An Economic Framework for Information Platform

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***Abstract*—Information platform is managed by IPSPs (Information Platform Service Providers) who aggregate and compile information from a large pool of source websites supported by Source Service Providers (SSPs). While information platform makes it much more convenient for users to browse information, there exists such an economic dilemma: Information platform may send extra user clicks to source websites (thus increasing SSPs' advertising revenue), some users get stuck on the information platform since information excerpts are presented. In this case, SSPs tend to accuse IPSPs of intellectual property infringement. To boost the development of information platform, it is better to make IPSPs and SSPs allies rather than enemies. In this paper, we propose a business framework which involves a single IPSP and multiple SSPs. Within the framework, IPSP gets paid for the user clicks sent from information platform to the source websites and SSPs donate certain amount of information to information platform. We formulate the framework as a two-stage game, assuming that IPSP and SSPs are selfish and rational players who target at utility maximization. We use backward induction to get Nash Equilibrium of the game and give the best strategies for IPSP and SSPs. The numerical results have shown that the enhancement of information quality provided by source websites and increased non-material profit of information platform will improve IPSP's utility. In addition, the price charged by IPSP for user clicks and aggregated information contributed by SSPs are also affected by these factors.**

I. INTRODUCTION

Information Platform refers to a system that does not produce information itself but integrates information with similar features from various source websites and presents the information to the consumers. A good example of information platform is Google News, which is an automated news aggregator developed by Google Inc. Specifically, Google News collects news from different publishers and displays the news at a single platform for users to view. In this way, readers are encouraged to get a broader perspective by digging deeper into the news.

Information platform initiates an efficient, multi-angle and content-oriented way for users to browse contents on the Internet. Usually, information platform presents an excerpt of the information for viewers to get a rough idea of the topic. Users who want to get a more detailed knowledge of the news would be redirected to the source websites by clicking the collection of links listed below the excerpt. Therefore, viewers are spared from the inconvenience of resorting to a number of websites until desired information is acquired. Many of the current information platforms are ad-free so that users can be more focused on the information itself without being distracted by annoying advertisement.

The emergence of information platform may create an exciting and promising market for both IPSPs and SSPs. As the owner and operator of information platform, IPSPs can take advantage of high viewer-visit-rate to make money. In addition, the information platform can complements the functionalities of some Internet companies who also provide a number of other services. For example, with Google News, users are more likely to use other Google services for sake of convenience. SSPs can also benefit from information platform. For obscure SSPs, information platform established by renowned IPSPs helps to extend their fames. For well-known SSPs who already enjoy public recognition, more users can be redirected to their websites since they often top the search results on the information platform.

Despite its many advantages, information platform faces both technical and economic challenges. In this paper, we mainly focus on the economic issues.

1) Lack of cooperation between IPSP and SSPs. Quite a few SSPs, especially prestigious ones, are afraid that users will go to information platform instead of directly to the source websites, thus reducing their advertisement revenue. And they resist information platform by resorting to intellectual property protection [1]. However, to simply block information platform may not be the best strategy for SSPs. It will be mutually beneficial if IPSPs and SSPs can reach an agreement that reciprocates both sides.
2) Lack of income source for IPSP. Focusing on information delivery, some IPSPs choose to run their information platform ad-free, thus gaining no revenue from advertising. Whereas IPSPs have to cover the cost of normal operation of information platform and also need funding for research and development.
3) Competition among SSPs for higher click though rate. SSPs mainly get their revenue from online advertising, which is primarily decided by the page-view rate of their websites. While information platform sends extra users to source websites, some SSPs may complain about low click through rate because their links are ranked at bottom on the information platform. SSPs compete with each other for ranking results on the information platform. SSPs that choose to block or provide little information to information platform will be at a competitive disadvantage if other SSPs welcome the information platform.

As far as we are concerned, there are few research works directly addressing the economic issue of information platform

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and the relationship between IPSP and SSP. One might argue that the business model of search engine advertising or sponsored search advertising is similar, in which advertisers pay the search engine to put the ads on the search results page [2] [3] [4]. However, to help users focus on the information itself, it is better for information platform to be ad-clean (such as Google News). Thus there is no income source for IPSP. Another business model is the website agency [5] [6] that helps users purchase certain kind of commodities or services, such as books or hotel stays, which are not provided by the website itself. Information platform is unlike the website agency and "information" is unlike common goods. Users of website agency are sure to go to the source websites to finish the deal. Unfortunately, many viewers get stuck at the information platform, simply satisfied with the information excerpt there, and never go to the source websites for the whole story. If so, there is no advertising profit for SSPs, who is therefore reluctant to let IPSP cite their information and more sensitive about their copyright.

