DIGITAL PRODUCT PIRACY and COMPETITION

by

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to my family

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DIGITAL PRODUCT PIRACY and COMPETITION

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Abstract

This thesis studies the optimal copyright protection level for a single firm. We consider two market settings: monopoly and duopoly under Cournot competition. We also analyze the optimal level in Cournot setting in two subsections: with and without a cost of implementing protection. The optimal level for the monopolist without any potential competitors is full protection. Under competition, for sufficiently high fixed cost values, the monopolist firm chooses a level which is below the monopoly setting. We also show that with implementation costs, competition is stronger.

Keywords: copyright protection, digital product, piracy, Cournot competition

DİJİTAL ÜRÜNLERİN KORSAN KULLANIMI ve REKABET

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Özet

Bu tezde tek bir firma için optimal "telif hakkı koruma" seviyesi çalışılmıştır. İki farklı piyasa modeli ele alınmıştır: Tekelci piyasa ve 2 firmalı (düopol) Cournot rekabet modeli. Cournot rekabet modeli de kendi içinde 2 ayrı başlıkta incelenmiştir: Koruma uygulamasının maliyetli ve maliyetsiz oluşu. Potansiyel bir rakibin olmadığı tekel için optimal seviye tam koruma iken rekabet ortamında ve yeterince yüksek sabit maliyet değerleri için tekelci piyasa seviyesinin altında bir koruma uygulanacaktır. Ayrıca uygulamanın maliyetli olduğu durumda rekabetin daha güçlü olduğu gösterilmiştir.

Anahtar Kelimeler: telif hakkı koruma, dijital ürün, korsan kullanımı, Cournot rekabet

Contents

1 Introduction

Digital products possess the distinctive characteristic that they can be copied without losing much quality. This property makes copy and original close substitutes so that copying activities have more effect on the demand for the original product compared to the availability of earlier reproduction methods. Especially with the significant progress in copying technologies, of which the most important and widespread one is the internet, digital product piracy has become the new phenomenon for consumers, policy makers and of course for producers.

Lately, most of the digital product industries are facing a challenge to transform their distribution mechanisms because of pervasive use of file sharing systems and nearly unpreventable illegal downloadings. Hence producers usually claim that they are suffering under the presence of piracy which reduces their profits significantly. The recording industry[1] supports this claim as well. There are also empirical papers, like *Mckenzie (2009),* which claim on the contrary, that the effect of piracy is insignificant on the sales of the digital retailers. Keeping in mind the estimates of the results, copyright protection has become a more controversial issue nowadays. Copyright or also known as intellectual property rights are the tools to give incentives to the producer to continue to create new products by preventing others to copy without permission of the holder of the intellectual property rights. Hence piracy has both short run and long run effects on digital product usage. We should emphasize that this effect, whether it is beneficial for the firm and society, depends on the structure of the market, such as the characteristic that the products possess or the number of firms and their relative sizes in the market etc.

Moreover, there is also the argument that the holders may prefer some level of piracy due to the nature of the good. Consider a software program with network effects whose value for individuals increases with the number people using it Then, the developer may enjoy some illegal reproduction of the product which will increase the total amount of people using this particular good. This is also true for information good producers who can promote their products through copies like in the paper by *Peitz and Waelbroeck (2004).* Since a remarkable amount of digital products are information goods e.g. music files, copies can be used to spread information about original products among consumers which will lead them

[1] IFPI's (the organization that keeps the statistics for record sales) records show that especially for the years 1999-2005 there is a dramatic fall in record sales

to identify its true value for themselves or just they can be used as means of advertising. However, in the analysis of this paper we are going to focus on a homogenous product setting at which products have neither an externality nor an experimentation property.

The motivation for our paper is different. We analyze the effect of copyright protection on the decision process of the firms in different settings. It has been widely recognized that, especially in the music industry, the availability of file sharing networks and digital downloads made entry of small and financially unsupported artists easier. It is also obvious that a firm that produces a product that can be illegally reproduced would ask for the protection of its intellectual property. On the other hand, strong copyright protection will encourage other potential developers or investors by raising the demand for an original product. If new entrants can produce a reasonably close substitute to the product of the incumbent, then one can argue that copyright protection actually lowers entry barriers. Thus, in this paper our aim is to show that: i) copyright protection, if can be obtained freely, will be fully pursued by an uncontested monopolist and ii) in the case of a threat of entry, the monopolistic may no longer pursue full protection. To our knowledge, this last issue has not yet been analyzed.

We have the classical assumptions within this literature that we are going to mention deeply in following sections; copy is a degraded version of the original, copy users incur a reproduction cost etc. In section 3.1, we develop a model for a single producer who will determine the protection level in the first stage, given that it has decided to develop the product, and the price in the following stage to maximize its profits. We focus on the optimal behavior of the monopolist in the existence of piracy rather than focusing on the socially optimal protection level as in *Yoon(2002).*This point is the distinguishing characteristic of our paper such that we allow the producer to determine the protection level which also determines the demand that he is going to face. Initially we assume that implementing copyright protection is costless. We show that under this setting the monopolist will choose a price-protection level pair at which he drives copy users out of the market. It is clear that since enforcement is costless and profits are increasing with more protection, monopolist will set the *full protection* level.

Another objective of this paper, as we mentioned above, is to demonstrate the strategic interactions between firms in the presence of piracy. For this purpose, in section 3.2 we establish the optimal outcomes for a two-firm setting. Specifically, we characterize the Cournot Nash equilibria in a duopoly. We assume that the two firms produce exactly the same product and the level of enforcement can be determined only by the incumbent firm. This is not due to any domination of firm 1 in the industry but is rather based on the structure of the timing of the decision process. Moreover in the digital product industries marginal costs are insignificant, in this thesis they are assumed to be equal to zero, and prices are very close even when products are horizontally quite differentiated. Hence based on our assumption about the decision process and the nature of the product we use a *Cournot* competition model rather than *Bertrand* or *Stackelberg* competition. The entrant chooses only its quantity in the second stage given that he decided to enter in the first stage after he observes the protection level set by incumbent firm.

Depending on the profit levels in section 3.2, we pursue an answer to the following question: " Which protection level would the incumbent firm choose in order to maximize its profits". Obviously, the answer to this question also depends on the distribution of fixed costs which is a key determinant of the entry decision. So in the following section we assume a particular level of degradation rate α to be able to answer this question and compare the protection levels we determined in section 3.2. We found that with the threat of a potential entrant, the incumbent firm will set a protection level that is, for sufficiently high fixed cost values, below the level of monopoly case. Full protection is not optimal anymore. The intuition behind this result is obvious. With more protection, demand for the original product increases which leads to an increase in the revenues of both firms. Thus the entrant is more likely to enter the market such that it can cover its fixed costs. On the other hand, the monopolist can prevent entry and make a higher profit than under the Cournot setting. We showed that for sufficiently high fixed costs, the best response of the incumbent firm is to deter entry. As we emphasized before, copying technology in these kind of industries are highly advanced which reproduces the product with a negligible loss in quality. Therefore we replicated the analysis with a smaller degradation rate. It turns out that it becomes slightly harder for incumbent firm to prevent entry with this new value. This is not surprising however. We will see that the profit functions are decreasing with respect to α. To attain the same demand with the previous analysis, firms should decrease the price level to attract the consumers on the same valuation level.

