Preventing Commercial Piracy when Consumers are Loss Averse*

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Abstract

I analyze how the loss aversion of consumers affects the strategies of the government and the incumbent for preventing commercial piracy. To that end, I develop a sequential duopoly model of vertical product differentiation with price competition in which consumers have a reference-dependent utility. Regardless of the quality of the illegal copy, conventional models that do not take into account the loss aversion of consumers overestimate the government's effort to deter piracy but underestimate the incumbent's effort. Contrary to conventional wisdom, I find that blocking the entry of a pirate by the government can provide more welfare than accommodating it. However, the government will not block it because socially it is better to encourage the incumbent to establish a price low enough to deter the pirate from entering.

Keywords: reference-dependent utility; loss aversion; commercial piracy; government; incumbent; pirate

JEL Classification: D23; D43; D90; K42; L13; O38.

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1 Introduction

The arrival of personal computers in homes around the world in the last quarter of the twentieth century opened up the possibility of copying digital goods without the consent of their owners. This action, known as piracy, reduced profits because it became widespread throughout the world, as can be seen in Table 1. For example, the Global Software Survey (2003) reports that in 1994 97% of the software installed in China was not licensed, i.e. was pirated. Even in developed countries such as France and Germany, pirated software accounted for half of all installed software. Given how widespread piracy has become, firms and governments have carried out strategies to curb and reduce it. As a result the piracy rate worldwide has been reduced from 49% in 1994 to 37% in 2017, according to the latest Global Software Survey (2018) conducted by the Business Software Alliance. Despite the progress made, piracy rates remain high, as can be seen in Table 1. Recent papers have analyzed differences in piracy rates between countries.[1] Martínez-Sánchez and Romeu (2018) find that in more developed countries there are fewer incentives to pirate products. They also find that countries with smaller, more efficient bureaucracies are likely to protect intellectual property more effectively. These results are backed up by Athey and Stern (2015), who suggest that the quality of the institutional environment is more closely linked with piracy than income per se.

[1] For surveys of the theoretical literature about piracy see Belleflame and Peitz (2012) and Peitz and Waelbroeck (2006), and for the empirical literature see Dejean (2009) and Waldfogel (2012).

Table 1: Piracy Rate (%)

Piracy Rate (%)	1994	2017	Dif. Pp.	Dif. (%)
China	97	66	-31	-32,0
France	53	32	-21	-39,6
Germany	48	20	-28	-58,3
Spain	77	42	-35	-45,5
UK	42	21	-21	-50,0
USA	31	15	-16	-51,6
Africa	77	56	-21	-27,3
Asia	68	57	-11	-16,2
Eastern Europe	85	57	-28	-32,9
Latin America	78	52	-26	-33,3
Western Europe	52	26	-26	-50,0
Total World	49	37	-12	-24,5

Source: BSA (2003, 2018)

On the other hand, behavioral economics has shown that humans behave non-rationally.[2] In particular, we are averse to losses (Kahneman and Tversky (1979), Tversky and Kahneman (1991)). This means that the pain of a loss is greater than the pleasure of a gain of equal size. Neumann and Böckenholt (2014) have empirically demonstrated that loss aversion manifests when consumers decide to buy a product. Models developed recently in the field of industrial economics incorporate these discoveries about the non-rational behavior of people.[3] They consider that consumers obtain utility not only when consuming a product but also when comparing it with the reference product. Therefore, if a consumer buys a more expensive (or lower quality) product, she experiences this as a loss in the price (quality) dimension. Previous literature has considered that consumers compare original products. However, this paper considers that consumers compare the original and the copy of a product. As far as I know, there are no papers that study piracy when consumers are averse to losses. This paper sets out to fill that gap and analyze the effect of loss aversion among consumers on strategies to prevent

[2] For a nice introduction to behavioral economics, I recommend Kahenman (2011) and Thaler (2015).

[3] See Heidhues and Koszegi (2018) for a review of the literature and Grubb (2015) for a review of the literature on the effect of consumer loss aversion on pricing.

piracy. It also seek to confirm whether making the model a little more realistic invalidates the conclusions of the traditional models that analyze piracy, and whether it provides new findings.

From the marketing literature, we know that lower price of illegal copies appears to be the main factor driving sales (Chiu and Leng (2016)), and that the more aware consumers are for paying lower prices, subject to some quality constraints, the more favorable they are to piracy (Ang et al. (2001) and Wang et al. (2005)). Illegal copies evoke positive emotions such as the pleasure of buying a product at a cheaper price (Marticotte and Arcand (2017)), but the availability of a cheaper illegal copy causes consumer dissatisfaction with the original brand (Juggessur and Cohen (2009)). Consumers are therefore very likely to be loss aversion when they decide to buy the original or the copy of a product.

In this paper, I analyze commercial piracy of digital goods, which occurs when some firms reproduce and illegally sell copies of original products without the authorization of the owner.[4] To that end, I develop a sequential duopoly model of vertical product differentiation with price competition.[5] This model is similar to those presented in Banerjee (2003), Martínez-Sánchez (2010) and Lopez-Cuñat and Martínez-Sánchez (2015). Banerjee (2003) analyzes the role of government in combating piracy. Among other results, he finds that blocking the entry of a pirate so that the incumbent can set monopoly prices is an equilibrium. This result contrasts with that obtained by Martínez-Sánchez (2010) and López-Cuñat and Martínez-Sánchez (2015). Martínez-Sánchez (2010) shows that the government will not help the incumbent to become a pure monopolist even if it installs an antipiracy system. It will let the pirate enter as either a follower or a leader, or encourage the incumbent to set a low enough price to successfully deter the pirate from entering the market, depending on its technology for monitoring the pirate. In a common framework, but with different assumptions, López-Cuñat and Martínez-Sánchez (2015) confirm that deterred or accommodated piracy can occur in equilibrium, but pure monopoly cannot occur in any anti-piracy policy.

[4] There are papers that analyze the case in which copies are made exclusively by end consumers. For example, Bae and Choi (2006), Chang et al. (2008), Darmon and Le Texier (2016), Huang et al. (2018), Martínez-Sánchez (2011, 2012) and Rasch and Wenzel (2013).

[5] For the vertical product differentiation model, see Mussa and Rosen (1978) and Ronnen (1991).

