

# Information collection and protection strategy based on platform competition model for advertiser and user

Haichao Yao<sup>\*, #</sup>, Mengwei Yang<sup>#</sup>

School of Economics and Management, Beijing Jiaotong University, Beijing, China, 100044

\*Corresponding author: 20711114@bjtu.edu.cn

<sup>#</sup>These authors contributed equally.

**Abstract.** In the era of digital economy, people pay more attention to the protection of users' personal information. The smart goods platform and advertisers who advertise on this platform understand the behavior and preferences of users by collecting users' personal information and undergoing professional processing and analysis. And accordingly, to provide users with corresponding personalized products and services, while improving consumer satisfaction and loyalty, you can obtain higher profits. However, the collection, processing and use of personal information by smart goods companies have raised privacy concerns among users. By establishing a model of the participation of the smart commodity platform, users and advertisers, analyze the amount of user data collected by the smart commodity platform and the degree of efforts made by the smart commodity to protect data for maximizing the interests of the three parties. Through balanced analysis and static analysis, it can be obtained that the total utility of the user increases first and then decreases. Under the premise that the smart commodity platform makes efforts to ensure the security of users' personal information, the profit of advertisers increases with the increase of users. As collecting too much user data can lead to the loss of some users and collecting too little amount of user data can lead to the platform losing some revenue from advertising. Therefore, smart goods platforms should collect a certain amount of user data and make certain efforts in data protection in order to maintain the balanced rights and interests of important stakeholders such as advertisers, users and themselves.

**Keywords:** User Privacy, Data Collection, Data Protection

## 1. Introduction

With the continuous development of the Internet of Things, cloud computing, 5G and other technologies, smart home has been rapidly developed. Smart home equipment through the Internet reaches to intelligent, convenient and comfortable lifestyle, making people's lives more convenient and intelligent<sup>[1]</sup>.

The popularity of smart home devices has not only changed people's lifestyles, but also brought risks to data privacy and security<sup>[2-3]</sup>. For example, the camera of a smart product will have the risk of leaking important personal information of users. Voice assistants in smart goods may eavesdrop on users' voice messages without their consent, and may even record sensitive user information, such as passwords, credit card numbers<sup>[4]</sup>. Privacy issues are important reasons why consumers are deterred from purchasing smart goods.

Young people are more concerned about privacy issues, and they are more concerned than other age groups about their personal information being shared or misused. Additionally, they are more inclined to protect their personal information, especially in social networks and mobile devices. However, young people are an important consumer group for buying wearable smart devices, and smart goods companies are not only obliged to protect consumers' personal information, but also attract more consumers to buy products<sup>[5]</sup>.

The research of domestic scholars on platforms, users and advertisers mainly focuses on how to price the platform and gives platform suggestions to maximize platform profits, and does not consider the balanced interests of the three parties. Xu Lu and others found that because users do not like advertising, the platform cannot attract as many as possible advertisers by reducing advertising prices

[6]. Therefore, it is necessary to consider the profit of both aspects of the platform to maximize the profit of the platform. In addition, most of the platforms that consider user privacy in the existing literature are online consumer platforms Taobao and Didi Chuxing [7]. Zou Jia and Guo Lihong studied the impact of different ways in charging user groups on the platform's profitability [8]. However, there is a lack of papers on the privacy considerations of smart commodity platforms. This paper considers the balanced interests of the platform, users and advertisers, which is in line with the optimal principle of social welfare and considers the user privacy issues existing in smart commodity platforms more specifically.

This article points out that part of the profits of smart goods companies come from consumers buying smart goods, and the other part is generated by advertisers advertising on smart goods platforms. Smart goods companies collect more consumer data, which can help advertisers deliver ads more precisely and help advertisers attract target consumers more quickly based on user characteristics. Collecting more consumer information can help attract more advertisers to advertise and increase the advertising revenue of smart goods companies. However, if a large amount of user personal information is collected, the loss to users when user information is leaked is greater, which reduces users' willingness to share data and purchase products [9]. This reduces the revenue from users for smart goods companies and requires more cost to protect data. The loss of users will also lead to fewer advertisements served on the platform. Therefore, smart home companies need to take effective measures to protect user data security and privacy, reduce the loss of the number of platform users, and balance the amount of consumer data collected, aiming to maximize the balance of profits between the three parties.

## 2. Platform competition model

There are three parties involved in the model, the smart goods company, the user and the advertiser. The model in this paper is based on Reisinger M the model of advertiser and user oriented platform competition, with the addition of factors such as the amount of data on personal information and the level of effort to protect it [10]. In addition, the model in this paper insures that smart goods companies that charge fees, while the model of Reisinger M insures that platforms do not charge fees [10].