In section 3.3.2 we relax the assumption that enforcement of protection is costless. Firms incur a cost to implement copyright protection in reality. We introduce a cost function and analyze how the best response of the incumbent firm changes when he carries the burden of protection. We find that, differently from the previous section, for all fixed value levels the optimal behavior of incumbent is to deter entry. This result is quite intuitive as well. Since choosing a higher protection level is costly, the incumbent monopolist will ask for less protection, sacrificing some of its sales but at the same time making entry less likely. Piracy turns out to be the means to fight with competitors .At the last section, we state the concluding remarks and discuss some possible extensions of our model.

Before continuing with the results that we found, we should note that unlike in the existing literature, we do not discuss the welfare implications of piracy in this thesis. We mostly focus on the producer side of this issue and analyzed the optimal level of protection from the perspective of the individual producer.

2 Literature Review

There is a broad range of papers which study the intellectual property rights and mostly related to digital products in recent years since the effect of piracy has become more apparent with the availability of sophisticated copying technologies. In this section we are going to introduce a selection of papers that we think will provide some intuition about our model either by comparing the differences or emphasizes the common features.

The paper by *Peitz and Waelbroeck (2003)* provides a useful review of digital product piracy literature. In this survey they investigate different models related to the question of how piracy effect the individual profits and social welfare based on different product characteristics. In most of the papers they survey, copy and original are vertically differentiated. For the first set of the papers, products don't have any network externalities and consumers are perfectly informed about the good. However the models differ from each other based on the assumptions about the size of industry, design of reproduction cost etc. So we can compare the results derived in these papers about the effect of piracy on society as a whole and individual producer under different market settings. Then they search for the papers which discuss the indirect appropriability and under what conditions firms can indirectly appropriates gains from copying. In the following group of papers, the products have network externalities and the third group of articles deal with the problem of piracy when consumers are not completely informed which is the case of experience goods setting. This diversification is very helpful to understand the effect of piracy for different type of products adding that the effect for the same type of product but with different assumptions. Finally they compare the existing digital products based on the characteristic that they have and investigates the effect of piracy on the market with these products.

Yoon (2002) is the main paper that we built our model on. He studies the effect of copyright protection on social welfare loss and investigates the socially optimal level. Individual producer is also taken into consideration but the main focus is on society as a whole. He considers a two stage game with a single producer. First producer decides, under a given copyright protection level, whether to develop the product or not when he faces a development cost of D. This is the stage what he calls "production stage". Then "consumption stage" follows at which, given reproduction cost and prices, consumers make their decisions about how to consume the product and producer determines price level concurrently. Each consumer has three options: they can buy the original product from producer, reproduce it without authorization or doesn't consume it at all. He considers a continuum of consumer types whose valuations are uniformly distributed on $[0, 1]$. Every type of consumers value original more than copy which means copy and original are not perfect substitutes. Reproduction cost is a function of protection level so that decision of copy use depends directly on that level along with individual valuations and price level. So far our model coincides with Yoon's paper except we allow producer to determine the protection level additionally in the first stage. This new assumption implies in a sense, producer determines the demand function he is going to face in the second stage. We also added competition to see how the incumbent firm, here is monopolist, can use copyright protection to maximize his profits. Additionally we considered a setting where the firm bears the cost of enforcing copyright protection. Yoon studies two different effects of copyright protection on the welfare loss whereas we didn't deal with efficiency problem in our paper. He shows that with an insufficient level of protection, profits will decrease due to unauthorized reproductions which may lead firms not to develop new products, this is underproduction effect. On the other hand consumer surplus will be higher in a situation where copy use is available. With the existence of copying opportunity, some of the consumers will decide to copy instead of not to consume the product and this will increase consumer surplus. Higher copyright protection will obstruct some of this welfare gain and this is the loss caused by underutilization. He states that social welfare loss is always decreasing due to underproduction while it can be either increasing or decreasing due to underutilization. Since profit function of the firm is non decreasing with protection level in this setting, the result for underproduction effect is inevitable. Depending on fixed costs, with sufficiently high piracy rate, producer may decide not to develop the product. On the other hand the effect of underutilization depends on the parameters such as degradation rate and marginal cost of producing the product. The paper concludes with the analysis of many firms setting. Distinctively from our paper,he doesn't include any competition. Firms differ from their development costs and paper studies the socially optimal level in this setting context. He shows that optimal protection level for society depends on the distribution of development costs.

Zhang (2002)'s paper is related to our study with competition feature. He constructs his model on the observation that digital products particularly music has some form of experimentation such that consumption of copies provide information about real characteristic of the product. He claims that existing distribution mechanism favors "big labels" and it is inefficient for society in the short run. He considers two producers with horizontally differentiated products located on the Hotelling line, prices are same for both firms and exogenously given,only a fixed number of audience can reach P2P and a proportion of these copy users will buy original from one of the firms eventually. The difference between big firm and marginal distributor emerges in the assumption of distribution of information. Big label can distort consumers perception herewith demand by advertising while marginal artist can not. Marginal distributors can use peer to peer(P2P) networks to spread information about their products which makes it easier to enter the market. He shows that introducing P2P technologies increases total welfare of society due to increase in consumers' and marginal firm's surplus meanwhile stars are losing with this network. He also refers to long run effects of file sharing by which producer may have no longer incentives to create new works due to insufficient benefits. But still he supports the claim that to prevent P2P is not an optimal solution rather he proposes a new distribution mechanism that he calls "a win win market for all". Zhang's paper is interesting for us because he also tries to model competition in the existence of copy use. Moreover we tried to extend Zhang's work by transforming advertising level to the amount of copy use which was going to be determined endogenously in the model. But we couldn't manage to deal with the timing problem of decision of copy use and its advertising effect.

Bae and Choi (2003) also considers a monopolistic firm setting which they analyze in two different time span. The short run setup is almost same with Yoon's model except the assumptions of uniform distribution, instead they use any continuous distribution function, and marginal cost of production is considered to be zero. They showed that with the existence of copy users price will be lower than monopoly level which actually leads an increase in demand for the product. This is important because the presence of unauthorized reproductions is generally assumed to cause a decrease in demand for originals. They separate reproduction costs into two different types: one of them is fixed and the other depends on the valuation of individuals. Similarly, we also consider a fixed cost of copying which is the same for everyone and the cost varies among individuals based on their valuations. They show that in the short run, an increase in the protection level can either decrease or increase social welfare when there are copy users who depend on the reproduction cost which affected by this change. But it will certainly lead to a decrease in total surplus in the lack of unauthorized reproductions. The paper concludes by calculating the long run effects of copy use which is captured by the idea that firms additionally decide on the quality of the product. Here they find that in the presence of copy users and under a price regime which derives copy users out of market, the level of quality supplied will be less than that under the monopolist setting without piracy. An increase in protection leads to higher quality and lesser copy use. On the other hand, at a price level at which there will be copy users, the effect will be either an increase in quality along with a fall in consumption of the original product, or a decrease in quality but an increase in legal use.

Another paper that studies piracy in the context of information goods is *Peitz and Waelbroeck (2004).* This paper investigates the effect of piracy distinctively in a multiproduct monopoly setting. It is not closely related to our work but still worth mentioning due to its multiproduct setting. They consider a monopoly which produces N horizontally differentiated products in the unit Salop circle. Uniformly distributed consumers can download the product or buy the original as usual. A copy allows the consumers to know their most favorite product which will lead to an outward shift in demand. They call this the matching effect. On the other hand, a copy can be used instead of an original, so copy and original are competitors in this sense and this effect is called the competition effect in their paper. Basically copy use can either decrease or increase the firm's profit depending on which effect is dominant. They claim that piracy may actually lead to an increase in profits contrary to the general acceptance that piracy is harmful for firms. Another remarkable part of this paper is that the authors study whether piracy can be profitable through decreasing the cost of promoting the product. Here again, copy plays an informational role so firms can spend less to inform consumers about their products. In this paper there is no competition between firms but the idea of using the existence of piracy to increase the profits is somewhat similar to our model. We investigate how illegal consumption can be used to deter a potential entrant and make higher profits than a setting where two firms compete.

