Economic Analysis Letters

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Protection in DRM and pricing strategies for digital products considering quality degradation

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ABSTRACT

In this paper, we develop a model in which a monopolistic firm manufactures and sells a digital product, by incorporating digital rights management (DRM), quality degradation of pirated products, and government copyright enforcement into the consumer's utility function. We determine the monopolist's optimal pricing strategies and the appropriate DRM protection level through mathematical deduction. Our results show that when the government copyright enforcement is moderate and the quality of pirated products is relatively high, implementing a DRM system is optimal for the monopolist. However, in most other cases, DRM-free is better for the monopolist. This result may explain why DRM is not very popular in some industries. Our results suggest that choosing the right price, focusing on content innovation, and weakening DRM protection may be a better strategy for firms now. The results also indicate that DRM-free may be more prominent in the digital music industry than in the software and video games industries.

KEYWORDS

Pricing; DRM-free; Digital piracy; Quality degradation

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ISSN 2972-3272
doi: 10.58567/eal02010003

Received 16 February 2023; Accepted 8 March 2023; Available online 21 March 2023

1. Introduction

Since the spread of the COVID-19 disease, many cities around the world have adopted lockdown measures, leading people to own home quarantine and causing a surge in film piracy. According to a recent report released by Android Authority, out of over 1,400 votes, 83.69% of polled users confirmed that they had pirated content in some way in 2022 (Simons, 2022). To deter piracy, many digital product firms have been spending a great deal of effort designing technical protections, in addition to using legal tools. Technical measures are typically developed by implementing "digital rights management" (DRM) systems, such as applying some restrictions to limit the number of devices or frequency of usage, etc. (see Peitz and Waelbroeck (2006) and Guo and Meng (2015)). Some digital product firms may find DRM helpful because it restricts consumers' illegal behaviors. However, consumers often complain about the inconvenience caused by DRM restrictions while using legal products, such as inflexibility in usage and bigger file sizes. A digital product firm needs to make the trade-off between the implementation of DRM technology and the decline in consumers' valuation of the legal product.

Related research has mainly focused on the trade-off problem between DRM protection level and value reduction of the legal product. See Guo and Meng (2015), Holm (2003), Sundararajan (2004), Kogan et al. (2013), Wu, et al. (2020), Zhang et al. (2021). Some studies have mainly focused on analyzing the performances between the members in a two-echelon supply chain from the perspective of game theory see Li and Lin (2009), Avinadav et al. (2014), Luo et al. (2017), Huang et al. (2017), Zhang and Peng (2020).

In this paper, we explicitly consider the trade-off between the DRM protection level and the consumers' value reduction for the legal product. In our model, we deduct the demands for the legal product and the illegal product by incorporating digital right management (DRM) r, quality degradation of pirated product q $(0 < q \leq 1)$, and government copyright enforcement into the consumer's utility function. By solving the profit maximization problem of the monopolist, we investigate the optimal DRM protection level and the pricing strategies of the monopolist.

2. Model

In our model, we consider a monopolistic firm that produces and retails a digital product. The monopolist needs to decide on the DRM protection level and the retail price of the product. We assume that consumers have heterogeneous preferences for the digital product, which are characterized by each consumer's valuation v of the legal product. These values are assumed to be uniformly distributed on the interval [0, 1]. Let us denote the level of protection in DRM by *r*, where $0 \leq r < 1$. As in most studies, a typical consumer has three choices: buying the legal product, using the pirated product, or doing nothing. Consumer *v* gets net utility $(1 - r)v - p$ when he or she buys the legal product, where p is the price of the digital product. When consumer *v* uses the pirated product, his or her net utility is $qv - c$, with $0 \leq q \leq 1$. The parameter q measures the quality of the pirated product. Here, we let $c = er$, and interpret *e* as the government's copyright enforcement. If consumers choose no consumption, their net utility is normalized to zero.

As usual in the literature, since digital products can be reproduced at a negligible marginal cost, we assume that the marginal cost of the legal product is zero. For simplicity of the analysis, we assume that $0 \leq e \leq 1/2$ throughout the rest of this paper. The assumption $e \leq 1/2$ denotes a weaker level of the government's copyright enforcement, which is suitable for some developing countries, such as China and India. These assumptions allow us to focus on analyzing how the monopolist chooses the right DRM protection level and the optimal pricing for the product.

By analyzing a utility-based consumer choice model, we can respectively derive the demand functions of legal product and pirated product d_l, d_p. For example, if $0 \leq r \leq q/e$, the demands are as follows, respectively:

$$d_l=\begin{cases}1-\frac{p}{1-r}, & p\le\frac{(1-r)er}{q}\\ 1-\frac{p-er}{1-r-q}, & \frac{(1-r)er}{q}\le p\le 1+er-r-q\\ 0, & p\ge 1+er-r-q\end{cases},\ d_p=\begin{cases}0, & p\le\frac{(1-r)er}{q}\\ \frac{p-er}{1-r-q}-\frac{er}{q}, & \frac{(1-r)er}{q}\le p\le 1+er-r-q\\ 1-\frac{er}{q}, & p\ge 1+er-r-q\end{cases}.$$

By performing a similar analysis, we can obtain the corresponding demand functions in other cases.