Commercial piracy has been and continues to be widely analyzed. Among the relevant publications,[6] Lu and Poddar (2012) study the case when the incumbent makes a costly investment to deter a commercial pirate in a given regime of intellectual property rights (IPR) protection. They find that when the consumers' tastes are sufficiently diverse and the IPR protection is weak, it is profitable for the incumbent to accommodate the pirate. In all other cases it is profitable to deter the pirate. Häckner and Muren (2015) consider two types of consumption externalities: i) consumers do not like the quantity of items (copies or originals) sold of a product; and ii) consumers do not like copies more than the originals. They show that there seem to be welfare gains from counterfeiting, but the government would typically want to keep counterfeiting at a low level, at least when externalities are strong and enforcement costs low. Recently, Madio (2018) presents a model for analyzing the competition between a subscription-based content provider and many pirate providers. He shows that the incumbent and the government always find it optimal to tolerate some degree of piracy. Finally, Klein (2020) presents a model that incorporates endogenous product quality and the interaction between public and private enforcement efforts. He shows that when public intellectual property enforcement is low, the authentic product firm optimally accommodates counterfeit entry by choosing low private enforcement and relatively high product quality. However, under high public enforcement the firm deters entry through high private enforcement. Although piracy hurts incumbents, these papers find that piracy has a positive effect on consumers because it forces owners to set a lower price. Therefore, tolerating piracy can be socially desirable. In the present paper, I check whether these conclusions hold when consumers are loss averse.

This research is related to recent literature that analyzes how the loss aversion of consumers affects price competition. Using the approach introduced by Köszegi and Rabin (2006), Heidhues and Köszegi (2008) modify the model introduced by Salop (1979) to consider that consumers are loss averse in relation to a reference point given by their recent expectations about the purchase. They find that consumers' loss aversion in terms of money increases the intensity of competition, reducing or eliminating price variation. Karle and Peitz (2014) modify the model developed by Heidhues and Köszegi (2008) to consider that firms commit to deterministic prices before consumers form their reference points. They find that loss aversion in

[6] See Slive and Bernhardt (1998), Kiema (2008) and Martínez-Sánchez (2013).

price is procompetitive, while loss aversion in taste is anticompetitive.

These papers consider that the reference point arises endogenously, but I assume that it is determined exogenously, as in Zhou (2011) and Amaldoss and He (2018). In a duopoly à la Hotelling (1929), Zhou (2011) finds that the firm whose product takes more consumers as a point of reference has an incentive to randomize its price. He also shows that loss aversion in price is procompetitive, while loss aversion in taste is anticompetitive. On the other hand, Amaldoss and He (2018) include reference-dependent utility in the spokes model developed by Chen and Riordan (2007). They find that loss aversion in price increases competition among low-value goods, whereas loss aversion in taste softens competition among high-value goods only if consumer sensitivity to the difference in taste is high enough.

Previous papers consider models in which firms are horizontally differentiated. However, in the model that I present in this paper firms are differentiated vertically because I assume that the quality of the copy is inferior to that of the original product. Recent papers have developed monopoly models with vertically differentiated products and loss averse consumers. In this framework, Carbajal and Ely (2016) study optimal price discrimination when consumers have reference-dependent preferences for the quality of the product. They find that, depending on the reference plan, optimal price discrimination may exhibit efficiency gains relative to second-best contracts without loss aversion. Hahn et al. (2018) also study price discrimination but they consider that consumers have reference-dependent preferences for the quality and price of the product. They show that offering menus with a small number of bundles is consistent with profit-maximizing firms that face loss averse consumers. Finally, Courty and Nasiry (2018) apply loss aversion within a class of products of the same quality but not across quality classes. They show that uniform pricing can be optimal across quality classes up to a quality threshold.

Here I analyze how the loss aversion of consumers affects the strategies of the government and the incumbent for preventing commercial piracy. To that end, I develop a sequential duopoly model of vertical product differentiation with price competition in which consumers are loss averse. I consider that consumers have a reference-dependent utility for the hedonic price of the product, where a hedonic price is defined as the price/quality ratio of a product. Loss aversion thus depends on the price and quality of a product, but the degree of loss aversion is the same for both characteristics. This last contention is empirically supported by Neumann and Böckenholt (2014), who find no general differences in loss aversion between price and quality. I find that, regardless of the quality of the illegal copy, conventional models that do not take into account the loss aversion of consumers overestimate the government's effort to deter piracy but underestimate the incumbent's effort. Contrary to conventional wisdom, I find that action by the government to block the entry of a pirate can provide more welfare than accommodating it. However, the government will not block it because socially it is better to encourage the incumbent to establish a price low enough to deter the pirate from entering.

The rest of the paper is organized as follows: Section 2 describes the model formally. Section 3 presents the equilibrium. Section 4 draws comparative statics. Finally, Section 5 concludes.

2 The model

An incumbent produces an original product with quality q_i and sells at monetary price p_i, while a pirate illegally copies the original product and sells the copy at price p_p. The quality of the copy is represented by q_p. I assume $q_p < q_i$. There is a continuum of consumers indexed by $\theta \in [0, 1]$, where θ is assumed to follow a uniform distribution and represents consumers' tastes for the quality of a product. Each consumer is assumed to buy either a single unit of the product or none at all. I consider the utility of consumers to be reference-dependent. This means that they experience a psychological disutility when buying a non-reference product whose hedonic price is higher than the hedonic price of reference product,[7] where a hedonic price is defined as the price/quality ratio of a product (p/q). I assume that a proportion ϕ of consumers take the original product as the reference product, while the rest of consumers take the illegal copy as the reference product. If the reference product of a consumer θ is the original product, his/her utility is:

[7] If the hedonic price of the non-reference product is lower than that of the reference product, consumers experience a psychological gain. As in Zhou (2011), I normalize the psychological gain utility to zero.

$$U(\theta)=\begin{cases}\theta q_i-p_i & \text{if he buys the original product}\\ \theta q_p-p_p-\lambda\max\left\{0,\frac{p_p}{q_p}-\frac{p_i}{q_i}\right\} & \text{if he buys the illegal copy}\\ 0 & \text{if he does not buy,}\end{cases} \tag{1}$$

but if the reference product is the pirated product or illegal copy, his/her utility is:

$$U(\theta)=\begin{cases}\theta q_i-p_i-\lambda\max\left\{0,\frac{p_i}{q_i}-\frac{p_p}{q_p}\right\} & \text{if he buys the original product}\\ \theta q_p-p_p & \text{if he buys the illegal copy}\\ 0 & \text{if he does not buy,}\end{cases} \tag{2}$$

where λ is the degree of loss aversion of a consumer, which represents the consumer's sensitivity to the difference in hedonic price with the reference product. I assume that the degree of aversion to loss is the same for all consumers and that $0<\lambda\leq 8$. This last assumption is not restrictive because, as Neumann and Böckenholt (2014) find, "people tend to react almost twice as strongly to losses than gains". Specially, they estimate that the loss aversion coefficient is 1.7.