Belleflamme and Picard (2005) study the strategic interaction among firms under the threat of piracy, too. However, they consider a Bertrand competition model contrary to our Cournot setting. Moreover, again, our model differs with the feature that one of the firms, here the incumbent, determines the protection level and hence the demand as well. In their paper, they compare the price level and total welfare in the Bertrand duopoly with a multiproduct monopoly setting. They consider two perfectly differentiated information goods and three types of consumers:buyers, copiers and switchers. They show that demand for the buyer and copiers are independent while for switchers it is interdependent in a way that the two goods become complementary because of the increasing return to scale copying technology. One of the result is that in the monopolistic case it is more profitable for firm to set close prices and target the switchers rather than setting a high and low price and targeting copiers and buyers separately. On the other hand the pricing strategy in Bertrand depends on the reproduction cost. For sufficiently high level of costs, both firms focus on switchers and there exists a unique symmetric pure Nash equilibrium. They support the claim that due to Cournot effect[2] the average price set by monopolist is lower than the level duopolist firms set for this case. However for sufficiently low costs there is no pure strategy equilibrium. Firms will randomize price level and mixed strategy equilibria may exist. They show that the expected price level is still larger than the price that the multiproduct firm sets. This paper is parallel with our study in the aspect of studying competition under the existence of piracy by showing that how the presence of piracy can change the usual independent demands for goods to interdependency between these products. They conclude their paper with a welfare analysis and state the comparison between two different market structures. In the short run, the monopolistic firm is more efficient while in a dynamic view the duopoly setting provides more incentive to create new works, so it enhances the social surplus.

[2]Since two goods are complemantary, the monopolist can decrease the price of one of the goods and increase the demand for the other.

3 Model

First we introduce a setting with a single product monopolistic firm producing a copyrightable digital product like a software program or a music file. We will assume that the good is neither an *experience good* nor a product with *network externality* so that we can eliminate the effect of other users on the maximum willingness to pay of a single consumer and the role of the copy as a tester to recognize the correct characteristic of the product. For the first part, we import the model built by *Yoon(2002)* but we focus on the optimal copyright protection level on behalf of the monopolistic firm rather than the socially optimal level. In other words, we let protection level be a choice variable for monopolistic firm that he has to decide the profit maximizing level of price and copyright protection level

On the consumer part of the model ,we assume that there is a continuum of consumers uniformly distributed over the interval $[0, 1]$. To simplify the analysis we also assume that the maximum willingness to pay or valuation v of consumers are also distributed over the same interval, so we can identify the set of consumers with their valuations. They have unit demand, that is they either consume one unit or none. The action set of consumers consists of three alternatives.

- Consume the original product by purchasing it from producer.
- Consume a copy by borrowing or downloading it.
- Don't consume at all.

We assume that the value of a copy is an $(1-\alpha) \in (0, 1)$ proportion of original. Thus, a consumer with valuation v assigns a value $v - \alpha v$ to the copy.α is rate of the degradation in valuation due to copy use. This feature of the model is based on the nature of most of the copyrighted materials. Although copy of these products does not deteriorate in quality much, still original CD's come with booklets that contain song lyrics, DVD's have extra features and different language options, plus the audio and video quality is usually noticeably higher. We will consider that consumers incur a reproduction cost of r which increases with protection level y that is $\dfrac{\partial r}{\partial y} > 0$. We can interpret this as the protection level increases,the probability of being detected increases, or the punishment of unauthorized file downloading increases due to lobbying and legal activities of firms in the market. Moreover in some papers this cost is considered as search cost to refer to the fact that we need to spend some time to find the material that we want. We assume for a concrete analysis that the relationship between r and y is perfectly linear that is $y = r$ so for the rest of the paper we denote protection level and reproduction cost with r. Notice that this is same across the individuals but on the other hand the total cost of reproduction depends on individual valuations too captured by the decrease with an amount α. So the gross cost of copying varies among consumers. We also assume for this and following subsections that it is costless to firm to apply more protection then in Section 3.5 we are going to relax this assumption.

On the production part of the model we assume that the monopolistic firm incurs a fixed cost of F and marginal cost of zero to develop the product[3]. So total cost of producing product is F, and 0 if the firm decides not to produce. The monopolist has to make two different decisions in two different stages. First,it decides whether to produce or not and the protection level to be imposed on market .In the second stage, the monopolist chooses price level p by taking into consideration the optimal actions chosen by consumers. Finally,consumers decide their optimal action given the protection level r and price p. By allowing the monopolist to determine the protection level, we will see that we also let it to change the form of the demand which depends on the protection level that we are going to derive in the following section.

3.1 Monopoly Setting

3.1.1 Analysis of optimal protection level and equilibrium outcomes

First we look at the problem faced by a monopolist. Suppose that the firm has developed the product in the first stage. Now, the fixed cost F is a sunk cost in the second stage. We introduce the sequence of events as follows. First, the monopolist chooses the protection level r then in the second round it chooses the optimal price level p given that consumers maximizes their utilities of the form below, taking into account the reproduction cost determined

[3] Software or more generally information has noticeable production characteristic in which the production of the first copy has a huge sunk cost whereas the second copy costs almost nothing.

(*The Economics of Network Industries,* Shy, O.)

in the previous stage.

$$U=\left\{\begin{array}{ll} v-p & \text{original} \\ v-\alpha v-r & \text{copy} \\ 0 & \text{no consumption} \end{array}\right\} \qquad \text{(utility func.)}$$

In order to work out the monopolist's optimization problem we need to derive the market demand function. Consumers choose their optimal action given the price and protection level. The next proposition describes optimal consumer choice at different price levels.

Proposition 1 *If* $p \langle \frac{r}{1-\alpha}$ *consumers between* $[0,p)$ *make no consumption and consumers who have valuations between* $[p,1]$ *consume the original. If* $p \geq \frac{r}{1-\alpha}$ *consumers between* $\left[0,\frac{r}{1-\alpha}\right)$ *make no consumption. Consumers between* $\left[\frac{r}{1-\alpha},\frac{p-r}{\alpha}\right)$ *make unauthorized reproduction and consumers whose valuations are between* $\left[\frac{p-r}{\alpha},1\right]$ *buy the original.*

Proof. It is obvious that consumers with $v-p<0$ and $(1-\alpha)v-r<0$ will not consume neither the original nor the copy. The ones with $v-p>(1-\alpha)v-r$ will buy the original and copy the product if the inequality is the other way around.