### 2.1. User

For users, their interests are influenced by the following factors: firstly, the value  $V$  brought by the product itself, which refers to the value the product can bring to users excluding the "smart" features of intelligent goods; secondly, the service value  $u(t)$  brought by personal shared data  $t$ , which reflects the "smart" features of the product, provides additional value to users through data empowerment, and with the gradual increase of information sharing, the marginal benefit of this additional value is decreasing, which we express using logarithmic function to represent its weak concavity; thirdly, the value  $\beta e$  brought to users by the efforts made by intelligent product companies; fourthly, the risk  $(1 - e)t$  of personal information leakage, due to the strength of protection, users' personal information may still be leaked, causing a bad experience for users; fifthly, the tag price  $p$  of intelligent products, which users pay an economic value to obtain. Therefore, the user's benefit  $\pi_1$ :

$$\pi_1 = V + u(t) + \beta e - (1 - e)t - p \quad (1)$$

$$(P = m * demand(m < 0), u(t) = \ln t)$$

### 2.2. Advertiser

For advertisers, their main sources of profit are related to the number of smart product users  $demand$  and the amount of data shared by users  $t$ . In addition, the advertising fee  $n * q$  paid to the smart product company will also affect their overall profit, where  $n$  represents the number of

ads placed by the smart product company and  $q$  represents the unit price of the advertisement paid by the advertiser. Therefore, the profit  $\pi_2$  of the advertiser is:

$$\pi_2 = \partial * demand * t - n * q \quad (2)$$

### 2.3. Smart goods company

For smart product companies, the sales of smart goods, measured by  $(p - c) * demand$ , and the advertising fees paid by advertisers, measured by  $n * q$ , are sources of profit. However, in order to prevent the personal information data shared by users from being leaked, the company needs to make continuous efforts, which incurs a certain cost. Moreover, the cost increases faster with the increase of protection efforts, expressed as the square term  $k * e^2$ . Therefore, the profit of the smart product company, denoted as  $\pi_3$ , is:

$$\begin{aligned} \pi_3 &= (p - c) * demand + n * q - k * e^2 \\ (n &= a * q \ (a < 0), q = b * demand \ (b > 0)) \end{aligned} \quad (3)$$

## 3. Equilibrium and static analysis

### 3.1. User-advertiser equilibrium

Letting equation (2) be zero, we can obtain the demand for purchasing the product in the boundary case where the advertiser's interest is zero,  $demand = \frac{nq}{\partial t}$ . Solving equation (1) yields the partial derivative of the user's interest for  $t$

$$u'(t) - (1 - e) + m \frac{ddemand}{dt} = 0 \quad (4)$$

Since  $demand = \frac{nq}{\partial t}$ , the solution yields

$$q = \frac{\partial(-t+(1-e)t^2)}{mn} \quad (5)$$

$$e = 1 - \left(\frac{1}{t} + \frac{mnq}{\partial t^2}\right) \quad (6)$$

Analyzing equation (5), where  $m$  is negative, the equation can still be written as  $q = \frac{\partial(-(1-e)t^2+t)}{|m|n}$ , it can be concluded that the relationship between  $q$  and  $t$  is a quadratic function with an opening downward, so there will be a point  $t_0$  where  $q$  is the maximum, i.e.  $t_0 = \frac{1}{2(1-e)}$ . When  $t > t_0$ ,  $q$  decreases as  $t$  increases. It can be seen that when the smart goods company collects too much user data, the advertiser's advertising unit price will decrease, not that the bargaining power is higher as the user data increases.

Also, analyzing equation (6), it can be concluded that as  $t$  increases, the degree of protection of user information by the smart goods company increases in order to maintain the interests of all parties greater than 0. According to equation (4), it is concluded that

$$\frac{dUser\_benefit}{dt} = -(1 - e)t^2 + t + \frac{mnq}{\partial} \quad (7)$$

That is, the user interest decreases, then increases, and then decreases again as  $t$  increases. It can be seen that when there is too little information, the service gain brought by the information is less than the risk of information leakage. With further increase of information, the product can bring more personalized service, and the service gain brought by the information will be greater than the risk of information leakage. However, if too much information is shared, the service gain brought by the information tends to be stable. But the risk brought by information leakage will continue to increase, and the user benefit will decrease. If for the whole user population, solving for its partial derivative with respect to  $t$

$$demand_{total} = \frac{2mnq}{\partial t} + 1 - v - \ln t - \beta e = 0 \quad (8)$$

It can be obtained as  $t_1 = -\frac{2mnq}{\partial}$ , when  $t < t_1$ , the total benefit of the user group increases with the increase of the amount of data  $t$  shared. But when it exceeds  $t_1$ , the total benefit of the whole user group decreases with the increase of the amount of data  $t$  shared, which is consistent with the conclusion of the benefit of individual users.

