In-feed Advertising Pricing and Privacy Information Utilization Strategies of Short Video Platforms

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Abstract. In this paper, short video platforms use users' privacy information to push In-feed advertising as the background, based on utility theory and two-sided market theory, we construct a single oligopolistic market decision-making model, and study the strategies of In-feed advertising pricing and privacy information utilization on short video platforms with the perspective of users' privacy concerns. Analysis shows that privacy concerns will negatively affect the utilization of platform privacy information. When privacy concerns increases, advertising price and platform's profit will decrease first and then increase. In addition, the platform always profits from positive cross-network externality, although the privacy information utilization increases first and then decreases as it rises.The privacy information utilization, advertising price and platform's profit decrease with the increase of unit technology cost and users' advertising aversion, and increase with the rise of users' perceived usefulness in privacy information utilization and advertisers' basic revenue.

Keywords: short video platform, In-feed advertising, privacy concerns, privacy information utilization

1 Introduction

The short video platform is a two-sided platform that connects short video producers and viewers, matching short video supply and demand. Advertising revenue is one of the main sources of revenue for short video platforms, accounting for more than 50% of the short video industry revenue[1]. Short video advertising includes four types : Splash advertising, In-feed advertising, Product Placement advertising and Branded Effect advertising[2], of which In-feed advertising is the main form. In-feed advertising is a kind of streaming advertising built on users' data analysis and embedded in a form similar to the content viewed by users,with common forms such as: graphics, images, short videos, etc[3]. Similar to In-feed advertising, short video In-feed advertising is a kind of intelligent and precise advertising based on geographical location instant positioning and database analysis, with the same form of short videoes viewed by users[4].

Short video In-feed advertising is widely favored by advertisers because of its originality and precision.However, the precise placement of In-feed advertising is based on the use of users' privacy information, which brings inevitable privacy invasion problems. It is easy to arouse users' concerns about the excessive use of privacy information and the extent to which their privacy information is used. Zarouali and Ponnet (2017) find that highly precise advertising will

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instead reduce users' purchase intention when their privacy concerns are high[5]. Influenced by users' privacy concerns, it is not the case that higher platform privacy information utilization is more favorable. Excessive utilization of privacy information may aggravate users' privacy concerns, which may lead to users' advertising avoidance, weaken the advertising effect and affect platforms' profit. Therefore, platforms need to consider the balance between users' privacy information utilization and users' privacy concerns when formulating In-feed advertising strategies, especially in the short video field where privacy information leakage incidents occur frequently in recent years.

Therefore, considering the characteristics of short video platforms, this paper will construct a decision-making model of In-feed advertising pricing and privacy information utilization of short video platforms in a single oligopoly market. We will solve issues as follows: (1) What are the optimal price and optimal privacy information utilization of In-feed advertising on short video platforms in a monopoly market? (2) What factors will affect the advertising price, privacy information utilization and profit of short video platform, and how will they change?

2 Literature review

2.1 Pricing of online video platforms

Online video platforms can be divided into long video platforms and short video platforms according to the playback time of a single video[6]. Both long video platforms and short video platforms are typical multi-sided market platforms. The main market participants include platforms, content providers, users and advertisers.

The charging modes of long video platforms are diversified. According to the different bilateral price structures of platforms, they can be divided into two-sided charging and one-sided charging. Two-side usually refers to advertisers and users. The platform's charging methods for advertisers include Cost Per mille (CPM) and Cost Per Click (CPC)[7, 8], while users' charging methods include free mode, also known as advertising mode, subscription mode and mixed mode. Researchs show that in addition to the platform's charging model, network externality, platform differentiation, users' heterogeneity and two-sided users' attribution will affect pricing strategies of long video platforms[9,10,11].

Compared with the pricing research of long video platforms, scholars have only focused on the pricing research field of short video platforms in recent years. This paper will briefly summarize the pricing decisions of short video platforms. Taking UGC(User Generate Content) short video platforms as the background, Fu(2019) assume that users of the UGC short video platform are both video viewers and video providers, considering the same-side network effect besides the cross-network effect[12].Chi and Fan(2021) consider the impact of user nuisance costs and the strength of cross-network externality on the pricing model, which include advertising model and mixed model,for short video platforms[13]. Zhou et al.(2019) argued that short video platform competition should not be pricing, but positioning[14]. Li et al. (2022) constructed a behavioral model of advertisers and developed an optimal advertising quality strategy for them[15].

2.2 Privacy information utilization and privacy concerns

Privacy information utilization refers to the degree of collection and utilization of users' personal information by the platform, which can also be called advertising precision, personalization and data utilization in different situations. Privacy concerns refer to users' concerns about the collection and use of their personal information on the network platform[16].

