{d\alpha} > 0$. Otherwise, when $\alpha \leq \hat{\alpha}$, the equilibrium outcomes are
\[
q^* = \frac{1}{c}, \quad p^* = \frac{1}{c} + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) \quad \text{and}
\]
\[
\pi^* = \frac{1}{2c} + [1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))] \alpha.
\]
Under this circumstance, we have $\frac{dq}{d\alpha} = \frac{dp}{d\alpha} = \frac{d\pi}{d\alpha} = 0$.

**Case (c).** When $\mu < \lambda \leq \xi$. In this case, $R^q_w = q - (\lambda - \mu) \Gamma(1 - \Gamma(1)) < R^p_w$. When $R^w < p \leq R^p$, if piracy exists, consumers initially use piracy and then switch to buy the licensed product; if piracy does not exist, they initially buy the licensed product. When $R^w < p \leq R^p$, if piracy exists, consumers initially use piracy and then switch to buy the licensed product; if piracy does not exist, they initially buy the licensed product. When $p \leq R^w$, consumers initially buy the licensed product regardless of whether piracy exists. The equilibrium outcomes in case (c) are detailed in Lemma 3.

**Lemma 3.** When $\mu < \lambda \leq \xi$, the technology quality, price of the licensed product, and profit of the producer in equilibrium are respectively
\[
q^* = \begin{cases} 
\frac{\alpha}{c} & \text{when } \alpha > \hat{\alpha}, \\
\frac{1}{c} & \text{otherwise}
\end{cases}
\]
\[
p^* = \begin{cases} 
\frac{\alpha}{c} + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) & \text{when } \alpha > \hat{\alpha}, \\
\frac{1}{c} & \text{otherwise}
\end{cases}
\]
\[
\pi^* = \begin{cases} 
\frac{\alpha^2}{2c} + [1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))] \alpha & \text{when } \alpha > \hat{\alpha}, \\
\frac{1}{2c} & \text{otherwise}
\end{cases}
\]
where $\hat{\alpha}$ satisfies
\[
\frac{1}{2c} \alpha^2 + [1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))] \alpha - \frac{1}{2c} = 0.
\]
Solving the above function, we get $\hat{\alpha} = -\Lambda + \sqrt{\Lambda + \Lambda^2}$, satisfying $\hat{\alpha} \in (0, 1)$.

When $\alpha > \hat{\alpha}$, the equilibrium outcomes are
\[
q^* = \frac{\alpha}{c}, \quad p^* = \frac{c}{\alpha} + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) \quad \text{and}
\]
\[
\pi^* = \frac{\alpha^2}{2c} + [1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))] \alpha.
\]
Under this circumstance, we have $\frac{d\pi}{d\alpha} > 0$, $\frac{dq}{d\alpha} > 0$ and $\frac{dp}{d\alpha} > 0$. Otherwise, when $\alpha \leq \hat{\alpha}$, the equilibrium outcomes are $q^* = \frac{1}{c}$, $p^* = \frac{1}{c}$ and $\pi^* = \frac{1}{2c}$. Under this circumstance, we have $\frac{dq}{d\alpha} = \frac{dp}{d\alpha} = \frac{d\pi}{d\alpha} = 0$.

**Case (d).** When $\mu \leq \xi < \lambda$. In this case, $R^q_w = q - (\lambda - \mu) \Gamma(1 - \Gamma(1)) \leq R^p_n$. When $R^q_w < p \leq R^p$, if piracy exists, consumers initially use piracy and then switch to buy the licensed product; if piracy does not exist, they forgo their use.
When $R_i^u < p \leq R_i^n$, if piracy exists, consumers initially use piracy and then switch to buy the licensed product; if piracy does not exist, they initially buy the licensed product. When $p \leq R_i^u$, consumers initially buy the licensed product regardless of whether piracy exists. The equilibrium outcomes in case (d) are detailed in Lemma 4.