In the first case where $p \langle \frac{r}{1-\alpha}$, for $v \in [0,p)$,we have $v-p<0$ and $v-\frac{r}{1-\alpha}<0$ which implies $(1-\alpha)v-r<0$ so there will be no consumption. For $v \in [p,1]$, we have $v-p \geq 0$ and $v-p>v-\frac{r}{1-\alpha}$ since $p<\frac{r}{1-\alpha}$. If we multiple both sides with $(1-\alpha)$ we get $(1-\alpha)(v-p)>(1-\alpha)v-r$ and $v-p>(1-\alpha)(v-p)$ since $0<(1-\alpha)<1$.So there is no copy consumption, consumers buy the original .The argument is similar for the second case so we skip it here. ■

>From proposition 1 we can derive the demand function as

$$D(p)=\left\{\begin{array}{lll} 1-p & \text{if} & p<\dfrac{r}{1-\alpha} \\ 1-\dfrac{p-r}{\alpha} & \text{if} & p \geq \dfrac{r}{1-\alpha} \end{array}\right\} \qquad \text{(demand function)}$$

Remark 1 *It is useful to assume that* $0 \leq r+\alpha \leq 1$ *.Suppose* $1>r+\alpha$ *then we have* $v>v(r+\alpha)$ *for all* v *and* $v>r+\alpha v$ *since* $v \in [0,1]$ *which implies that* $v(1-\alpha)-r<0$. *Without this assumption there would be no copy users which is not an interesting case.*

Note that the position of the kink in the demand curve depends on the value of r. Now we can define equilibrium outcomes for different levels of copyright protection.

Proposition 2 ***i)****For the case* $0 \leq r \leq \dfrac{(1-\alpha)\,\alpha}{1+\alpha}$ *we have equilibrium outcomes as*

$p = \frac{\alpha+r}{2}$ *and* $q = \frac{\alpha+r}{2\alpha}$ *and corresponding profit is* $\pi_1^m = \frac{(\alpha+r)^2}{4\alpha}$

ii)*For the case* $\dfrac{(1-\alpha)\,\alpha}{1+\alpha} < r \leq \dfrac{1-\alpha}{2}$ *the equilibrium outcomes are*
$p = \frac{r}{1-\alpha}$ *and* $q = 1 - \frac{r}{1-\alpha}$ *and the corresponding profit is* $\pi_2^m = (\frac{r}{1-\alpha})(1 - \frac{r}{1-\alpha})$

iii)*For the case* $\frac{1-\alpha}{2} < r < 1-\alpha$ *equilibrium outcomes are*
$p = \frac{1}{2}, q = \frac{1}{2}$ *and* $\pi_3^m = \frac{1}{4}$

Proof.

- Constrained profit maximization problem for $p \geq \dfrac{r}{1-\alpha}$ is $\max_p (1 - \frac{p-r}{\alpha})p$ subject to $p \geq \dfrac{r}{1-\alpha}$. From first order (FOC) and complementary slackness(CS) conditions we have

$$\begin{aligned} 1 - \frac{2p-r}{\alpha} + \lambda &= 0 \rightarrow \lambda = \frac{2p-r}{\alpha} - 1 \\ \lambda(p - \frac{r}{1-\alpha}) &= 0 \end{aligned} \quad \text{(FOC and CS)}$$

combining FOC and CS conditions, two critical points are $p_1^* = \dfrac{\alpha+r}{2}$, and $p_2^* = \dfrac{r}{1-\alpha}$.The first one is the unconstrained maximizer of the problem the second one is the minimum price that satisfies the constraint. So for the first price to satisfy the constraint the following must be true.

$$\begin{aligned} p_1^* &\geq \frac{r}{1-\alpha} \\ \frac{\alpha+r}{2} &\geq \frac{r}{1-\alpha} \\ r &\leq \frac{(1-\alpha)\alpha}{(1+\alpha)} \end{aligned} \quad (1)$$

We also need to compare the profits for these two prices to find the optimal level. After we evaluated p_1^* and p_2^* in the profit function $(1 - \frac{p-r}{\alpha})p$,we see that $\Pi(p_1^*) = \dfrac{(\alpha+r)^2}{4\alpha} \geq \Pi(p_2^*) = \dfrac{r\alpha(1-\alpha-r)}{\alpha(1-\alpha)^2}$ for the r values that satisfies the contsraint. So p_1^* is the optimal level. The corresponding quantity level is $q = \dfrac{\alpha + r}{2\alpha}$ and profit is $\pi = \dfrac{(\alpha + r)^2}{4\alpha}$ .We should note that for this case the amount of copy users is $\dfrac{\alpha - r}{2\alpha} - \dfrac{r}{1-\alpha}$.

- Price level p_1^* is increasing along with the protection level r until it reaches critical value of r that satisfies the (1).Meanwhile, the number of copy users decreases. At the point where the constraint binds ,p_1^* and p_2^* are equal. With $r > \dfrac{(1-\alpha)\alpha}{(1+\alpha)}$, the optimal price becomes p_2^* and there are no copy users.(1) continues to bind for $r \leq \dfrac{1-\alpha}{2}$.Passing that threshold we switch to the other part of the demand function which will be shown below.

- For $p < \dfrac{r}{1-\alpha}$, the problem is $\max_p (1-p)p$ and from FOC of $1 - 2p = 0$ we have , $p_3^* = \frac{1}{2}$.Again for this price to satisfy $p < \dfrac{r}{1-\alpha}$,the following must be true

$$\begin{array}{c} \frac{1}{2} < \frac{r}{1-\alpha} \\ r > \frac{1-\alpha}{2} \end{array} \tag{2}$$

>From the demand function above, it is straightforward to see that the optimal quantity and profit levels are stated as in the proposition. ■

.

Remark 2 *For the first case, profit is an increasing function of* r*. For the second case, with* $\frac{(1-\alpha)\alpha}{1+\alpha} < r \leq \frac{1-\alpha}{2}$ *, profit also increases with* r*, that is* $\frac{\partial\pi}{\partial r} \geq 0$*. If we evaluate the maximum profit at maximum attainable protection level for the first case in the proposition above, the profit level is* $\frac{\alpha}{(1+\alpha)^2}$ *For the second case, we have maximum profit of* $\frac{1}{4}$*.* $\frac{1}{4} \geq \frac{\alpha}{(1+\alpha)^2}$ *for* $\alpha < 1$*.*

Proposition 3 *In the first stage the producer will develop the product for* $F < \frac{1}{4}$ *and choose any protection level of* $r \in \left(\frac{1-\alpha}{2}, 1-\alpha\right]$

If $F \geq \frac{1}{4}$ *the producer will not develop the product for any* r *level*

Proof. Proof is straightforward from discussion above. We have demonstrated that the maximum profit level which monopolist can achieve is $\frac{1}{4}$.It won't develop product for the F values greater than this level since it will not over the fixed cost obtained in the first stage. On the other hand for $F < \frac{1}{4}$,by imposing a protection level $r \in \left(\frac{1-\alpha}{2}, 1-\alpha\right]$,it will attain positive profits which leads the decision of to produce the product. ■

Since profits is an increasing function of copyright protection level under the given intervals above and enforcement cost is zero, monopolist will choose the protection level at which its profits is the maximum. This means that with a protection level $r \in \left(\frac{1-\alpha}{2}, 1-\alpha\right]$,he can make a profit of $\frac{1}{4}$ which we showed in the second remark, is bigger than other profit level. For this level of protection, notice that there are no copy users. So producer's optimal response is to apply full protection which means to derive copies out of the market.

3.2 Duopoly Setting

3.2.1 Analysis of optimal protection level and equilibrium outcomes

In this section we want to analyze the optimal choices taken by the monopolistic firm in the existence of a threat of entry. We now introduce an entrant (firm 2) with the same fixed cost of F and a marginal cost of 0. The products are homogenous and we assume that only the incumbent firm (firm 1) can determine the protection level. The reasoning is that the incumbent monopolist has been active for a longer period in the market plus the fact that entry has not been realized yet. We do not model this situation as a dynamic game however. Here again the cost of applying copyright protection is considered to be zero. The sequence of events is as follows. We are going to denote the incumbent as firm 1, and the entrant as firm 2.