To obtain the demand function of each firm, I first define indifferent consumers. Among those consumers whose reference product is the original, let $\widehat{\theta}_i=p_i/q_i$ be the consumer who is indifferent between buying the original product and not buying at all; let $\widehat{\theta}_p$ be the consumer who is indifferent between buying the pirated product and not buying at all; and, let $\widehat{\theta}$ be the consumer who is indifferent between buying the original and the pirated product, where

$$\begin{aligned}\widehat{\theta}_p &= \begin{cases}\frac{p_p}{q_p}+\frac{\lambda}{q_p}\left(\frac{p_p}{q_p}-\frac{p_i}{q_i}\right) & \text{if } \frac{p_i}{q_i}\leq\frac{p_p}{q_p},\\ \frac{p_p}{q_p} & \text{if } \frac{p_i}{q_i}\geq\frac{p_p}{q_p},\end{cases}\\ \widehat{\theta} &= \begin{cases}\frac{p_i-p_p}{q_i-q_p}+\frac{\lambda}{q_i-q_p}\left(\frac{p_i}{q_i}-\frac{p_p}{q_p}\right) & \text{if } \frac{p_i}{q_i}\leq\frac{p_p}{q_p},\\ \frac{p_i-p_p}{q_i-q_p} & \text{if } \frac{p_i}{q_i}\geq\frac{p_p}{q_p}.\end{cases}\end{aligned}$$

Furthermore, among those consumers whose reference product is the pirated product, let $\widetilde{\theta}_p=p_p/q_p$ be the consumer who is indifferent between buying the pirated product and not buying at all; let $\widetilde{\theta}_i$ be the consumer who is indifferent between buying the original product and not buying at all; and, let $\widetilde{\theta}$ be the consumer who is indifferent between buying the original and the pirated products, where

$$\widetilde{\theta}_i = \begin{cases} \frac{p_i}{q_i} & \text{if } \frac{p_i}{q_i} \leq \frac{p_p}{q_p}, \\ \frac{p_i}{q_i} + \frac{\lambda}{q_i}\left(\frac{p_i}{q_i} - \frac{p_p}{q_p}\right) & \text{if } \frac{p_i}{q_i} \geq \frac{p_p}{q_p}, \end{cases}$$

$$\widetilde{\theta} = \begin{cases} \frac{p_i - p_p}{q_i - q_p} & \text{if } \frac{p_i}{q_i} \leq \frac{p_p}{q_p}, \\ \frac{p_i - p_p}{q_i - q_p} + \frac{\lambda}{q_i - q_p}\left(\frac{p_i}{q_i} - \frac{p_p}{q_p}\right) & \text{if } \frac{p_i}{q_i} \geq \frac{p_p}{q_p}. \end{cases}$$

If $p_i/q_i < p_p/q_p$, then $\widetilde{\theta}_p > \widetilde{\theta}_i > \widetilde{\theta}$ and $\widehat{\theta}_p > \max\left\{\widehat{\theta}_i, \widehat{\theta}\right\}$. This means that demand for the pirated product is zero and demand for the incumbent coincides with demand for a monopolist. Thus, the hedonic price chosen by the incumbent is the price of a monopolist, which is greater than that chosen by the pirate because $q_i > q_p$. This contradicts the idea that $p_i/q_i < p_p/q_p$. Therefore, in equilibrium, $p_i/q_i > p_p/q_p$. This result means that those consumers whose reference product is the original will not experience a psychological disutility from buying the illegal copy. Thus, if the reference product of all consumers is the original ($\phi = 1$), no consumer experiences this psychological disutility and the model coincides with the one previously presented in Martínez-Sánchez (2010). From here on I only consider the case in which $p_i/q_i > p_p/q_p$.

Let $\beta \equiv \lambda(1-\phi)$ be the degree of loss aversion in the market, where $1-\phi$ is the proportion of consumers who take the illegal copy as the reference product. These consumers suffer a psychological disutility when buying the original product because $p_i/q_i > p_p/q_p$. Thus, a higher proportion of these consumers implies a greater loss aversion in the market. Moreover, the degree of loss aversion in the market positively depends on the degree of loss aversion of one consumer. Finally, note that $0 \leq \beta \leq 8$ since $0 < \lambda \leq 8$ and $\phi \in [0,1]$
.

Demand for the original and the pirated product is defined as follows:

$$\begin{aligned} D_i(p_i, p_p) &= \phi\left(1 - \widehat{\theta}\right) + (1-\phi)\left(1 - \widetilde{\theta}\right) \\ D_p(p_i, p_p) &= \phi\left(\widehat{\theta} - \widehat{\theta}_p\right) + (1-\phi)\left(\widetilde{\theta} - \widetilde{\theta}_p\right) \end{aligned} \tag{3}$$

As in Martínez-Sánchez (2010), I assume that consumers do not face the risk of prosecution for the use of copies because they do not illegally make and sell copies of the original product.[8] The government is responsible for monitoring and penalizing the pirate who illegally reproduces and sells copies of the original product. Let α be the monitoring rate and G the penalty. Thus, α is the probability of detecting the pirate. I assume $G \in \left[0, \overline{G}\right]$, where $\overline{G}$ is the maximum legal penalty. Let $C(\alpha)$ be the cost of monitoring piracy. I assume $C(0) = 0, C'(\alpha) > 0$. If the pirate's illegal operations are detected, he must pay the penalty G and he loses his income. Let $\alpha G + \alpha p_p D_p(p_i, p_p) - C(\alpha)$ be the net expected revenue of the government. I assume that a firm remains in the market if and only if it is making a positive profit. So the expected profits of the incumbent and the pirate, taking into account that detection takes place after sale, are:

$$\pi_i(p_i, p_p) = p_i D_i(p_i, p_p) \text{ and } \pi_p(p_i, p_p) = (1-\alpha) p_p D_p(p_i, p_p) - \alpha G$$

As in Banerjee (2003) and Martínez-Sánchez (2010), I consider that the cost incurred by the incumbent in developing an original product is a sunk cost and the marginal production costs of both the incumbent and the pirate are zero. I also assume that the incumbent, the pirate and the government are risk neutral.

The complete information game is as follows. The government chooses α and G to maximize social welfare, which is the sum of the profits of the incumbent and the pirate, the consumer surplus, and the net expected revenue of the government. Then the incumbent prices first and becomes the leader on prices. Next, the pirate prices the pirated product and becomes a follower. Finally, consumers decide to buy the original product, the illegal copy or neither after they have observed firms' prices.

In the next section, I seek to find the subgame perfect equilibrium (SPE) of the game by backward induction.