**Lemma 4.** When $\mu \leq \xi < \lambda$, the technology quality, price of the licensed product, and profit of the producer in equilibrium are respectively

$$q^* = \begin{cases} 
\frac{1-\alpha}{c} & \text{when } \alpha < \tilde{\alpha} \\
\frac{1}{c} & \text{when } \alpha \geq \tilde{\alpha}
\end{cases}$$

$$p^* = \begin{cases} 
\frac{1-\alpha}{c} + 1 - (\lambda - 1) \Gamma (1 - \Gamma (1)) - \Gamma (1) & \text{when } \alpha < \tilde{\alpha} \\
\frac{1}{c} + 1 - (\lambda - 1) \Gamma (1 - \Gamma (1)) - \Gamma (1) & \text{when } \alpha \geq \tilde{\alpha}
\end{cases}$$

$$\pi^* = \begin{cases} 
\frac{(1-\alpha)^2}{2c} & \text{when } \alpha < \tilde{\alpha} \\
1 - \Gamma (1) - (\lambda - 1) \Gamma (1 - \Gamma (1)) + \frac{1}{2c} & \text{when } \alpha \geq \tilde{\alpha}
\end{cases}$$

where $\tilde{\alpha}$ satisfies

$$\frac{1}{2c} \tilde{\alpha}^2 - \frac{1}{c} \tilde{\alpha} - [1 - \Gamma (1) - (\lambda - 1) \Gamma (1 - \Gamma (1))] = 0.$$ 

Solving the above function, we get $\tilde{\alpha} = 1 - \sqrt{1 + 2\Lambda}$, satisfying $\tilde{\alpha} \in (0,1)$.

Here, we assume $\lambda < \frac{1-\Gamma (1)}{\Gamma (1) - \Gamma (1)} + \frac{1}{2c} \frac{1}{\Gamma (1) - \Gamma (1)}$ to guarantee the equilibrium profit in case (d) is always positive.

When $\alpha < \tilde{\alpha}$, the equilibrium outcomes are $q^* = \frac{1-\alpha}{c}$, $p^* = \frac{1-\alpha}{c}$ and $\pi^* = \frac{(1-\alpha)^2}{2c}$. Under this circumstance, we have $\frac{d\pi}{d\alpha} < 0$, $\frac{d\pi}{d\alpha} < 0$ and $\frac{d\pi}{d\alpha} < 0$. Otherwise, when $\alpha \leq \tilde{\alpha}$, the equilibrium outcomes are

$$q^* = \frac{1}{c}, \quad p^* = 1 - (\lambda - 1) \Gamma (1 - \Gamma (1)) - \Gamma (1)$$

$$\pi^* = 1 - \Gamma (1) - (\lambda - 1) \Gamma (1 - \Gamma (1)) + \frac{1}{2c}.$$ 

Under this circumstance, we have $\frac{d\pi}{d\alpha} = \frac{d\pi}{d\alpha} = \frac{d\pi}{d\alpha} = 0$.

Combining the equilibrium outcomes and static analysis in cases (a)-(d), we can obtain Theorem 3 and Proposition 4.

**Appendix E. Proof of Proposition 5.** We first derive consumer surplus and social welfare in the following cases, respectively. Then we conduct static analysis on consumer surplus and social welfare in every case.

**Case (a).** when $\mu > \xi$. In this case, consumers initially buy the licensed product and the product price is equal to their reservation price. Therefore, $CS^* = 0$ and $SW^* = \pi^*_n = \frac{1}{2} \Gamma (1) + 1 - (\lambda - 1) \Gamma (1 - \Gamma (1)) - \Gamma (1)$. We can easily obtain that $\frac{dCS^*}{d\alpha} = 0$ and $\frac{dSW^*}{d\alpha} = 0$.

**Case (b).** when $\lambda \leq \mu \leq \xi$. In this case, the producer has two pricing strategies. When $\alpha > \tilde{\alpha}$, the producer extracts total consumer surplus from the partial market
where piracy does not exist, and thus consumers surplus only derives from the partial market where consumers keep using piracy. Therefore, we have

\[
CS^* = (1 - \alpha) (1 - \Gamma(1) - (\mu - 1) \Gamma(1 - \Gamma(1))) \quad \text{and}
\]

\[
SW^* = \frac{\alpha^2}{2c} + [(\mu - \lambda) \Gamma(1 - \Gamma(1))] \alpha + 1 - \Gamma(1) - (\mu - 1) \Gamma(1 - \Gamma(1)) .
\]

In this situation, we have \( \frac{dCS^*}{d\alpha} < 0 \) and \( \frac{dSW^*}{d\alpha} > 0 \). When \( \alpha \leq \alpha \), consumers surplus derives from the whole market where consumers initially buy the licensed product. Therefore, we have

\[
CS^* = 1 + q^* - p^* - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) \quad \text{and}
\]

\[
SW^* = \pi^* + CS^* = \frac{1}{2c} + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))
\]

In this situation, we have \( \frac{dCS^*}{d\alpha} = 0 \) and \( \frac{dSW^*}{d\alpha} = 0 \).