Research examining privacy information utilization and privacy concern can generally be placed into two groups by methods.One group uses empirical methods to assess the impact of privacy concern on advertising effectiveness. Zhang et al. (2019) design a field-controlled experiment based on privacy computing theory and find that privacy concerns play a partial mediating role in advertising precision and advertising effectiveness[17].The other group is to use the game theory to explore the impact of privacy concerns on the privacy information utilization in two-sided markets[18]. Gal-Or et al. (2018) concludes that decreased user privacy concerns lead to greater platform competition intensity and varied utilization of privacy information[19].

In summary, researches on video platform pricing and privacy information utilization have achieved rich results, providing a theoretical basis and method reference for this study.However,most researches focus on long video platforms rather than short video platforms whose advertising is more precise and based on users' privacy information utilizaition. Therefore, this paper focuses on the issue of In-feed advertising on the short video platform from the perspective of users' privacy concerns, and explores the pricing and privacy information utilization strategies in monopoly markets.

3 The model and analysis

The basic assumption of the model is : There is a short video platform in the monopoly market, which provides services for users and advertisers. It is free for users and charge advertisers with a one-time price p, adopting CPM models. The total utility gained by users from using the short video platform is U_C , and users will join the short video platform when $U_C \geq 0$. The total utility advertisers receive from the platform is U_a, and advertisers will join the short video platform when $U_a \geq 0$.

We assume that the number of users and advertisers in the market are both 1 and that an advertiser places only one advertisement on the platform.Besides, we denote the numberof users and advertisers on the platform as n_c and n_a, respectively.In order to achieve personalised recommendations, the short video platform collects users' privacy information and utilize it, denoted privacy information utilization as e ($e \in (0,1)$).As the cost of the platform's effort increases, the level of privacy utilization effort decreases at the margin. When advertisers access the platform, the basic revenue obtained by advertisers is $r(r > 0)$, and the use of platform privacy information can bring re revenue increase to advertisers. The positive cross-network effect coefficient of users on advertisers is α_1 ($\alpha_1 \in (0,1)$), and the positive cross-network externality is $\alpha_1 n_c$. The fixed cost for each advertiser to make an advertisement is η, which is uniformly distributed on [0,1]. Therefore, the advertiser's utility function is shown in equation (1) .

$$U_a = \alpha_1 n_c + r(1 + e) - p - \eta \tag{1}$$

When a user access the short video platform, the base utility that can be obtained is v, which is uniformly distributed on [0,1]. With the frequent occurrence of privacy data leakage, users begin to pay more attention to privacy data.We denote the user's privacy conceners as γ, $\gamma \in [0,1]$. The closer γ is to 1, the more attention the user pays to private data. According to Gal-Or (2018)[**Error! Bookmark not defined.**], when users start to concern about privacy information, it will cause users' distrust of the platform, resulting in negative utility, which denoted as γe. The the user's perceived usefulness of the use of private information is s ($s > 0$), and se is the positive utility that the user derives from the use of the platform's private information. Generally, users are prefer to use platforms without advertisements which disturb users' consistent browsing experience[**Error! Bookmark not defined.**]. In-feed advertising can reduce advertising disturbance in the form because of its originality, but the following advertising deception may result in higher advertising nuisance costs[20]. We assume that all users in the market are ad-haters, and the negative cross-network effect coefficient of advertisers on users is $\alpha_2(\alpha_2 \in (0,1))$, and $\alpha_2 n_a$ is negative cross-network externality.Therefore, the user's utility function is shown in equation (2) .

$$U_c = v - \alpha_2 n_a + se - \gamma e \tag{2}$$

Short video platforms mainly rely on advertising fees to make profits, but also need to pay technical costs to realize the use of private information. We denote $k(k \in (0,1))$ as the unit technology cost of the platform's effort in collecting and analyzing privacy information, then the cost is $\frac{ke^2}{2}$. Therefore, the platform's profit is π and its function is shown in equation (3) .

$$\pi = pn_a - \frac{ke^2}{2} \tag{3}$$

The decision-making sequence is as follows. First, the short video platform determines the In-feed advertsing price and privacy information utilisation. Second, advertisers decide whether to place ads on the platform and viewers decide whether to use the platform.