3 Equilibrium

3.1 Firms' strategies

Let $A \equiv 2q_i - q_p + \beta$. Given that $q_i > q_p > 0$ and $\beta > 0$, it results that $A > 0$. The pirate becomes a follower whose best-response function is:

[8] According to the penal codes of most countries, this assumption is true (for example, see articles 270 to 272 of the Spanish penal code).

$$p_p^{BR}(p_i) = \begin{cases} \frac{p_i q_p}{2q_i} & \text{if } 0 \leq p_i \leq \frac{2q_i(q_i-q_p)}{A} \\ q_p \frac{p_i(q_i+\beta)-q_i(q_i-q_p)}{q_i(q_p+\beta)} & \text{if } \frac{2q_i(q_i-q_p)}{A} \leq p_i \leq \frac{Aq_i}{2(q_i+\beta)} \\ \frac{q_p}{2} & \text{if } \frac{Aq_i}{2(q_i+\beta)} \leq p_i \end{cases} \tag{4}$$

The pirate prices as a monopolist if the price of the incumbent is high, as a duopolist if the price of the incumbent is low and, for intermediate price of the incumbent, establishes the price that makes the incumbent 's demand equal to zero. Substituting (4) in the pirate's profit gives the pirate's maximum profit $\pi_p^c(x_i) = (1-\alpha)\gamma(p_i) - \alpha G$, where

$$\gamma(p_i) = \begin{cases} \frac{q_p(q_i+\beta)}{4q_i^2(q_i-q_p)} p_i^2 & \text{if } 0 \leq p_i \leq \frac{2q_i(q_i-q_p)}{A} \\ \frac{q_p(q_i(q_i-q_p)-p_i(q_i+\beta))(p_i-q_i)(q_i+\beta)}{q_i^2(q_p+\beta)^2} & \text{if } \frac{2q_i(q_i-q_p)}{A} \leq p_i \leq \frac{Aq_i}{2(q_i+\beta)} \\ \frac{q_p}{4} & \text{if } \frac{Aq_i}{2(q_i+\beta)} \leq p_i \end{cases} \tag{5}$$

The pirate decides to enter the market when $\pi_p^c(p_i) > 0$, i.e. when $\gamma(p_i) > g = \alpha G/(1-\alpha)$, where g is increasing in α and G, and indicates the government's effort to prevent piracy. So, if the government decides to establish a greater penalty or increase the probability of detecting the pirate, the variable g increases. Notice that $\gamma(p_i) > g$ is equivalent to $p_i > p_i^{ne}$, where p_i^{ne} is the no-entry or limit price, which is[9]

$$p_i^{ne} = \begin{cases} \sqrt{4g\frac{q_i^2(q_i-q_p)}{q_p(q_i+\beta)}} & \text{if } 0 \leq g \leq \frac{q_p(q_i-q_p)(q_i+\beta)}{A^2} \\ \frac{q_i\left(Aq_p-(q_p+\beta)\sqrt{q_p(q_p-4g)}\right)}{2q_p(q_i+\beta)} & \text{if } \frac{q_p(q_i-q_p)(q_i+\beta)}{A^2} \leq g \leq \frac{q_p}{4} \\ +\infty & \text{if } \frac{q_p}{4} < g \end{cases} \tag{6}$$

Therefore, the pirate's optimal decision is to enter and price $p_p^{BR}(p_i)$ if $p_i > p_i^{ne}$; and not to enter if $p_i \leq p_i^{ne}$. According to the pirate's optimal decision, the incumbent expects the profit of a monopolist if $p_i \leq p_i^{ne}$, and the profit of a duopolist if $p_i > p_i^{ne}$. Thus, the incumbent's continuation profit is described in equation (7).

$$\pi_i^c(p_i) = \begin{cases} p_i\left(1-\frac{p_i}{q_i}\right) & \text{if } 0 \leq p_i \leq p_i^{ne} \\ p_i D_i\left(p_i, p_p^{BR}(p_i)\right) & \text{if } p_i^{ne} < p_i \end{cases} \tag{7}$$

[9] For convenience of analysis I assume that p_i^{ne} is $+\infty$ when $q_p/4 < g$. This means that the pirate is deterred from entering at any price when the government's effort is very high.

Locally maximizing the incumbent's profit in equation (7), I obtain that the incumbent becomes a monopolist which prices at a monopoly price of p_i^m when $p_i < p_i^{ne}$ and a duopoly price of p_i^d when $p_i > p_i^{ne}$, where

$$p_i^m = \frac{q_i}{2}; p_i^d = \frac{q_i\,(q_i - q_p)}{A}; p_p^d = \frac{q_p\,(q_i - q_p)}{2A}. \tag{8}$$

So that the incumbent's profit and the pirate's income, $p_p D_p$, are:

$$\pi_i = \begin{cases} \pi_i^m = \frac{q_i}{4} & \text{if } p_i < p_i^{ne} \\ \pi_i^{ne} = p_i^{ne}\left(1 - \frac{p_i^{ne}}{q_i}\right) & \text{if } p_i = p_i^{ne} \\ \pi_i^d = \frac{q_i(q_i - q_p)}{2A} & \text{if } p_i > p_i^{ne} \end{cases} \tag{9}$$

$$I_p = \begin{cases} 0 & \text{if } p_i \leq p_i^{ne} \\ I_p^d = \frac{q_p(q_i - q_p)(q_i + \beta)}{4A^2} & \text{if } p_i > p_i^{ne} \end{cases} \tag{10}$$

Taking into account that p_i^{ne} depends on g and comparing the local maximums of the incumbent's profit in equation (9), it is obtained that the incumbent becomes a monopolist which prices at a monopoly price of p_i^m when the entry of the pirate is blocked by high government effort ($g \geq g_m$). When the government effort to prevent piracy is very low ($g < g_{ne}$), the pirate decides to enter as a follower in prices, so the incumbent and he behave as duopolists. However, for intermediate levels of government effort ($g_{ne} \leq g < g_m$), the incumbent sets a low enough price (p_i^{ne}) to prevent the entry of the pirate. These results are summarized in the following proposition.

Proposition 1 *In any SPE, the optimal strategies of the incumbent and the pirate are as follows:*

(a) If $g < g_{ne}$, the incumbent will price at p_i^d and the pirate will enter and price at p_p^d, where

$$g_{ne} = \frac{q_p\,(q_i + \beta)\left(q_i + \beta - \sqrt{(q_p + \beta)\,A}\right)}{8\,(q_i - q_p)\,A}. \tag{11}$$

(b) If $g \geq g_{ne}$, the pirate will not enter and the incumbent will price at p_i^{ne} if $g_{ne} \leq g < g_m$, and at $p_i^m = \frac{q_i}{2}$ if $g_m \leq g$, where

$$g_m = \begin{cases} -\frac{q_p(q_i+\beta)(q_i - 2q_p - \beta)}{4(q_p+\beta)^2} & \text{if } \frac{3q_p+\beta}{2} \geq q_i \\ \frac{q_p(q_i+\beta)}{16(q_i - q_p)} & \text{if } \frac{3q_p+\beta}{2} \leq q_i. \end{cases} \tag{12}$$

As in Martínez-Sánchez (2010), I find that when $g \geq g_m$ the entry of the pirate is blocked by the high expenditure of the government on preventing it, so the incumbent becomes a monopolist which can set a monopoly price. I call this outcome *pure monopoly.* However, when $g_{ne} \leq g < g_m$ the entry of the pirate is discouraged because the incumbent shares the cost of deterring commercial piracy with the government. This outcome is called *restricted monopoly* because the incumbent sets a limit price to deter the entry of the pirate.