**Case (c).** when \( \mu < \lambda \leq \xi \). In this case, the producer has two pricing strategies. When \( \alpha > \hat{\alpha} \), the producer extracts total consumer surplus from the partial market where piracy does not exist, and consumers surplus only derives from the partial market where consumers initially buy the licensed product. Therefore, we have

\[
CS^* = (1 - \alpha) (1 - \Gamma(1) - (\mu - 1) \Gamma(1 - \Gamma(1))) \quad \text{and}
\]

\[
SW^* = \frac{\alpha^2}{2c} + [(\mu - \lambda) \Gamma(1 - \Gamma(1))] \alpha + 1 - \Gamma(1) - (\mu - 1) \Gamma(1 - \Gamma(1)) .
\]

Therefore, we can derive that when \( \alpha > \hat{\alpha} \), \( \frac{dCS^*}{d\alpha} < 0 \) and \( \frac{dSW^*}{d\alpha} > (\cdot)0 \) if \( c < (\cdot)(\lambda - \mu) \Gamma(1 - \Gamma(1)) \). When \( \alpha \leq \hat{\alpha} \), consumer surplus derives from the partial market where piracy users switch to buy the licensed product and the partial market where consumers initially buy the licensed product. Therefore, we have

\[
CS^* = (1 - \alpha) [\hat{v} + q^* - p^*] + \alpha [1 + q^* - p^* - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))]
\]

\[
= (1 - \alpha) [1 - \Gamma(1)] + \alpha [1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))]
\]

\[
= 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) \alpha
\]

\[
SW^* = \pi^* + CS^* = \frac{1}{2c} + 1 - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1)) \alpha
\]

In this situation, we have \( \frac{dCS^*}{d\alpha} < 0 \) and \( \frac{dSW^*}{d\alpha} < 0 \).

**Case (d).** when \( \mu \leq \xi < \lambda \). In this case, the producer has two pricing strategies. When \( \alpha \geq \hat{\alpha} \), consumers surplus derives from the partial market where consumers initially buy the licensed product and the partial market where piracy users switch to buy the licensed product. Therefore, we have

\[
CS^* = (1 - \alpha) [\hat{v} + q^* - p^*] + \alpha [1 + q^* - p^* - \Gamma(1) - (\lambda - 1) \Gamma(1 - \Gamma(1))]
\]

\[
= (1 - \alpha) [(\lambda - 1) \Gamma(1 - \Gamma(1))]
\]

\[
\text{and } SW^* = \pi^* + CS^* = \frac{1}{2c} + 1 - \Gamma(1) - \alpha (\lambda - 1) \Gamma(1 - \Gamma(1))
\]

In this situation, we have \( \frac{dCS^*}{d\alpha} < 0 \) and \( \frac{dSW^*}{d\alpha} < 0 \). When \( \alpha < \hat{\alpha} \), consumers surplus only derives from the partial market where piracy users switch to buy the licensed
product. Therefore, we have
\[
CS^* = (1 - \alpha) [\bar{v} + q^* - p^*] = (1 - \alpha) (1 - \Gamma (1)) \text{ and }
\]
\[
SW^* = \pi^* + CS^* = \frac{(1 - \alpha)^2}{2c} + (1 - \alpha) (1 - \Gamma (1)).
\]
In this situation, we have \( \frac{dCS^*}{d\alpha} < 0 \) and \( \frac{dSW^*}{d\alpha} < 0 \).

Combining the results in the above cases, part (i) and (ii) of Proposition 5 can be proved. Note that when \( \mu \leq \xi < \lambda \) and \( \alpha < \tilde{\alpha} \), we have \( \frac{d\pi^*}{d\alpha} < 0 \), \( \frac{dCS^*}{d\alpha} < 0 \) and \( \frac{dSW^*}{d\alpha} < 0 \). Thus, part (iii) of Proposition 5 can be proved.