To address the above challenges regarding information platform, we proposed a business framework which involves a single IPSP and multiple SSPs. In this framework, IPSP decides to run its information platform ad-free. To earn profit, IPSP charges SSPs for user clicks sent by information platform to their source websites. SSPs grant IPSP the right to include their contents in the information platform, but impose a restriction on how many contents can be taken. The ranking results, determined by IPSP, will depend on the contribution of each SSP to the information platform. IPSP and SSPs are rational and selfish, aiming at profit maximization. The contributions of the paper are as follows:

1) We propose an economic framework for information platform, which brings commercial benefit for both IPSP and SSPs, thus promoting the future development of information platform. The framework also takes into consideration the influence of position bias on the click through rate of each SSP's source website.
2) We formulate the framework as a two-stage game, in which IPSP and SSPs try to maximize their utility by choosing optimal strategies. We use game theory to work out the Nash Equilibrium for the game.
3) We evaluate the economic model via simulation. Numerical results have shown that the utility of IPSP increases with information quality provided by source websites as well as non-material profit generated by information platform. We also analyze how the price charged by IPSP for user clicks and aggregated information contributed by SSPs are affected by the above factors.

The rest of the paper is organized as follows. In section II, we outline the economic framework, introducing click through rate and presenting utility functions for IPSP and SSPs. We use theoretical analysis to determine the optimal strategies of IPSP and each SSP in section III. Simulation results are given in section IV and the whole work is summarized in Section V.

II. System Model

In this section, we first give a brief description of the business framework of the information platform. Then, we introduce the concept of click through rate. Finally, we analyse the utility that IPSP and SSP can derive from the successful implementation of information platform.

A. General Business Framework

In this paper, we consider a business framework consisting of a single IPSP and multiple SSPs. IPSP runs an information platform, being in charge of daily maintenance and technical support. Instead of producing information itself, IPSP hopes to gather information from various SSPs. We assume that there are a total number of N SSPs in concern, each of whom possesses its own websites and produces the original information. Let $\{S_i\}_{i=1}^N$ represent the set of SSPs. Both IPSP and SSPs are rational and selfish entities, whose ultimate objectives are utility maximization.

The information platform is ad-free, i.e., only news abstracts are shown. Therefore, the information platform does not yield any advertising revenue for IPSP. In order to cover the operational and capital cost, IPSP charges SSPs for sending extra viewers to their source website. We assume that IPSP asks for a unit price of α for each click that is directed from information platform towards the source websites. Let α_0 denote the highest price that SSPs are willing to pay for each click.

B. Click Through Rate

The concept of click through rate was first introduced to study the effectiveness of online advertisements [7]. We define click through rate of a particular source website as the ratio of viewers who click the link towards the source website to the total number of viewers who visit the information platform. Let T_i denote the click through rate for S_i.

Although the information platform presents the relevant information to viewers at the same time, the information is biased due to many reasons. A key factor that influences click through rate is ranking results. The existence of position-bias in click through rate has been proved by a great number of experiments [8] [9] [10] [11]. Eye-tracking experiments show that the user is less likely to examine results near the bottom of the list [11]. In case of information platform, the situation is even worse because after reading the excerpt presented on the information platform, many users get stuck there and never bother to go to the original source to view the whole story. According to Cascade model, users browse the information from the top to the bottom, the click through rate of S_i is the probability that a user deciding to click the link multiplying the probability that the user skipping all the ranks above [8].

$$T_i = \lambda_i \prod_{k=1}^{R(i)} (1 - \lambda_{R^{-1}(k)}) \quad (1)$$

in which $R(i)$ is a ranking function which maps S_i to a rank in the resulting list, determined by IPSP; λ_i is the underlying