3.2 Government's optimal policy

The government chooses the optimal policy that maximizes social welfare, taking into account the optimal strategies of the incumbent and the pirate. Social welfare is the sum of the profits of the incumbent and the pirate, the consumer surplus, and the net expected revenue of the government:[10]

$$W = \begin{cases} CS^d + \pi_i^d + p_p^d D_p^d \left(p_i^d, p_p^d\right) - C\left(\alpha\right) & \text{if } 0 \leq g < g_{ne}, \\ CS^{ne} + \pi_i^{ne} - C\left(\alpha\right) & \text{if } g_{ne} \leq g < g_m, \\ CS^m + \pi_i^m - C\left(\alpha\right) & \text{if } g_m \leq g \end{cases} \tag{13}$$

where CS^k is the consumer surplus when the entry of the pirate is accommodated ($k = d$, the case of duopoly), deterred ($k = ne$) or blocked ($k = m$). The consumer surpluses of those consumers whose reference product is the original ($\widehat{CS}$) and those whose reference product is the illegal copy ($\widetilde{CS}$) are defined as follows:

$$\widehat{CS} = \int_{\widehat{\theta}_p}^{\widehat{\theta}} \left(\theta q_p - p_p\right) d\theta + \int_{\widehat{\theta}}^{1} \left(\theta q_i - p_i\right) d\theta$$

$$\widetilde{CS} = \int_{\widetilde{\theta}_p}^{\widetilde{\theta}} \left(\theta q_p - p_p\right) d\theta + \int_{\widetilde{\theta}}^{1} \left(\theta q_i - p_i - \lambda\left(\frac{p_i}{q_i} - \frac{p_p}{q_p}\right)\right) d\theta$$

Taking into account that ϕ is the proportion of consumers who take the original product as the reference product and $1 - \phi$ the proportion who take the illegal copy as the reference product, I define the total consumer surplus

[10] The pirate's profit has been included in welfare function because he is an agent who generates revenue and helps to prevent the incumbent from exercising market power, although it may not include the pirate on ethical and moral grounds.

as $CS = \phi\widehat{CS} + (1-\phi)\,\widetilde{CS}$. Let $B \equiv q_i\left(4q_i^2 - q_p^2 + q_i q_p\right)$. The value of the consumer surpluses in each outcome are:

$$
\begin{aligned}
\widehat{CS}^d &= \frac{q_i\left(4\beta\left(2q_i+\beta\right)+4q_i^2+q_p\left(q_i-q_p\right)\right)}{8A^2} \qquad (14)\\
\widetilde{CS}^d &= \frac{B+\lambda\left(q_i\left(1-2\phi\right)\left(4q_i+\lambda\left(1-2\phi\right)\right)+q_p\left(6q_i-2q_p+\lambda\left(3-4\phi\right)\right)\right)}{8A^2}\\
CS^d &= \frac{B+\beta\left(\lambda\left(q_i+q_p\left(3-4\phi\right)\right)+2\left(2q_i^2-q_p^2+3q_iq_p\right)\right)}{8A^2}\\
CS^{ne} &= \frac{\left(q_i-p_i^{ne}\right)^2}{2q_i}; CS^m = \frac{q_i}{8}
\end{aligned}
$$

Given that a higher monitoring rate (α) entails a higher cost but a higher penalty does not entail a higher cost, the government will choose the maximum penalty, which is $\overline{G}$. Moreover, welfare in each outcome is decreasing in α because (i) CS^k,π_i^k, $I_p^k, k \in \{d, m\}$ are independent of α; (ii) $CS^{ne} + \pi_i^{ne} = \left(q_i^2 - \left(p_i^{ne}\right)^2\right)/2q_i$ is decreasing in α because $CS^{ne} + \pi_i^{ne}$ is decreasing in p_i^{ne}, p_i^{ne} is increasing in g and $g = \alpha\overline{G}/\left(1-\alpha\right)$ is increasing in α; and (iii) the cost of monitoring piracy is increasing in α, $C'\left(\alpha\right) > 0$. So in order to maximize welfare in each outcome the government will choose the maximum penalty , $\overline{G}$, and the minimum monitoring rates that lead to different outcomes, which are $\alpha_d = 0, \alpha_{ne} = g_{ne}/\left(g_{ne} + \overline{G}\right)$ and $\alpha_m = g_m/\left(g_m + \overline{G}\right)$, where $\alpha_d < \alpha_{ne} < \alpha_m$. Moreover, given that welfare is decreasing in g because g is increasing in α, the values of g that lead to different outcomes are $g_d = 0$, g_{ne} and g_m, where $g_d < g_{ne} < g_m$. The maximum welfare in each outcome is as follows:

$$
W^d = CS^d + \pi_i^d + I_p^d, W_{ne}^{ne} = CS_{ne}^{ne} + \pi_{i,ne}^{ne} - C\left(\alpha_{ne}\right), W^m = CS^m + \pi_i^m - C\left(\alpha_m\right). \qquad (15)
$$

where $\pi_{i,ne}^{ne}$ and CS_{ne}^{ne} are the incumbent's profit and the consumer surplus assessed at $g = g_{ne}$, respectively. Let $\widehat{W}^k = CS^k + \pi_i^k + I_p^k$ be the gross social welfare in outcome $k \in \{d, ne, m\}$. The value of the gross welfare in each outcome is:

$$
\begin{aligned}
\widehat{W}^d &= \frac{q_i\left(3q_i(4q_i-3q_p)+q_p^2\right)+\beta(4(2q_i-q_p)(q_i+q_p)+\lambda(q_i+3q_p-4\phi q_p))}{8A^2}; \quad \widehat{W}^m = \frac{3q_i}{8}; \qquad (16)\\
\widehat{W}_{ne}^{ne} &= \frac{q_i\left(3q_i-2q_p+\beta+\sqrt{(q_p+\beta)A}\right)}{4A}.
\end{aligned}
$$

Figure 1 shows graphically that discouraging the entry of the pirate because the incumbent sets a low enough price (restricted monopoly) provides the greatest gross welfare. Moreover, given that $C'(\alpha) > 0$ and $\alpha_{ne} < \alpha_m$, it emerges that $C(\alpha_{ne}) < C(\alpha_m)$. Thus, I deduce that discouraging the pirate from entering (restricted monopoly) is socially better than the government blocking it (pure monopoly).[11] Therefore, the outcome that maximizes social welfare is the restricted monopoly or that in which the entry of the pirate is accommodated (duopoly), depending on the cost of monitoring the pirate in the restricted monopoly. In particular, if that cost is high enough social welfare is maximized by letting the pirate enter as a follower. Otherwise, it is maximized by encouraging the incumbent to set a limit price that deters the pirate from entering. Recall that, in the restricted monopoly, the pirate is discouraged by the joint effort of the government and the incumbent. This result is described in Proposition 2.