### 3.2. User and smart goods company equilibrium

Analyzing equation (4) and simplifying it yields  $\frac{ddemand}{dt} = \frac{1-e-\frac{1}{t}}{m}$ . When the benefit of smart goods company is 0, solve the partial derivative of equation (3) for  $t$  and substitute  $\frac{ddemand}{dt} = \frac{1-e-\frac{1}{t}}{m}$  can obtain

$$(p - c) \frac{1-e-\frac{1}{t}}{m} + n \frac{dq}{ddemand} \frac{1-e-\frac{1}{t}}{m} = 0 \quad (9)$$

$$\frac{dq}{ddemand} = \frac{c-p}{n} \quad (10)$$

That is, when the number of users increases, the unit price of advertisement decreases instead. When the number of users decreases, the unit price of advertisement increases instead. Then solve the partial derivative of equation (2) for demand, and get  $t_2 = \frac{c-p}{\partial}$ . When  $t > t_2$ , the advertiser's benefit will increase with the increase of demand. Since  $t_2 < 0$  and  $t$  is positive, the advertiser's benefit must increase with the increase of demand, i.e., the more users buy smart goods, the more benefits the advertisement brings due to the more information it brings, and thus the advertiser's benefit will increase.

### 3.3. Triple equilibrium

Solving the partial derivative of equation (2) for  $t$  and substituting  $\frac{ddemand}{dt} = \frac{1-e-\frac{1}{t}}{m}$ ,  $\frac{dq}{ddemand} = \frac{c-p}{n}$ , we get

$$\partial t \frac{1-e-\frac{1}{t}}{m} + \partial demand - n \frac{c-p}{n} \frac{1-e-\frac{1}{t}}{m} = 0 \quad (11)$$

solve the boundary condition as  $t_3 = \frac{1}{1-e}$ , only when  $t < \frac{1}{1-e}$  can ensure that the advertiser's benefit is positively correlated with  $t$ . Therefore, the smart goods company needs to increase the degree of effort in order to collect more user information and ensure that the advertiser's benefit also increases. At the same time, the relationship between the amount of user information that the smart goods company can afford and the degree of effort to protect the information under the condition of positive multi-party benefit is clarified.

When the user's benefit is 0, solve the partial derivative of equation (1) for the degree of effort  $e$  yields, getting  $\beta - m \frac{ddemand}{de} = 0$ , i.e.  $\frac{ddemand}{de} = \frac{\beta}{m}$ . When the advertiser's benefit is 0, solve the partial derivative of equation (2) with respect to the effort level  $e$  and substitute  $\frac{ddemand}{de} = \frac{\beta}{m}$ , obtaining  $\partial t \frac{\beta}{m} - n \frac{dq}{ddemand} \frac{\beta}{m} = 0$ , and further solve to obtain  $\frac{dq}{ddemand} = \frac{\alpha t}{n}$ . To better analyze the effect of effort on the benefit of smart goods company, solve the partial derivative of equation (3) with respect to  $e$ , and get

$$(p - c) \frac{\beta}{m} + n \frac{\alpha t}{n} \frac{\beta}{m} - 2ke < 0 \quad (12)$$

It shows that the portion of the increase in demand, and thus the increase in revenue, that results from the smart goods company's behavior of making more effort to protect customers' private data is insignificant compared to the cost of protection paid for this process.

### 3.4. Static Analysis

To better clarify the extent to which smart goods companies collect information about their users, and the extent to which they use it. Combined with the dynamic analysis in the previous part, if the smart goods company excessively increases the amount of user information  $t$ , it will make the number of users in this platform demand appear to decrease, and the advertising unit price  $q$  decreases, which makes advertisers think that the value of placing ads on this platform decreases and reduce the advertising expenditure in this company, and the danger of information leakage brought by users due to excessive sharing of information far exceeds the sharing of information. This behavior is not conducive to achieving tripartite equilibrium for the three parties.

Therefore, it is necessary to set an interval for  $t$ . First, we need to ensure that  $t < \frac{1}{1-e}$ , so that the advertiser's benefit is positively related to the size of  $t$ . Also, for a single user,  $t$  should be located in the interval  $[\frac{1-\sqrt{1+4(1-e)\frac{mnq}{\partial}}}{2(1-e)}, \frac{1+\sqrt{1+4(1-e)\frac{mnq}{\partial}}}{2(1-e)}]$ , so that a single user will increase as  $t$  increases. For the whole group of users, the amount of information shared,  $t < -\frac{2mnq}{\partial}$ , makes the benefit of the whole group of users positively correlated with the size of  $t$ .