- In the first stage, given that firm 1 already decided to create the product, firm 2 decides whether to develop the product or not and firm 1 determines the protection level concurrently.
- In the second stage, firms decide how much to produce by taking into account consumers' optimal choices given the price level and the reproduction cost.

Again, consumers have three options. To purchase the original product from one of the firms, to obtain a copy, or not to consume. If both firms decide to develop the product, the game takes the form of simple Cournot competition with equal marginal costs. In the second stage,we can rewrite the demand function as an "inverse demand function" as follows:

$$D(Q) = \left\{ \begin{array}{lll} 1-Q & \text{when} & q_1+q_2 > 1-\frac{r}{1-\alpha} \\ \alpha+r-\alpha Q & \text{when} & q_1+q_2 > 1-\frac{r}{1-\alpha} \end{array} \right\} \tag{Inv.demand.Func}$$

The demand function and the derivation of the second stage (quantity competition) equilibrium are similar to the monopoly case. We derive the optimal price, the quantity level and the corresponding profits in the proposition below.

Proposition 4 ***i)****For* $0 \leq r \leq \dfrac{\alpha(1-\alpha)}{2+\alpha}$ *the equilibrium outcomes are*

$p = \dfrac{\alpha+r}{3}$, $q^1 = q^2 = \dfrac{\alpha+r}{3\alpha}$ $\quad \pi^1 = \pi^2 = \dfrac{(\alpha+r)^2}{9\alpha}$

ii)*For* $\dfrac{\alpha(1-\alpha)}{2+\alpha} < r \leq \dfrac{1-\alpha}{3}$ *the equilibrium outcomes are*

$p = \frac{r}{1-\alpha}$, $q^1 = q^2 = \frac{1}{2}\frac{r}{1-\alpha}$ $\quad \pi^1 = \pi^2 = \frac{1}{2}(\frac{r}{1-\alpha})(1-\frac{r}{1-\alpha})$

iii) *For* $\dfrac{1-\alpha}{3} < r < 1-\alpha$ *the equilibrium outcomes are*

$p = \frac{1}{3}$, $q^1 = q^2 = \frac{1}{3}$ *and* $\pi^1 = \pi^2 = \frac{1}{9}$

Proof. This is nothing but a constrained maximization problem in a Cournot setting. Let first derive the optimal outcomes for the second part of the demand function. Hence the maximization problem for firm 1 becomes

$$\max_{q1}(\alpha+r-\alpha(q_1+q_2))q_1$$

and for firm 2 it is

$$\max_{q2}(\alpha+r-\alpha(q_1+q_2))q_2$$

subject to same constraint $q_1+q_2 \leq 1-\frac{r}{1-\alpha}$. Best response functions for non-binding optimization are:

$$\frac{\alpha+r-\alpha q_2}{2\alpha} = q_1 \tag{BR_1^1}$$

$$\frac{\alpha+r-\alpha q_1}{2\alpha} = q_2 \tag{BR_2^1}$$

The Nash equilibrium outcomes are $q^1 = q^2 = \dfrac{\alpha + r}{3\alpha}$. To satisfy the constraint $q_1 + q_2 \leq 1 - \frac{r}{1-\alpha}$, the following must be true.

$$\begin{aligned} 2.\frac{\alpha + r}{3\alpha} &\leq 1 - \frac{r}{1-\alpha} \\ \frac{2r}{3\alpha} + \frac{r}{1-\alpha} &\leq \frac{2}{3} \\ r &\leq \frac{\alpha\left(1-\alpha\right)}{2+\alpha} \end{aligned}$$

Similarly for the case that constraint binds, the optimal total quantity level is $Q = 1 - \frac{r}{1-\alpha}$ and the best response functions are

$$q_1 = 1 - \frac{r}{1-\alpha} - q_2 \tag{BR$_1^2$}$$

$$q_2 = 1 - \frac{r}{1-\alpha} - q_1 \tag{BR$_2^2$}$$

To simplify analysis we will only consider the symmetric Nash equilibrium of this game, that is $q_1 = q_2 = \frac{1}{2}\frac{r}{1-\alpha}$.These quantity levels are going to be optimal until r reaches the value $\dfrac{1-\alpha}{3}$. After that threshold demand changes as stated in the first part of the Inv.demand.Func. For that case firms' problems become

$$\max_{q_1}(1 - q_1 - q_2)q_1 \qquad \text{for the first firm}$$
$$\max_{q_2}(1 - q_1 - q_2)q_2 \qquad \text{for second firm}$$

Best response functions are as follows:

$$q_1 = \frac{1 - q_2}{2} \tag{BR$_1^3$}$$

$$q_2 = \frac{1 - q_1}{2} \tag{BR$_2^3$}$$

Optimal outcomes are $q^1 = q^2 = \frac{1}{3}$. Again it can easily be shown that $\dfrac{1-\alpha}{3} < r$ must be true to satisfy the constraint $q_1 + q_2 > 1 - \frac{r}{1-\alpha}$. For the values the inequality is other way around, demand function switches to the second part in Inv.demand.Func. ■

The derivation of optimal outcomes follows a similar path with the monopolistic case in the sense of the constraint maximization. Of course in that setting firms have to act strategically and determine the quantity they will produce rather than enforcing a price level.

Remark 3 *For the first case, profit is an increasing function of r and for the second case with* $\frac{(1-\alpha)\alpha}{2+\alpha} < r \leq \frac{1-\alpha}{3}$ *, profit also increases with r that is* $\frac{\partial \pi}{\partial r} \geq 0$*. If we evaluate profit at the maximum attainable protection level for the first case in the proposition it will be* $\frac{\alpha}{(2+\alpha)^2}$*, and this is smaller than* $\frac{1}{9}$ *for* $\alpha \in (0,1)$*. In second case for* $r = \frac{1-\alpha}{3}$ *profit level is again* $\frac{1}{9}$*.*

We should once emphasize that profits are increasing with protection level for duopoly setting as well. After deriving optimal choices for a specific optimal protection level, we want to analyze how the incumbent firm will react to the possibility of competition. But its response depends on the distribution of the fixed cost, F. For any fixed cost level $F \geq \frac{1}{9}$, there will be no entry. We can see that the most profitable situation for the entrant is the third case in the proposition below in which its profit is at most $\frac{1}{9}$. Obviously, the entrant prefers a higher level copyright protection as this increases the demand for its product and the entrant does not have to pay for it. On the other hand for incumbent firm there will be a trade off between implementing high or a low protection level. Imposing a high protection level has two contrary effects. As we stated above, profits increase with protection level but on the other hand with this increased profits it is easier for firm 2 to cover its fixed cost which leads it to enter the market. Hence the optimal strategy for incumbent is ambiguous. Actually it depends on the fixed cost levels and the α level. We are going to pursue the optimal behavior of firm 1 for a given degradation rate in the following section.