Since a digital product can be reproduced with a negligible cost, we assume the marginal cost of producing the legal product is zero. Thus, the monopolist's profit is $\pi=pd_l$.

3. Main results and managerial implications

We will first find the optimal price of the legal product assuming the DRM protection level is given, and then derive the optimal DRM protection level based on the optimal price. After a tedious analysis, we have the following conclusions.

Proposition 1. If $(\sqrt{2}-1)/2\le e\le 1/2$ and $q\ge 4e^2/(4e^2+4e-1)$, then $r=1-q$ is the best choice for the monopolist; otherwise, $r=0$ is the best choice for the monopolist, i.e., DRM-free is the optimal strategy for the monopolist.

Proposition 2. Basing on the presumption $e\le 1/2$, when $(\sqrt{2}-1)/2\le e\le 1/2$ and $q\ge 4e^2/(4e^2+4e-1)$, the monopolist's optimal pricing is to set the price at $p=q/2$. Correspondingly, we can obtain the optimal profit is: $\pi=q/4$; otherwise, the monopolist's optimal pricing is to set the price at $p=(1-q)/2$ to maximize the monopolist's profit. In this case, the optimal profit is: $\pi=(1-q)/4$.

From Proposition 1, we can see that a DRM-free strategy is the optimal choice for the monopolist in some cases. This result may explain why DRM is not so popular in some industries. In recent years, increasing reports reveal that DRM-free digital products are becoming more widespread. Generally, software and video games are strongly DRM-protected, while DRM-free products are more prominent in digital music distribution. However, more types of digital products are joining the ranks of DRM-free now.

Furthermore, from Propositions 1 and 2, we can see that if the monopolist implements DRM policy into his product, then both the optimal price of the legal product and the monopolist's profit will decrease with the increase of r. However, in this case, the monopolist's optimal strategy depends on the quality level of the pirated product. On the other hand, if the monopolist doesn't implement DRM policy into his product, the monopolist's optimal pricing strategy and profit will not be affected by the DRM protection level.

By summarizing Proposition 1 and Proposition 2, we have the following proposition.

Proposition 3. 1) When $(\sqrt{2}-1)/2\le e\le 1/2$ and $q\ge 4e^2/(4e^2+4e-1)$, the monopolist can obtain the maximum profit $\pi=q/4$ by setting the DRM protection level at $r=1-q$ and the price at $p=q/2$. Correspondingly, we have $d_l=1/2,\ d_p=0$.

2) In other cases, the monopolist can obtain the maximum profit $\pi=(1-q)/4$ by choosing the DRM-free strategy and setting the price at $p=(1-q)/2$. Correspondingly, we have $d_l=1/2,\ d_p=1/2$.

From the first result in Proposition 3, we can see that if the copyright enforcement imposed by the government is moderate (i.e., $(\sqrt{2}-1)/2\le e\le 1/2$) and the quality of the pirated product is above a certain level (i.e., $q\ge 4e^2/(4e^2+4e-1)$), the monopolist can achieve higher profit by raising the price and decreasing the DRM protection level as the quality of the pirated product increases. Further, in this case, the monopolist could keep a stable and optimal profit by setting a right price, so that there is no demand for the pirated product.

From the second result in Proposition 3, we can see that DRM-free is the optimal strategy for the monopolist under any case except the condition indicated in the first result. The monopolist will lower the price as the quality of the pirated product increases. In this case, the legal product and the pirated product do coexist. Since the

competition between these two products becomes more intense when the pirated product has a higher quality, the monopolist must lower the price in order to obtain more profit. However, the higher the quality of the pirated product, the lower the monopolist's maximum profit will be.

4. Conclusions

In this paper, we present a model that incorporates this trade-off and analyze the profit maximization problem of the monopolist. After strict mathematical analysis and deduction, we show that if the copyright enforcement imposed by the government is moderate and the quality of the pirated product is sufficiently high, the monopolist tends to implement a DRM system. However, in most other cases, DRM-free is the optimal strategy for the monopolist. Our research provides useful insights for firms to develop appropriate DRM policies and pricing strategies to increase profits. We hope that the theoretical results in this paper can serve as the basis for future empirical studies.

This study can be further extended in the following several directions. First, in this paper, we assume that there is no cost for the monopolist to implement the DRM system and change the DRM protection level. It will be interesting to consider these costs in future studies. Second, in this paper, we assume that the copying cost is only related to the DRM protection level. In reality, copying cost may be affected by ~~some~~ other factors besides the DRM protection level. Then, assuming the copying cost is related to other factors will be a future direction. Third, we consider a monopolistic firm, but there are more rich results if there are multiple firms in the market. We will study the oligopoly market in future work. Finally, our results are mainly derived based on the theoretical model; it is beneficial to engage in further empirical studies.

Funding Statement

This work was supported by MOE (Ministry of Education in China) Project of Humanities and Social Sciences, grant number 22YJC630203.

Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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