”snippet relevance” of each piece of news, decided by internal quality of the news provided by S_i; $R^{-1}(k)$ is the SSP who is ranked at the kth position. We make the simplifying assumption that $\lambda_1 = \lambda_2 = ... = \lambda_N = \lambda$. Therefore, the click through rate is

$$T_i = \lambda(1-\lambda)^{R(i)} \tag{2}$$

C. Rank Result

According to (2), the ranking results directly affect click through rate. Naturally, IPSP will rank the links towards different source websites according to their ”contribution” to the information platform. Let I_i denote the amount of information that S_i allows IPSP to put on the news aggregator. I_i is a conceptual value. It can represent the number of pictures or the length of text. The ranking result of S_i depends on S_i's proportional donated contents.

$$R(i) = r\frac{\sum\limits_{j \neq i} I_j}{\sum\limits_{j=1}^{N} I_j} \tag{3}$$

in which r is a constant parameter. The more information an SSP contributes, the lower its rank will be.

D. Utility of IPSP

The utility of IPSP consists of two parts: revenue from click through rate and non-monetary benefits. Non-monetary benefits come from increased user loyalty since the implementation of information platform complements other online services provided by the same IPSP.

The Sigmoid function has been widely used for estimating the satisfaction of users with regard to service quality [12]–[17]. In this paper, we employ Sigmoid function to quantify the intangible utility of IPSP. The utility of IPSP is the sum of the proceeds from click through rate and the non-material interests:

$$U = \alpha \sum_{i=1}^{N} (T_i V) + \frac{\omega_I}{1+e^{-I}} \tag{4}$$

in which V is the total number of viewers who arrive at the information platform, $I = \sum\limits_{i=1}^{N} I_i$ is the total amount of information gathered by information platform, and ω_I is the parameter to quantify the non-material profit of information platform. In Sigmoid function, there is an information threshold below which the viewers generally consider the quality of information platform to be very poor and obtain very limited satisfaction. However, when the quantity of information is above the threshold, viewers' contentment increases rapidly with I and finally reaches an asymptotic value, where the quantity of information is no longer the determinant factor of the user satisfaction.

E. Utility of SSP

SSPs gain profit from advertising revenue, which is closely associated with the page-view-rate of their source websites. Apart from the viewers who directly visit the source websites, SSPs also receive extra viewers forwarded by information platform.

The expense of SSP is two-fold: payment to IPSP for clicks and cost for producing original information.

The utility of S_i is defined as its advertisement returns minus its expenditure on re-directed clicks and information production:

$$U_i = \omega_c \ln(T_i V) - \alpha T_i V - c_i I_i \tag{5}$$

in which c_i is the unit cost of producing information; ω_c is the parameter to quantify SSPs' advertisement revenue. Advertising revenue is characterized by a natural logarithmic function, which conforms to the common economic rule that the marginal revenue is decreasing in the clicks [18] [19].

III. Theoretical Analysis

In this section, we formulate the business framework of information platform as a two-stage game. We prove that Nash Equilibrium exists for the game, which defines the optimal strategy for the IPSP and each SSP.

The game proceeds through two stages. In the first stage, the IPSP attempts to maximize its utility by selecting the best unit price for clicks. In the second stage, on observing the price α, each SSP determines simultaneously how much information to contribute. As SSPs are selfish and rational players, we use non-cooperative game to study their competition for rank result on information platform. We use backward induction, a common tool to derive Nash Equilibrium in multi-stage games.

A. Information ”War” among SSPs

The ranking result of a particular SSP does not only rely on its own contribution, but also subjects to those of other SSPs.

Let I_{-i} represent the strategy of all S_i's components. Given I_{-i}, S_i always chooses the information amount that can yield maximum utility, namely $I_i^* = \arg\max\limits_{I_i} U_i(I_i, I_{-i})$. This strategy is often called the best response of S_i. In a non-cooperative game, a player has no incentive to deviate from its best response because any alteration will decrease its utility.

Proposition 1: When the following condition

$$\alpha_0 V \lambda < \omega_c \tag{6}$$

is satisfied, given I_{-i}, the best response of S_i is

$$I_i^* = I - \frac{I^2 c_i}{r\ln(1-\lambda)\{\alpha V \lambda[1 + r\ln(1-\lambda)] - \omega_c\}} \tag{7}$$

.