3.3 Analysis of Optimal Protection With Competition: A Numerical Example

In the first section of the model, we tried to construct a framework for the optimal outcomes of the firm in a monopolistic setting. Next, we added competition to this setting and analyzed how firms react to this competition and how the incumbent firm will use the protection level as a tool to deter entry. It turns out that without any further restrictions the model is too involved to solve for the optimal choice of the protection level by the incumbent firm. Remember that the choice of protection level changes the shape of the demand curve and hence firm profits are highly non-linear functions of it. Furthermore, the fixed cost of entry will determine whether we have a monopoly or an oligopoly setting. To simplify the analysis we need to impose a specific alpha (α) level to find the critical protection level to deter entry and try to compare it with the monopolistic case.

Let us define and calculate the critical values of the protection level at which the demand functions have a kink. Observe that these values differ among monopolistic and Cournot case since the optimal price levels that should satisfy the condition $p < \dfrac{r}{1-\alpha}$ or $p \geq \dfrac{r}{1-\alpha}$ are different.

Here, first we assume that $\alpha = 0.25$ .For this α value the corresponding protection and profit level values for each case are as follows:

$r_1^m = \dfrac{(1-\alpha)\,\alpha}{1+\alpha} = 0.15$	Critical protection level in the first case of monopoly setting.
$r_2^m = \dfrac{(1-\alpha)}{2} = 0.375$	Critical protection level in the second case of monopoly setting.
$r_1^c = \dfrac{(1-\alpha)\,\alpha}{2+\alpha} = 0.083$	Critical protection level in the first case of duopoly setting
$r_2^c = \dfrac{(1-\alpha)}{3} = 0.25$	Critical protection level in the second case of duopoly setting
$\pi_1^m = 4(0.125 + \frac{r}{2})^2$	Optimal monopoly profit of firm 1 for first case
$\pi_2^m = -1.78r(r-0.75)$	Optimal monopoly profit of firm 1 for the second case
$\pi_3^m = \frac{1}{4}$	Optimal Cournot profit of both firms in the first case
$\pi_1^{c_1} = \pi_1^{c_2} = 0.44(0.25+r)^2$	Optimal Cournot profit of both firms in the first case
$\pi_2^{c_1} = \pi_2^{c_2} = -0.89(r-0.75)^2$	Optimal Cournot profit of both firms in the second case
$\pi_2^{c_1} = \pi_2^{c_2} = \frac{1}{9}$	Optimal Cournot profit level of both firms in the third case

Now the problem of the incumbent firm is reduced to comparing the profits in each case where entry occurs and the profits without entry. We still assume that implementing protection is costless for the incumbent firm

Proposition 5 *i) For fixed cost values less than* 0.027 *there is no protection level that firm 1 can choose to deter entry*

ii) For $F \in [0.027, 0.049]$ *firm 1 can deter entry by implementing* r^{max_1} *but* $\pi_1^{ne} < \frac{1}{9}$ *so it prefers firm 2 to enter the market and share a profit level of* $\frac{1}{9}$

iii) For $F \in (0.049, 0.08]$ *firm 1 will deter entry by implementing* r^{max_2} *and make a profit of* π_2^{ne} *which is greater than* $\frac{1}{9}$

iv) For $F \in (0.08, \frac{1}{9})$ *firm 1 will deter entry by implementing* r^{max_2} *and make a profit of* $2F$ *which is greater than* $\frac{1}{9}$

v) For $F \geq \frac{1}{9}$ *firm 2 prefers not to enter the market. So firm 1 will choose* $r \in \left(\frac{1-\alpha}{2}, 1-\alpha\right]$ *Which is the most profitable choice for monopolistic setting.*

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Proof. Starting from the lowest level of protection, for $r \,\epsilon\, [0, 0.083]$, in order to deter entry and maximize its profits, firm 1 's problem will look as follows:

$$\max_r \pi_1^m \text{ subject to } \pi_1^{c_2} \leq F$$

Since the optimal monopoly profit for this case is $\pi_1^m = 4(0.125 + \frac{r}{2})^2$ and $\dfrac{\partial \pi_1^m}{\partial r} > 0$,the constraint $\pi_1^{c_1} \leq F$ will bind and we can find the maximum protection level that deters entry as $r^{\max_1} = -0.25 + 1.5\sqrt{F}$. This is the protection level which does not allow firm 2 to enter the market for a given F. For this protection level to satisfy the condition that r belongs to $[0, 0.083]$, F should be in the interval $[0.027, 0.049]$ and the profit level in the absence of entry is $\pi_1^{ne} = 2.25F$ for this case. Even for the maximum F within this interval, namely 0.049, firm 1's profit will be equal to $\frac{1}{9}$.

For the case of $r \,\epsilon (0.083, 0.15]$, the demand function is as in the first case in Inv.demand.Func .The profit function takes the form of π_1^m in case firm 1 does not allow entry whereas it will be $\pi_2^{c_1} = \pi_2^{c_2} = -0.89(r - 0.75)^2$ if entry occurs. So the objective function of firm 1 is

$$\max_r \pi_1^m \text{ subject to } \pi_2^{c_2} \leq F$$

Again, since profit level π_1^m is an increasing function with respect to r, and $\dfrac{\partial \pi_2^{c_2}}{\partial r} > 0$ for the interval given above , the constraint $\pi_2^{c_2} \leq F$ will be binding. Then, the maximum protection level that can be imposed to deter entry is $r^{\max_2} = 0.375 - 0.375\sqrt{F}$.This is the maximum attainable protection level while entry is prevented. To satisfy the condition that $r\ \epsilon (0.083, 0.15]$,F should be in the interval. $(0.049, 0.08]$. The profit of firm 1 in this case becomes $\pi_2^{ne} = -0.14(\sqrt{1-8F} - 1.67)^2$ and for the range $F \in (0, 0.125)$ it is an increasing function with respect to F. Additionally, for values of $F \in [0.049, \infty)$ profit level π_2^{ne} is greater or equal than $\frac{1}{9}$ which implies that for $F \in (0.049, 0.08]$, $\pi_2^{ne} \geq \frac{1}{9}$ too.

For $r\ \epsilon (0.15, 0.25]$, the profit for the monopoly case is $\pi_2^m = -1.78r(r - 0.75)$ and for the Cournot case it is $\pi_2^{c_2} = -0.89(r - 0.75)^2$ We should emphasize that $\pi_2^m = 2\pi_2^{c_2}$. The objective of firm 1 is

$$\max_r \pi_2^m \text{ subject to } \pi_2^{c_2} \leq F$$

We should also note that the profit functions π_2^m and $\pi_2^{c_2}$ attain their maxima at $\dfrac{1-\alpha}{2}$ and particularly at 0.375 for $\alpha = 0.25$.So this means $\dfrac{\partial \pi_2^m}{\partial r} > 0$ and $\dfrac{\partial \pi_2^{c_2}}{\partial r} > 0$ for the given interval above. This implies that the constraint binds, which means $\pi_2^{c_2} = F$. If firm 1 deters entry by choosing $r^{\max_2} = 0.375 - 0.375\sqrt{1-8F}$, it makes a profit of $2F$. Only for $F \in (0.08, \frac{1}{9}]$ we are able to choose $r^{\max_2}$ to deter entry and stay on the same demand function. For these F values, $2F$ is always greater than $\frac{1}{9}$. ■

>From discussion above, we can reach the proposition stated below.