We use backward induction to solve the equilibrium. Users enter the short video platform when $U_c \geq 0$, so the number of users is shown in equation (4).

$$n_c = 1 - \alpha_2 n_a - \gamma(e - s) \tag{4}$$

Advertisers enter the short video platform when $U_a \geq 0$, that is, the advertisers' revenue needs to exceed at least its advertising production cost, so the number of advertisements is shown in equation (5).

$$n_a = \alpha_1 n_c + r(1 + e) - p \tag{5}$$

Simultaneous equations (4) and (5),we can find advertisers' number and users' number are shown in equations (6) and (7).

$$n_a = \frac{-p+r+er+(1-e\gamma+s\gamma)\alpha_1}{1+\alpha_1\alpha_2} \tag{6}$$

$$n_c = \frac{1-e\gamma+s\gamma+(p-(1+e)r)\alpha_2}{1+\alpha_1\alpha_2} \tag{7}$$

Substituting (6) in (3), the profit of the platform is shown in equation (8).

$$\pi = \frac{p(r-p+er+(1-e\gamma+s\gamma)\alpha_1)}{1+\alpha_1\alpha_2} - \frac{e^2k}{2} \tag{8}$$

Next, we can analyze the equilibrium of the model.

Proposition 1 If $r > \gamma\alpha_1$ and $\frac{(r-\gamma\alpha_1)^2}{2+2\alpha_1\alpha_2} < k < \frac{(r-\gamma\alpha_1)(1+\alpha_1-\gamma\alpha_1)}{2\alpha_1\alpha_2}$ and $s < \frac{2k+2k\alpha_1\alpha_2-\alpha_1(1-\gamma)(r-\gamma\alpha_1)}{\gamma\alpha_1(r-\gamma\alpha_1)}$,the optimal price of In-feed advertising is $p^* = \frac{k(r+(1+s\gamma)\alpha_1)(1+\alpha_1\alpha_2)}{2k-r^2-\gamma^2\alpha_1^2+2\alpha_1(r\gamma+k\alpha_2)}$, and the optimal privacy information utilization is $e^* = \frac{(r-\gamma\alpha_1)(r+(1+s\gamma)\alpha_1)}{2k-r^2-\gamma^2\alpha_1^2+2\alpha_1(r\gamma+k\alpha_2)}$, and the platform's optimal profit is $\pi^* = \frac{k(r+(1+s\gamma)\alpha_1)^2}{4k-2r^2-2\gamma^2\alpha_1^2+4\alpha_1(r\gamma+k\alpha_2)}$.

Proposition 2 As the unit technical cost of the platform using users' privacy information (k) increases, the optimal privacy information utilization (e^*) and the optimal price (p^*) and the platforms' optimal profit (π^*) decreases.

Propostion2 means that if unit technical cost increases, the platform needs to pay more efforts to improve the same privacy information utilization. Therefore, the platform will reduce the utilization of users' privacy information.Meanwhile, the precision of In-feed advertising will decline, so its attraction to advertisers will decline. In order to retain advertisers, the platform will decrease the advertising price. The the platform's profit will decrease by the decrease in advertising price and the number of advertisers. .

Proposition 3 The optimal privacy information utilization (e^*) decreases as users' privacy concerns (γ) rise. The optimal price (p^*) decreases as users' privacy concerns (γ) rises, if $\gamma < \frac{\sqrt{-2ks^2+r^2(1+s)^2+\alpha_1^2+2\alpha_1(r+rs-ks^2\alpha_2)}-r-\alpha_1}{s\alpha_1}$. The platform's optimal profit (π^*) decreases as as users' privacy concerns (γ) rises, if $\gamma < \frac{r^2-2ks+r^2s+r\alpha_1-2ks\alpha_1\alpha_2}{\alpha_1(r+rs+\alpha_1)}$.

Proposition 3 shows that users' privacy information concerns has a strong constraint on the platform's privacy information utilization. Due to the complex changes in advertising price and platform's profit, we will select a set of parameter values that meet the constraints for interpretation, $k = 0.5, s = 0.2, \alpha_1 = 0.6, \alpha_2 = 0.4, r = 0.6$. As shown in Figure 1(a) and Figure 1(b), the optimal advertising price and platform's optimal profit decreases first and then increases as γ rises. When users pay less attention to privacy, the number of users is more sensitive to γ (as shown in Figure 1(c)). The platform reduces the privacy information utilization, and the size of advertisers decreases due to reduced utility of advertisers(as shown in Figure 1(d)). At this point, the platform reduces advertising price to retain advertisers, and platform's profit decrease.However, as γ increases further, the platform users' scale tends to 1, and the scale of advertisers is slowly expanding due to the positive cross-network external performance to make up for their utility. In addition, the number of advertisers is not sensitive to changes in privacy concerns.So the platform will slowly rise advertising price for greater

profit. The platform's profit increases by the reduction of the technical cost of privacy information utilization and the increased charging from advertisers.