Proposition 2 *In any SPE in which $q_i = 1$, the optimal strategy of the government is:*

(a) $g = 0$, *if* $C(\alpha_{ne}) > \widehat{W}_{ne}^{ne} - \widehat{W}^{d}$.

(b) $g = g_{ne}$, *if* $C(\alpha_{ne}) < \widehat{W}_{ne}^{ne} - \widehat{W}^{d}$.

A novel and unexpected result deduced from Figure 1 is that a pure monopoly can provide more welfare than a duopoly. That is, contrary to conventional wisdom, a setting of lower competition can generate higher welfare. According to the model presented here, this happens when the quality of the copy is not high enough and the degree of loss aversion of consumers is high enough. In particular, for not high enough levels of quality of the copy, a pure monopoly provides higher welfare if the proportion of consumers who take the illegal copy as the reference product $(1 - \phi)$ and the loss aversion of consumers (λ) are high enough. And for low levels of quality of the copy, a pure monopoly provides higher welfare for almost all values of ϕ and λ, except for very low values of λ and very high values of ϕ. However, the findings of the previous literature hold for high enough levels of quality of the copy.

[11] In order not to distort the incumbent's incentives to develop new products, I assume that the incumbent's revenue is high enough to support the cost of developing the original product.

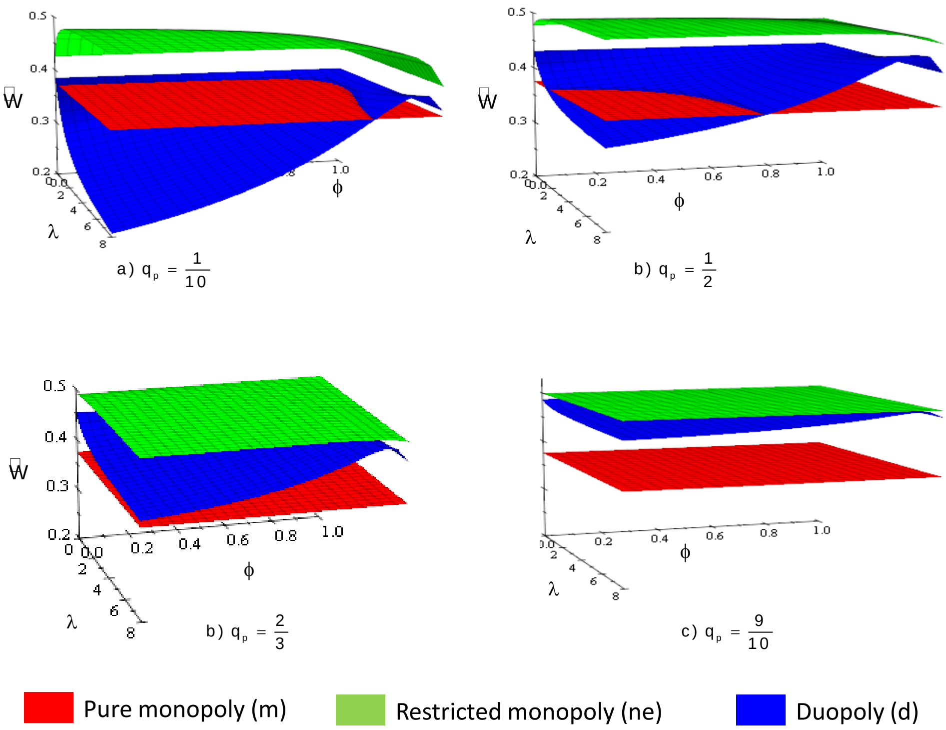


Figure 1: Comparison of gross welfare ($q_i = 1$).

4 Comparative Statics

4.1 The effect of loss aversion

The illegal copy is cheaper, so those consumers whose reference product is the illegal copy but who buy the original product suffer psychological damage by buying the expensive product. Thus, loss aversion in the hedonic price dimension negatively affects these consumers. In response to a larger λ, the incumbent lowers the price of the original product and the pirate reacts by decreasing the price of the illegal copy but to a lesser extent. The result is that the incumbent maintains demand for its product and demand for the illegal copy increases. Therefore, greater loss aversion in hedonic price means less profit for both the incumbent and the pirate. These results are summarized in Proposition 3.

Proposition 3 *At the equilibrium when the pirate is accommodated, greater loss aversion on the part of consumers (a higher λ) means lower prices for both products, lower profits for both the incumbent and the pirate, and more demand for the illegal copy. The demand for the original product is constant.*

Proof See Appendix.

Proposition 3 shows that loss aversion in the hedonic price is procompetitive because it increases the incentives of firms to reduce their prices. This result is in line with those obtained by Zhou (2011) and Amaldoss and He (2017), though they consider prices and not hedonic prices.[12]

When the proportion of consumers whose reference product is the original increases, there are proportionally fewer consumers who experience a psychological disutility when buying the original product, which is more expensive. In this case, the incumbent reacts by increasing prices and the pirate does likewise but to a lesser extent. As a result, the incumbent maintains demand for its product and demand for that of the pirate decreases. Therefore, a greater proportion of consumers whose reference product is the original means more profit for both the incumbent and the pirate. These results are summarized in Proposition 4.

[12] Zhou (2011) and Amaldoss and He (2017) develop a model of horizontal product differentiation and also consider loss aversion in products. They find that loss aversion in products is anticompetitive.

Proposition 4 *At the equilibrium when the pirate is accommodated, a greater proportion of consumers who take the original product as their reference product (a higher ϕ) means higher prices for both products, higher profits for both the incumbent and the pirate, and lower demand for the illegal copy. The demand for the original product is constant.*

Proof See Appendix.