Observe that the response of firm 1 to the entry threat depends on the distribution of the fixed cost of F. For low values of F it is not profitable to deter entry as we can see from the discussion above. Indeed for values less than 0.027, firm 1 can not deter entry at all. The only case that it will accommodate with entry is the second one which firm 2 has relatively low fixed cost. Notice that firm 1 can deter entry by setting $r^{\max_1}$ but remember also for this level of protection , the demand function takes the form like in the first part**??**.So for this case there are copy users in the market which decreases demand of both firms already and leads lower profits. Alternatively incumbent may set a protection level $r \in \left(\frac{1-\alpha}{3}, 1-\alpha\right]$ such that firm 2 enters the market and they share demand equally and each makes a profit of $\frac{1}{9}$.We showed that for $\alpha = 0.25$ and $F \in [0.027, 0.049)$,accommodating is more profitable.

It is obvious that if firm 1 decides not to block entry, it will choose the protection level at which profits are maximum for duopoly setting, particularly $r \in \left(\frac{1-\alpha}{3}, 1-\alpha\right]$.

We should also note that each optimal protection level under the threat of entry is smaller for all values of F but not less than 0.049 contrast to the monopoly setting. The intuition behind this can be explained with the fact that :incumbent firm can use protection level as a mechanism to change the demand function by allowing more copy users to the market. This will lead a decrease in demand for potential entrant and for firm 1 as well. But still profits by deterring will be greater than accommodate for fixed costs bigger than 0.049.

In the following section we are going to analyze the optimal choices with a lower degradation rate.

3.3.1 A Comparative Analysis

In this section we replicate the previous analysis with a different degradation level to see how firms will react to this new parameter value. Since, as we mentioned before, digital products and their copies are close substitutes by using sophisticated reproduction technologies, we are going to assume that $\alpha = 0.1$ to be consistent with this fact and analyze the optimal solutions in contrast to $\alpha = 0.25$. This means that copy and original are now closer substitutes and piracy is a more serious threat compared to the previous analysis. Now incumbent firm has to set a lower price to drive all the copy users out of the market which corresponds to the first part of theInv.demand.Func. On the other hand it will be easier to deter entry even for low fixed cost values since this new cost structure reduces the profit of both firms. We are going to see that incumbent will have the chance to prevent entry for small F values at which it didn't have before. Moreover it will accommodate with entry for some fixed cost levels at which it was more profitable to block it previously. First let us to introduce the corresponding protection and profit levels for $\alpha = 0.1$.

$$r_1^m = \frac{(1-\alpha)\,\alpha}{1+\alpha} = 0.082 \qquad \text{Critical protection level in the first case of monopoly setting.}$$
$$r_2^m = \frac{(1-\alpha)}{2} = 0.45 \qquad \text{Critical protection level in the second case of monopoly setting.}$$
$$r_1^c = \frac{(1-\alpha)\,\alpha}{2+\alpha} = 0.043 \qquad \text{Critical protection level in the first case of duopoly setting.}$$
$$r_2^c = \frac{(1-\alpha)}{3} = 0.3 \qquad \text{Critical protection level in the second case of duopoly setting.}$$
$$\pi_1^m = 10(0.5+\tfrac{r}{2})^2 \qquad \text{Optimal monopoly profit of firm 1 for first case}$$
$$\pi_2^m = -1.234r(r-0.9) \qquad \text{Optimal monopoly profit of firm 1 for the second case}$$
$$\pi_3^m = \tfrac{1}{4} \qquad \text{Optimal monopoly profit of firm1 for the third case}$$
$$\pi_1^{c_1} = \pi_1^{c_2} = 1.1(0.1+r)^2 \qquad \text{Optimal Cournot profit of both firms in the first case}$$
$$\pi_2^{c_1} = \pi_2^{c_2} = -0.617(r-0.9)^2 \qquad \text{Optimal Cournot profit of both firms in the second case}$$
$$\pi_2^{c_1} = \pi_2^{c_2} = \tfrac{1}{9} \qquad \text{Optimal Cournot profit level of both firms in the third case}$$

Notice that the price level that should be set to drive the copiers out of the market is smaller now. Particularly it should be less than $r_1^m = 0.082$ for monopolistic case and less than $r_1^c = 0.043$ for Cournot competition while the corresponding levels were 0.15 and 0.083 in the previous analysis. So profit levels for each case will be smaller.

Proposition 6 ***i)*** *For fixed cost values less than* 0.011 *there is no protection level that firm 1 can choose to deter entry.*

ii) For $F \in [0.011, 0.023]$ *firm 1 will accommodate with entry.*

iii) For $F \in (0.023, 0.041)$ *firm 1 will accommodate with entry.*

iv) For $F \in (0.041, 0.055)$ *firm 1 will accommodate with entry*

For $F \in \left[0.055, \frac{1}{9}\right]$ *firm 1 will deter entry by setting* $r^{max_2} = 0.45 - 0.45\sqrt{1-8F}$

v) For $F \geq \frac{1}{9}$ *firm 2 prefers not to enter the market. So firm 1 will choose* $r \in \left(\frac{1-\alpha}{2}, 1-\alpha\right]$ *Which is the most profitable choice for monopolistic setting*

Proof. With a similar argument in the previous section, here we skip all the derivations done there, the result will be as follows: By decreasing the degradation value α, the cost of reproduction also decreases in an amount depending on individual valuations. But we should note that the cost is smaller for every consumer type in contrast to $\alpha = 0.25$. In proposition 6 we depict the difference between proposition 5 such that with a smaller α, we have the opportunity to deter entry for small values that we could not before. The intuition is quite obvious. Since copy is a closer substitute, firms have to set prices lower than the previous setting to attract consumers who buy original before and can switch to copying now. This will lead a decrease in the profits and make easier to deter entry. For $F \in [0.011, 0.023]$ firm 1 can prevent entry and make a profit of 0.051 which is less than $\frac{1}{9}$ so to accommodate will be optimal strategy. For the case $F \in (0.023, 0.041)$ the blocking profit level will be $0.51(\sqrt{1-8F}-1.22)^2$ which is smaller than $\frac{1}{9}$ for $F \in (0, 0.125)$ which also includes our interval of fixed cost. So again it is optimal to let firm 2 to enter the market. The same reasoning is true for the values of $F \in (0.041, 0.055)$.However for $F \in \left[0.055, \frac{1}{9}\right]$, whenever incumbent deter entry it will make a profit of $2F$ which is greater than $\frac{1}{9}$ for this range of fixed values. Finally for any $F \geq \frac{1}{9}$ firm 2 will not enter to the market at any protection level therefore incumbent will maximize its profit by choosing $r \in \left(\frac{1-\alpha}{2}, 1-\alpha\right]$ like it does as a monopolist. ■

3.3.2 Analysis of optimal protection level with enforcement cost

In the previous sections, we assumed that implementing protection is costless for the incumbent firm. But in reality firms incur a cost to impose copyright protection on their products. This cost can consist of expenses due to lawsuits [4] against illegal activities or to persuade policy makers to take actions against piracy which will be more agresive. Especially for digital products this cost can be attained by imposing different mechanisms to the product itself. Then copying will be impossible or more costly for the consumer.[5]. So far we assumed that only incumbent firm can determine protection level hence he also bears all the enforcement costs.

For this section we will assume that the incumbent firm incurs a total cost of $TC = c.\frac{r^2}{2}$ to impose protection level r .This is an increasing convex function which captures the idea that to be able to increase the protection level for high values of r, we have to bear more cost contrast to the case of low values.

To be able to compare results we found in the previous sections, we are going to analyze our problem by assuming a specific value for c such that $c = 0.5$. The profits of the

[4] One of the most famous lawsuits is the Napster case in which the peer-to-peer file sharing platform lost against the record label in 2000.