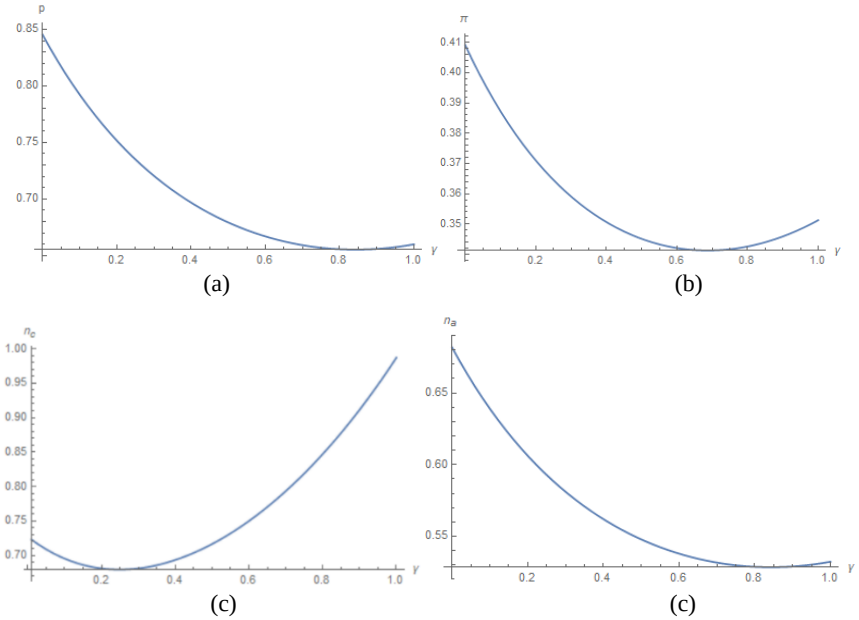

Fig1. Changes in the price and profit and the number of users and advertisers about γ.

Proposition 4 The optimal privacy information utilization (e^*) and the optimal price (p^*) and the platform's optimal profit (π^*) as the degree of users' aversion(α_2) to advertising decreases.

When users hate advertising, as α_2 rises further, even the highest precision advertising will still cause greater utility losses to users. Therefore, the platform reduces e^* to save technical costs, which cause the number of advertisers decreases.The platform decreases the price to retain advertisers and the platform's profit decreases.

Proposition5 If $\alpha_1 < \delta$[1], the optimal privacy information utilization (e^*) increases as the positive cross-network externalitiy increases. The optimal price (p^*) and the platform's optimal profit (π^*) as positive cross-network externalitiy rises.

Proposition 5 shows that the privacy information utilization increases first and then decreases as α_1 rises.When $\alpha_1 < \delta$, the size of advertisers continue to expand as α_1 rises, but the number of users decreases sharply, which causes the platform increasing $e^*$to improve users' experience. However, as α_1 increases further, the number of advertisers grows slowly but the number of users still decreases, and the platform will decrease e^* to retain users. The optimal price and the platform's profit rise becuase of the increasing number of advertisers as α_1 rises.

[1] $\delta = \frac{-2\gamma k+\sqrt{2}\sqrt{\gamma(-k)(\gamma+\alpha_2 r)(2\alpha_2 kr(\gamma s+1)-2k(\gamma s+1)^2+r^2(\gamma+\gamma s+1)^2)}-2\gamma^2 ks+\gamma^2 r^2+\gamma r^2+\gamma^2 r^2 s}{\gamma(2\alpha_2(\gamma ks+k)+\gamma r(\gamma+\gamma s+1))}$

Proposition6 The optimal privacy information utilization (e^*) and the optimal price (p^*) and the platform's optimal profit (π^*) increase as users' perceived usefulness of the use of private information(s) and the basic revenue of advertisers rise(r).

4 Conclusions

With the rapid increase in the number of short video In-feed advertising, how to price the short video In-feed advertising and how to determine the utilization of privacy information is an urgent problem to be solved. Therefore, from the perspective of privacy concerns, this paper constructs a model about In-feed advertising pricing and privacy information utilization decising on short video platforms in a monopoly market, and determines the optimal advertisement price and the privacy information utilization that maximises the platform's profit.We conclude that users' privacy concerns will negatively affects the platforms' privacy information utilization.When users' privacy concerns is low, the platform reduces the advertising price and the platform profit decreases as the privacy concerns increases. The unit technology cost and users' advertising aversion will negatively affect the platform's privacy information utilization, advertising price and platform's profit, while the perceived usefulness of user privacy information utilization and the basic revenue of advertisers are the opposite. As the positive cross-network externality increases, the advertising price and platform's profit increase, and the platform's privacy information utilization increases first and then decreases.

The short video platform should pay attention to the users' privacy concerns, and can formulate the platform advertising price and the platform privacy information utilization by investigating users' privacy concerns in advance. When users are very concerned about their privacy, the platform can make greater profits by increasing advertising price. However, privacy control may weaken the user 's attention to privacy information. Future research can consider the impact of privacy control on users' privacy concerns.

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