Proof:

The first and second derivative of U_i with respect to I_i are

$$\frac{\partial U_i}{\partial I_i} = r[-\omega_c + \alpha V \lambda (1-\lambda)^{R(i)}]\ln(1-\lambda)\frac{\sum\limits_{j\neq i} I_j}{I^2} - c_i \tag{8}$$

$$\frac{\partial^2 U_i}{\partial I_i^2} = r\frac{\sum_{j\neq i} I_j}{I^4}\ln(1-\lambda)\{2I[\omega_c - \alpha V\lambda(1-\lambda)^{R(i)}] - \alpha V r\lambda(1-\lambda)^{R(i)}\sum_{j\neq i} I_j \ln(1-\lambda)\} \tag{9}$$

Given condition (6), it can be easily prove that the second derivative of U_i with respect to I_i is less than zero so that U_i is concave in I_i. Maximum U_i can be achieved when the first derivative of U_i with respect to I_i equals zero. (We use the approximation that $(1-\lambda)^{R(i)} \approx 1 + \ln(1-\lambda)R(i)$) ■

If every SSP employs the best response with regard to other SSPs' decisions, no SSPs have motivation to change their strategy unilaterally. In this case, the non-cooperative game among SSPs reaches the Nash Equilibrium.

Proposition 2: There exists a Nash Equilibrium for the non-cooperative game among SSPs and the optimal value of I_i is

$$I_i{}^* = \frac{I}{C}[C - (N-1)c_i] \tag{10}$$

where $C = \sum_{i=1}^{N} c_i, I = \frac{r(N-1)\ln(1-\lambda)}{C}\{\alpha V\lambda[1 + r\ln(1-\lambda)] - \omega_c\}$.

Proof:

Jointly consider the best response of every SSP, that is, solve the equations set which consists of N equations, the results can be easily obtained. ■

B. Best Pricing Strategy of IPSP

IPSP is aware of the impact of its pricing strategy on the information contribution of each SSP. Once the IPSP set the price, the SSPs react according to proposition 2. Based on this knowledge, WSP is able to choose the optimal unit price in order to procure maximum utility.

Proposition 3: When the condition

$$\omega_I K_2 - 2K_1 > 0 \tag{11}$$

is satisfied, IPSP maximize its utility if and only if the price-per-click is set as

$$\alpha^* = \begin{cases} \alpha_m, \alpha_m \leq \alpha_0 \\ \alpha_0, \alpha_m > \alpha_0 \end{cases} \tag{12}$$

In which

$\alpha_m = \frac{K_3 - I}{2K_2}, I = \ln\frac{\omega_I K_2 - 2K_1 + \sqrt{4\omega_I K_1 K_2 + \omega_I^2 K_2^2}}{2K_1}, K_1 = \lambda V\sum_{i=1}^{N}(1-\lambda)^{r(N-1)c_i/C}, K_2 = K_3 V\lambda[1 + r\ln(1-\lambda)], K_3 = \frac{-\omega_c r(N-1)\ln(1-\lambda)}{C}$.

Proof:

The first and second derivatives of U with respect to α are:

$$\frac{\partial U}{\partial \alpha} = K_1 - \frac{K_2\omega_I e^{-I}}{(1+e^{-I})^2} \tag{13}$$

$$\frac{\partial^2 U}{\partial \alpha^2} = -\frac{K_2^2\omega_I e^{-I}}{(1+e^{-I})^3}(1 - e^{-I}) \tag{14}$$

The second derivative of U with respect to α is less than zero so that U is concave in α. By forcing (13) to be zero, we can get two roots for e^{-I}. When condition $\omega_I K_2 - 2K_1 > 0$ is satisfied, both roots are positive and their multiplication equals 1. Since $I > 0$, $e^{-I} < e^0 = 1$. We choose the smaller root and get the local maximum point α_m. If $\alpha_m > \alpha_0$, U keeps increasing with α, so IPSP will set α to be highest possible value, namely the reserve price α_0 of SSPs. ■

TABLE I
SIMULATION PARAMETER

Parameter	Description	Value
N	Number of SSPs	100
r	Ranking parameter	2
ω_c	Advertising profit parameter	30
V	Visit rate of information platform	1
λ	Information quality	0.3
ω_I	Non-material profit parameter	1000

IV. SIMULATION RESULTS

In this section, we evaluate the economic framework for information platform through simulation. Due to page limitation, we cannot present all the simulation results. We mainly focus on how the information quality λ and non-material profit parameter ω_I affect 1) the utility of IPSP; 2) unit price of clicks and 3) information provided by SSPs. The values for each parameter listed in Table I. We assume that c_i follows Gaussian distribution with mean 1 and variance 0.01.