[5] some softwares include a a web based funciton to prevent illegal users to function the program online (Bae and Choi)

entrant will not change since the party that implement protection is the incumbent firm. The formulation of firm 1's problem is same except the changes in profits. Since the profits of the entrant remain unchanged, the constraints on which incumbent firm will maximize its profits are same as in the previous section.

Proposition 7 *With enforcement costs, for every possible value of F in the interval $\left[0.027, \frac{1}{9}\right]$, firm 1 will deter entry*

Proof. The problem can be formulated as follows,

i) For the case $F \in [0.027, 0.049]$ firm 1 tries to maximize its profit in case of blocking entry such that

$$\max_r (r + 0.25)^2 - 0.25r^2$$

$subject\ to \pi_1^{c_2} \leq F$

Since $\frac{\partial \pi^{mb}}{\partial r} > 0$, as we emphasized above that constraints are same, the maximum protection level that firm 1 will implement to prevent entry remains same too that is $r^{\max_1} = -0.25 + 1.5\sqrt{F}$. After we substitute this value in $(r + 0.25)^2 - 0.25r^2$ for r, we obtain the monopoly profit level in case of blocking the entry which is $\pi_1^{MB} = 1.68F + 0.187\sqrt{F} - 0.015$. If it does not deter entry than the profit level will be $\pi_1^{ce} = 0.44(0.25 + r)^2 - 0.25r^2$. Cournot profit is increasing with protection level. So incumbent firm will prefer to set the maximum protection level for Cournot case at which we stay in the first part of the demand function which is 0.083 for this case. The profit level evaluated at this value is $\pi_{0.083}^{ce} = 0.047$. For F values between $(0.021, \infty)$,$\pi_1^{MB} > \pi_{0.083}^{ce} = 0.047$ which also contains our interval $F \in [0.027, 0.049]$.

ii) For the case $F \in (0.049, 0.08)$ firm 1's problem can be states as

$$\max_r (r + 0.25)^2 - 0.25r^2$$

$subject\ to$

$$\pi_2^{c_2} = -0.89(r - 0.75)^2 \leq F$$

Now for this case the maximum protection level to deter entry is $r^{\max_2} = 0.375 - 0.375\sqrt{F}$. Again after we substitute this value in profit function $(r+0.25)^2 - 0.25r^2$, we obtain monopoly profit level of $\pi_2^{MB} = 0.461 - 0.4\sqrt{1 - 8F} - 0.844F$. If it does not deter entry then he will get the profit level of $\pi_2^{ce} = -0.89(r - 0.75)^2 - 0.25r^2$. This profit function is increasing for the r values smaller than 0.29. This implies that incumbent firm will choose the maximum protection level at which we stay in the same part of the demand function. In this case it is 0.25.The profit level evaluated at this protection level is $\pi^{ce}_{0.25} = 0.09$. For F values between $(0.015, 0.125)$, $\pi_2^{MB} > \pi_2^{ce}$ which also contains our interval $F \in (0.049, 0.08)$.

iii) In the case $F \in [0.08, \frac{1}{9}]$ we deal with the problem of firm 1which takes the form of

$$\max_r - 1.78r(r - 0.75) - 0.25r^2$$

subject to

$$\pi_2^{c_2} = -0.89(r - 0.75)^2 \leq F$$

To deter entry firm 1 can choose $r^{\max_2} = 0.375 - 0.375\sqrt{F}$ and the profit evaluated at this protection level is $\pi_3^{MB} = -0.07 + 2.28F + 0.07\sqrt{1 - 8F}$. Again the non block profit level is $\pi_2^{ce} = -0.89(r - 0.75)^2 - 0.25r^2$ and its maximum value is $\pi^{ce}_{0.25} = 0.09$.We found that for $F \in [0.08, \frac{1}{9}]$, $\pi_3^{MB} > \pi^{ce}_{0.25}$. ■

We established in the previous section that for high values of protection level, firm 2 is more likely to enter market due to an increase in the demand for original products. Only for relatively low values of the fixed cost will firm 1 accommodate entry. In this section we reached the result that by adding a cost to implement protection, even for low values of F, the incumbent firm will choose to block entry. Competition is stronger now. For this case it is not profitable anymore to allow entry by choosing $r \in \left(\frac{1-\alpha}{3}, 1 - \alpha\right]$.It is obvious that due to the implementation cost the profit level will be less than $\frac{1}{9}$, hence to choose less protection and deter entry is more profitable even for low fixed costs.

4 Conclusion

This thesis studies how optimal copyright protection level against digital product piracy changes when there is competition in the market and when there is an copyright implementation cost for a single producer. The basic difference between the thesis and existing papers in the literature is that we identified the incumbent firm as being the party that determines the protection level. This makes the choice of protection an endogenous decision variable and a means to deter entry.

First we showed that the monopolist pursue full protection without any potential entrant and no enforcement cost. This is the outcome at which there are no copy users in the market. Next, to be able to make a concrete analysis, we had to assume a specific value for the degradation level. Since copy of digital products does not lose much quality, we believe that 0.25 is a plausible value for this specification. Under this assumption, we found that for relatively high fixed costs to deter entry, the incumbent firm will enjoy some piracy in the market. This means that it will choose a level below full protection. Then we made a comparative analysis by assuming a lower value for degradation rate which is 0.1. Considering the improvements in copying technologies, this assumption will be more meaningful. Although the original of a digital product usually has some extra features, consumer help after purchase for example, copies become more closer in quality to the original product. We established that in this case it will be harder to deter entry. Piracy becomes more dangerous for both firms. The profit levels will be lower, and for the incumbent preventing entry will be beneficial only for relatively higher fixed costs of entry. Furthermore, by relaxing the assumption we made earlier that implementation of protection is costless, we established that even for low fixed costs, to deter entry will be profitable for the incumbent firm in the case where α is 0.25.

The results in this paper suggest that in the presence of competition, existing firms would prefer some level of piracy in the market to strengthen the entry barriers even if they have to sacrifice some proportion of their profits. However if piracy becomes more effective in the market, then they would prefer to deter entry only for a slightly higher fixed cost level.

In this thesis, we try to model the effect of piracy on the individual producers with perfectly homogenous products where one of the firms decides on the protection level in the market which also determines the demand that is going to be faced. The analysis could be extended to a heterogenous products setting as well. Here copies can be used to transmit information about the original or without any information good setting firms promote their products through copies which is very common in music industry in reality. In both cases copies have an advertising effect. *Zhang(2004)* and *Peitz and Waelbroeck* built a framework with a similar purpose. However, in Zhang's paper the proportion of copy users is exogenously given, where the latter paper distinguishes the analysis where either everyone copies or there is no copy use at all. Moreover, they investigate the case of the multiproduct monopoly rather than competition. It is possible to pursue a framework such that the choice variables for the incumbent firm are copyright protection level and advertisement level. In this framework, the incumbent firm would choose an advertising level, facing an convex cost function, to inform the consumers about the availability of its product in the market whereas entrant doesn't have any budget to advertise its own product. The only way for firm 2 to transmit information is through the copy users. So again in this framework , the amount of copy users is endogenously determined like in our present model and the copy users spread the information about the product. Hence they create a P2P effect. With higher protection level the incumbent firm can increase its revenues but then has to spend more on advertisement which reduces its profits. The optimal level will depend on which effect is dominant. We tried to extend the present model in this direction but encountered difficulties in establishing the right timing structure. Since the P2P effect on the consumption of these kind of products is important, an advertisement feature still deserves attention and is left for future research.

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