From propositions 3 and 4, I deduce that greater loss aversion in the market (higher λ or lower ϕ) means lower income for the pirate.[13] Therefore, it should be easier for the government and the incumbent to deter the pirate when the loss aversion in the market increases. Next, I check whether the model confirms this hypothesis. To that end, I analyze the effect of greater loss aversion in the market (β) on the strategies of the government and the incumbent for preventing commercial piracy. In particular, I analyze the effect on g_{ne} and on $p_{i,ne}^{ne}$, where $p_{i,ne}^{ne}$ is the no-entry or limit price set at g_{ne}. To obtain $p_{i,ne}^{ne}$, I plug g_{ne}, equation (11), into the no-entry price function, equation (6), which results in the following equation:[14]

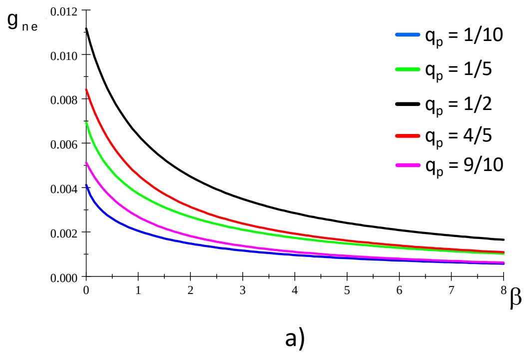
$$p_{i,ne}^{ne} = \sqrt{\frac{q_i^2\left(q_i + \beta - \sqrt{(q_p + \beta)(2q_i - q_p + \beta)}\right)}{2(2q_i - q_p + \beta)}}$$

From Figure 2, I find that regardless of the quality of the illegal copy, greater aversion to losses in the market means less effort on the part of the government, along with the owner, to dissuade the pirate from entering, i.e. to achieve a restrictive monopoly. Thus, a greater β (greater λ or smaller ϕ) means a smaller g_{ne}.

As mentioned above, the pirate's income negatively depends on the loss aversion in the market. Thus, the incumbent's effort to avoid piracy could be less when loss aversion in the market increases, which means that it can set a higher no-entry or limit price. However, loss aversion in the market also affects the limit price $p_{i,ne}^{ne}$ through the government's effort. Equation (6) shows that there is a positive relationship between government effort and the limit price. This means that if the government's effort to prevent piracy

[13] Remember that the degree of loss aversion in the market is represented by $\beta \equiv \lambda(1-\phi)$.

[14] To obtain this expression the following is necessary: $g_{ne} < \frac{q_p(q_i-q_p)(q_i+\beta)}{(2q_i-q_p+\beta)^2}$. The proof of this is provided in Lemma 1 in the Appendix.



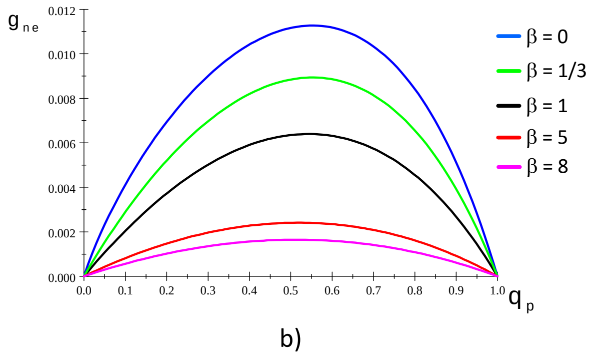


Figure 2: The monitoring effort for deterring piracy, g_{ne} $(q_i = 1)$.

increases, the incumbent will try less and will set a higher limit price. Given that greater loss aversion in the market means less effort by the government, the incumbent should do more to prevent commercial piracy. There are thus two contradictory effects of loss aversion in the market on the limit price. To see which effect prevails, consider Figure 3, which shows that greater loss aversion means a lower limit price, so the incumbent should do more to prevent piracy. This result is explained by the indirect effect of loss aversion in the market on the limit price through the government's effort to prevent commercial piracy.

According to these results, conventional models that do not take into account loss aversion in the market overestimate the government's effort to deter piracy but underestimate that of the incumbent. That is, when consumers experience a psychological disutility when buying an expensive non-reference product, the government must reduce the monitoring rate and the incumbent must set a lower limit price to prevent commercial piracy. Proposition 5 summarizes these results:

Proposition 5 *In a restricted monopoly, when* $q_i = 1$, g_{ne} *and* $p^{ne}_{i,ne}$ *decrease in* β.

4.2 The effect of illegal copy quality

Figure 2 shows that there is an inverted U-shaped relationship between government efforts to deter piracy and the quality of illegal copies. This means

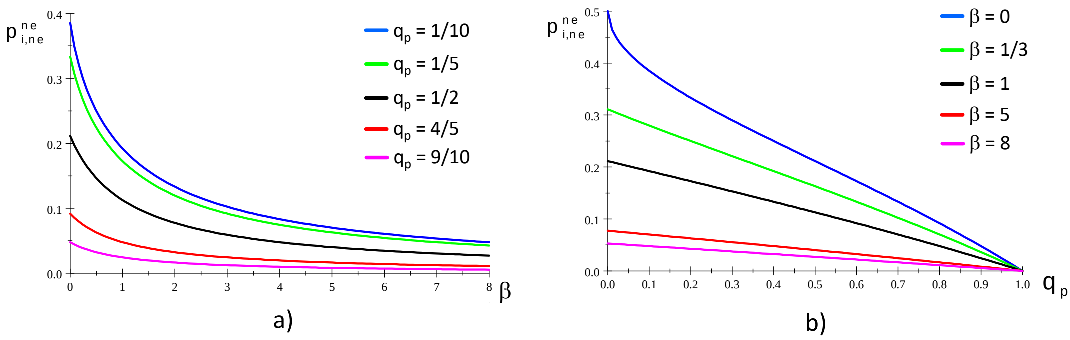


Figure 3: The price of the original product in a restricted monopoly, $p^{ne}_{i,ne}$ ($q_i = 1$).

that government efforts to deter piracy are greater for intermediate levels of quality and lower for extreme levels, so deterring piracy is easier for extreme levels of illegal copy quality. This result is summarized in Proposition 6.

Proposition 6 *There is a value q_p^* such that g_{ne} increases in q_p if $q_p \leq q_p^*$ and decreases otherwise.*

This is because there is an inverted U-shaped relationship between the pirate's income and the quality of the illegal copy, given that $\frac{\partial I_p^d}{\partial q_p}$ is positive for low levels of q_p (or higher product differentiation between the original product and the copy), but negative for high levels (or lower product differentiation). In particular, the following emerges:

$$\frac{\partial I_p}{\partial q_p} = \frac{(q_i + \beta)(q_i(2q_i + \beta) - q_p(3q_i + 2\beta))}{4A^3} \lesseqgtr 0 \Leftrightarrow q_p \gtreqless \frac{q_i(2q_i + \beta)}{3q_i + 2\beta}$$

The intuition is as follows. When the quality of the illegal copy is low, demand for the pirated product is low, so the pirate's income is low; but when the quality of the copy is high the original and the copy are similar, so the price competition between the incumbent and the pirate is tougher and the pirate's income falls. Therefore, deterring commercial piracy is easier at extreme levels of quality of the illegal copy.

Figure 3 shows that $p^{ne}_{i,ne}$ is decreasing in q_p. This is because the competition between the incumbent and the pirate becomes tougher as the quality of the illegal copy increases. The incumbent therefore decreases the limit price to deter the pirate from entering the market. Proposition 7 summarizes this result.