When the quality of information collected by information platform increases, users are more satisfied, which contributes to the non-material profit of IPSP. At the same time, user click through rate also increases due to high information quality, bringing more advertising revenue for SSPs. In this case, IPSP has incentive to ask SSP for higher price of each click, as shown in Fig.2. Total information gathered by information platform decreases (as shown in Fig.3) owing to two reasons. On one hand, high price of clicks drags down information supply from SSPs. On the other hand, IPSP needs less information because of high information quality. On the whole, utility of IPSP will be improved (as shown in Fig.1) if general information quality is enhanced.

The higher ω_I is, the higher the non-material profit information platform brings about. Hence, utility of IPSP keeps rising with ω_I as shown in Fig.4. IPSP also expects more information from SSPs because every piece of information generates higher non-monetary profits. Therefore, IPSP sets a lower unit price for each click in order to lure SSPs to contribute more information. Fig.5 shows that the price per click drops when the non-material profit parameter increases.

V. CONCLUSION

In this paper, we propose a business framework for successful implementation and operation of information platform. In the framework, SSPs allow IPSP to access a certain amount of their information and IPSP ranks the links towards SSPs' source websites according to how much information each SSP offers. IPSP not only obtains revenue by "selling" clicks

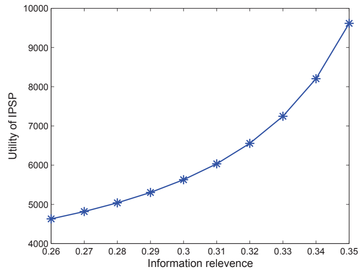

Fig. 1. Utility of IPSP U versus the information quality.

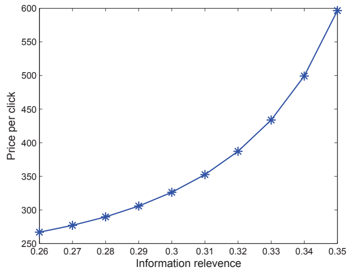

Fig. 2. Price per click versus information quality.

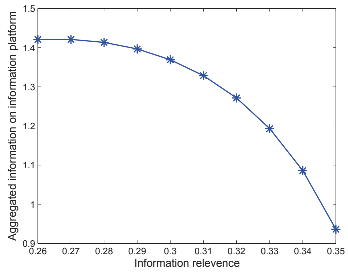

Fig. 3. Aggregated information of information platform versus information quality.

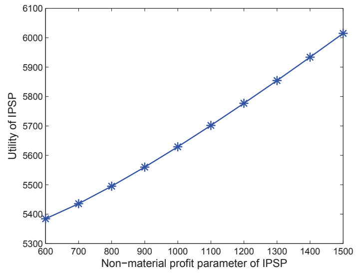

Fig. 4. Utility of IPSP versus non-material profit parameter ω_I.

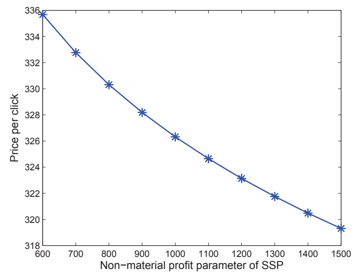

Fig. 5. Price per click versus non-material profit parameter ω_I.

to SSPs, but also gains fame by providing comprehensive services to Internet users. SSPs benefit from increased number of viewers who click through the links on the information platform to their source websites at the cost of paying IPSP for each received click. We formulate the business framework as a two-stage game, in which each SSP maximizes its individual utility by choosing the right amount of information for IPSP to access and IPSP tries to achieve highest utility by strategic pricing. We prove that the game has a Nash equilibrium and give the optimal strategies for IPSP and SSPs respectively. We conduct numerous experiments to evaluate the framework. We find that the utility of IPSP ascends with the information quality and non-material profits of information platform. The pricing decision of IPSP and information supply decision of SSPs are influenced by multiple factors.

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