In this range, increasing the value of  $t$ . For advertisers, although an increase in  $t$  makes the demand decrease, the advertiser's benefit increases with  $t$  because the smart goods company is able to protect user information well, i.e.,  $t < \frac{1}{1-e}$ . And the decrease in the number of users is not significant relative to the increase in  $t$ . For users, it is necessary to compare the size of the conditional upper and lower bounds of individual users and groups. In order to ensure that the changes in the benefits of individual users and groups are in the same direction, as the interests of groups are rising while the interests of individual users are also rising, the users will engage in such behavior and also

increase the benefits of the entire group of users. Therefore  $\frac{1-\sqrt{1+4(1-e)\frac{mnq}{\partial}}}{2(1-e)} < -\frac{2mnq}{\partial}$ , i.e.  $1 + \frac{\partial}{4mnq} < e$ . Also, for the smart goods company's side, the increase in the information charged and the decrease in the demand will make the  $q$  increase and the increase in the revenue brought by the advertisement. This is because if the smart goods company chooses to charge a small amount of user information in order to get more users, it makes the demand increase. But at this time, because the personal information provided by the user is too small for personalized advertising push, which makes the benefits of advertising bad and advertisers will reduce the advertising expenditure on the smart goods company. So in order to maintain the revenue in terms of advertising, the smart goods company needs to maintain a certain amount of  $t$ . For this reason, although the lower the level of effort for the smart goods company, the higher its revenue will be, the smart goods company needs to maintain the level of effort satisfy  $1 - \frac{1}{t} < e$  for the purpose of tripartite equilibrium and the revenue from the amount of information collected. Therefore, considering the equilibrium of the three parties' interests and maintaining the larger value of the parties' interests, it is necessary to make  $t$ ,  $e$  satisfy the conditions as described above.

## 4. Conclusion

This paper mainly discusses the influence of data collection and effort level controlled by smart goods company on smart goods company itself, advertisers and users through equilibrium and static analysis. Specifically, for equilibrium analysis, as the user data increases, the advertising price of advertisers will decrease; the individual user's benefit will first decrease, then increase, and then

decrease again; the total benefit of the user group will first increase and then decrease. As the number of users increases, the advertising price will decrease; the benefit of advertisers will increase. For static analysis, in the interval where  $t$  is located in  $[\frac{1-\sqrt{1+4(1-e)\frac{mnq}{\partial}}}{2(1-e)}, \frac{1+\sqrt{1+4(1-e)\frac{mnq}{\partial}}}{2(1-e)}]$  and  $t$  value is less than  $-\frac{2mnq}{\partial}$ , satisfying  $1 - \frac{1}{t} < e$  can achieve a three-party balance of interests, maintaining the maximum values of interests for all parties. In conclusion, this paper is instructive in terms of the extent of user data collection and data protection for smart goods companies.

## References

- [1] Yang Bing, Wang Lin. Research on communication customer service mode under the background of 5G technology. [J].Shandong Social Sciences,2020,No.294(02):112-118.
- [2] Lin Shanshan, Jiang Zhengtao, Li Huiqiang. Analysis of smart home security and privacy issues in the Internet of Things environment [J]. Confidential science and technology, 2021, No.125(02):40-45.
- [3] Feng Tong. Research on smart home device APP and data security protection method[D]. Northwest University, 2020.
- [4] Zhou Min, Qian Peng. Research on the evolution of personal data protection and excessive collection of apps under government supervision [J]. Intelligence exploration,2020(11):8-18.
- [5] Zhu Shuwei,Zhang Hao. Intelligent recommendation analysis of new retail products based on scene characteristics and data [J]. Business Economic Research,2019, No.785(22):87-90.
- [6] Xu Lu, Ye Mi, Wang Yuqian. Platform competition and pricing strategy for advertisers and users [C]//Chinese Management About Modernization Research Association, Fudan Management Award Foundation. Proceedings of the 17th (2022) China Management Annual Conference. [Publisher unknown],2022:463-467.
- [7] Bao Lei, Zhao Wenxuan, Zhang Xuan. Research on the Competitive Model of Online Platforms Considering Consumer Privacy [J]. Journal of Jiangxi Normal University (Natural Science Edition),2023,47(01):36-44.
- [8] Zou Jia , Guo Lihong . A study on bilateral platform price model based on seller's decentralized decision [J]. Soft Science,2017,31(06):139-144.
- [9] Yang Man, Wen Xiuyan. Mediating Effects of Privacy Protection Willingness: Privacy Concern, Privacy Protection Self-efficacy and Precision Advertising Avoidance [J]. The Press,2020(07):41-52.
- [10] Reisinger M . Platform competition for advertisers and users in media markets[J]. International Journal of Industrial Organization, 2012, 30(2):243-252.