Proposition 7 *In a restricted monopoly, when* $q_i = 1$*,* $p_{i,ne}^{ne}$ *decrease in* q_p*.*

5 Conclusions

In this paper, I analyze how the loss aversion of consumers affects the strategies of the government and the incumbent for preventing commercial piracy. To that end, I develop a sequential duopoly model of vertical product differentiation with price competition in which consumers are loss averse, i.e. they have a reference-dependent utility. In particular, I consider that they have a reference-dependent utility for the hedonic price of a product.

I find that regardless of the quality of the illegal copy, greater loss aversion means less effort from the government to achieve the outcome in which the incumbent sets a low enough price to deter the pirate from entering, but greater effort from the incumbent to achieve it. Therefore, according these results, conventional models that do not take into account the loss aversion of consumers overestimate the government's effort to deter piracy but underestimate that of the incumbent. This means that the incumbent should set a lower price of the original product and the government should allocate less resources to pursue commercial pirates. For example, the government can reduce the size of units looking for commercial pirates, less frequently improve the work teams of previous units...

Contrary to previous literature, I find that the government blocking the entry of the pirate can provide more welfare than accommodating it. This result is novel and unexpected because it means that a pure monopoly can provide more welfare than a duopoly. That is, contrary to conventional wisdom, a setting with lower competition can generate higher welfare. This happens when the quality of copy is not high enough and the loss aversion is high enough. Otherwise, the findings in the previous literature hold. However, the government will not block the entry of the pirate because socially it is better to encourage the incumbent to establish a price low enough to deter it from entering, as in Martínez-Sánchez (2010). Thus, I find that, depending on the cost of monitoring piracy, the government will allow the sale of illegal copies or will encourage the incumbent to set a low enough price to deter the pirate from entering. In particular, it encourages the incumbent to deter the entry of the pirate when the monitoring cost is low enough; otherwise, it lets the pirate enter as a follower. These results hold provided that the incumbent's revenue is high enough to support the cost of developing an original product. Otherwise, the government will let the incumbent become a monopolist so as not to upset its incentives to develop a new product.

Hitherto the literature on piracy has found that the entry of a pirate into the market has a positive effect on consumers, as it reduces the incumbent's market power, and a negative effect on the incumbent, as it reduces its profit. This positive effect explains why the government tolerates piracy. In this paper I identify a negative effect on consumers, since the availability of a copy enables consumers to make comparisons, which reduces their utility because they are loss averse. This negative effect explains why, contrary to conventional wisdom, a setting with less competition can generate higher welfare. This result depends on there being consumers whose reference product (the illegal copy) is sufficiently different from the product that they buy (the original). Thus, a natural extension of this model is to analyze whether consumers can have a product of reference that is considerably different from the product that they are going to buy. To determine this it will be necessary to analyze the mechanisms that make a product a reference.

An important feature in some industries of digital goods is the existence of network effects. Although many papers have incorporated it for analyzing piracy (Slive and Bernhart (1998), Banerjee (2003), Chang et al. (2008) and Rasch and Wenzel (2013)), I refrain from including the network effects to focus on loss aversion. This implies that the welfare of accommodating and deterring piracy is underestimated in this paper because the network effects increase the welfare of those outcomes in which the number of consumers are greater. Since welfare is maximized by accommodating or deterring piracy, the main results of this paper are maintained if the network effects are incorporated. However, it is possible that the result that a pure monopoly can provide more welfare than a duopoly depends on the strength of the networks effects, but I leave this question for future research.

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Appendix

Proof of Proposition 3.

$$D_i^d = \frac{1}{2}; D_p^d = \frac{q_i + \beta}{2A}$$

$\frac{\partial p_i^d}{\partial \lambda} = -\frac{(1-\phi)q_i(q_i-q_p)}{A^2} < 0$; $\frac{\partial p_p^d}{\partial \lambda} = -\frac{(1-\phi)q_p(q_i-q_p)}{2A^2} < 0$;
$\frac{\partial D_p^d}{\partial \lambda} = \frac{(q_i-q_p)(1-\phi)}{2A^2} > 0$; $\frac{\partial \pi_i^d}{\partial \lambda} = -\frac{(1-\phi)q_i(q_i-q_p)}{2A^2} < 0$;
$\frac{\partial I_p^d}{\partial \lambda} = -\frac{q_p(q_i-q_p)(1-\phi)(q_p+\beta)}{4A^3} < 0$. ■

Proof of Proposition 4.
$\frac{\partial p_i^d}{\partial \phi} = \frac{\lambda q_i(q_i-q_p)}{A^2} > 0$; $\frac{\partial p_p^d}{\partial \phi} = \frac{\lambda q_p(q_i-q_p)}{2A^2} > 0$;
$\frac{\partial D_p^d}{\partial \phi} = -\frac{\lambda(q_i-q_p)}{2A^2} < 0$; $\frac{\partial \pi_i^d}{\partial \phi} = \frac{\lambda q_i(q_i-q_p)}{2A^2} > 0$;
$\frac{\partial I_p^d}{\partial \phi} = \frac{\lambda q_p(q_i-q_p)(q_p+\beta)}{4A^3} > 0$. ■

Lemma 1 *When $q_i = 1$, $g_{ne} < \frac{q_p(q_i-q_p)(q_i+\beta)}{(2q_i-q_p+\beta)^2}$.*
Proof of Lemma 1. *Assume that $q_i = 1$. g_{ne} is represented in red and $\frac{q_p(q_i-q_p)(q_i+\beta)}{(2q_i-q_p+\beta)^2}$ is represented in blue. As can be seen, the blue area is above the red one. Thus, $g_{ne} < \frac{q_p(q_i-q_p)(q_i+\beta)}{(2q_i-q_p+\beta)^2}$.*
■

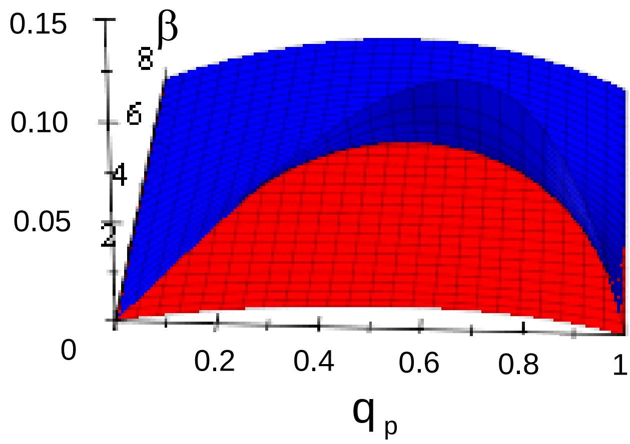

Figure 4: Lemma 1.