Routledge
Taylor & Francis Group

International Journal of Electronic Commerce

ISSN: 1086-4415 (Print) 1557-9301 (Online) Journal homepage: http://www.tandfonline.com/loi/mjec20

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To cite this article: Wei Zhou , Subhajyoti Bandyopadhyay , Hsing K. Cheng & Praveen Pathak (2008) A Mechanism for On-line Advertisement Placement to Deter Click Fraud, International Journal of Electronic Commerce, 13:2, 9-28

To link to this article: https://doi.org/10.2753/JEC1086-4415130201

Published online: 08 Dec 2014.

A Mechanism for On-line Advertisement Placement to Deter Click Fraud

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ABSTRACT: The principal-agent problem of the on-line advertising market is investigated with respect to the publisher, the coordinator, and the advertiser. The publisher-coordinator contract is a double-sided moral hazard problem; the coordinator-advertiser contract is a double moral hazard problem with the agent's effort observed. These findings are compared to the auction-based model, and the cause and conditions of click fraud under both models are explained. The discussion shows that an efficient market deters click fraud, but an auction-based market is unable to achieve full efficiency.

KEY WORDS AND PHRASES: Click fraud, double-sided moral hazard, on-line advertising.

On-line advertising revenue has been growing phenomenally over the past few years, reaching nearly $17 billion in 2006, which represents an increase of 35 percent over 2005 [17]. Compared to traditional media, such as outdoor advertising, business paper advertising, and TV advertising, the Internet has proved to be an equally, if not more, important advertising medium that is much more accountable and measurable. With the booming of Web ads, many Web content providers have adopted business models that maximize their revenue by selling advertising space to advertisers and providing free service to on-line viewers.

The growth of on-line forms of expression like Web logs and wikis has greatly expanded the avenues for ad placement. The on-line media have literally thousands of Web sites in the form of Web logs that cater to loyal niche audiences. The low cost of setting up Web sites (Web log accounts can be signed up for free) has enabled individuals to express their ideas and expertise to their audiences in ways unavailable in traditional media. Such loyal audiences are valuable to advertisers because their profiles are much better defined than in traditional media, and therefore they are probably much more mindful of targeted ads.

In the early days, on-line advertisers and publishers borrowed the *cost-per-thousand-impressions* (CPM) pricing model from the traditional advertising media. In this model, the advertiser is charged a flat fee for site exposure, and actual performance is let alone. In the context of CPM pricing, given that a Web page has only a limited amount of space for advertising, great effort is devoted to efficiently scheduling Web ads with specified constraints and certain performance measures [1, 6, 16]. As opposed to the CPM model, *performance-based models* make the advertiser pay the publisher a fixed amount for every click or every purchase (i.e., only when a customer takes action in response to the ad). An Internet user who enters a Web site with on-line advertising of certain keywords gets back a page with normal Web content as well as a number of Internet advertisements embedded in the page. The ads are clearly

International Journal of Electronic Commerce / Winter 2008–9, Vol. 13, No. 2, pp. 9–27.

1086-4415/2009 $9.50 + 0.00.
DOI 10.2753/JEC1086-4415130201

distinguishable from the Web content, and the same Web page may provide different users with different ads at different times. While advertisers target their ads based on keywords, Internet advertising coordinators arrange to place the many ads on the different Web requests at different times. For example, if a car dealer buys the word “Chevy,” then each time a user browses a Web page with keyword “Chevy,” a link to the car dealer may appear on the requested Web page. A user who clicks on the ads link is sent to the advertiser’s Web page. The advertiser then pays the Internet advertising coordinator for sending the user to its Web page on a pay-per-click basis. In the context of performance-based models, many companies have adopted ad *targeting* that matches viewer profiles and behavior to related ads in order to enhance the advertising performance [3].

Performance-based models may be more effective, but they are susceptible to agency issues. Specifically, the proprietor of a Web page is paid for the number of ads clicked. In the absence of effective monitoring, this gives the proprietor an incentive to manufacture fictitious clicks that will not generate revenue for the advertiser—in other words, to engage in a form of click fraud.

The discussion in this paper models the interaction between the advertiser, the proprietor of the Web page where the ad appears (hereinafter called the publisher), and the coordinator in between these two entities.

The on-line advertising coordinator, such as Google (through its AdWord/AdSense program), MSN (AdCenter), or Yahoo, plays an important role in this industry. It bridges the many Internet publishers with the many potential advertisers. Publishers and advertisers can be virtually anywhere in the world and do not necessarily know each other. The on-line ads coordinator chooses appropriate advertisements relevant to the publisher’s Web content and places them on the publisher’s Web page. Since poor matching results in low user interest and consequently a low click-through rate, the coordinator’s performance directly influences the efficiency of the on-line advertising.

The Internet publisher, by providing spaces for ads, is the “landlord” of the Internet estate. The publisher has the right to work either with a coordinator or directly with the advertisers. A publisher that chooses to find advertisers for itself retains all the revenue but has to bear the cost of searching for the most suitable content in the very dynamic world of on-line content. A publisher that chooses instead to work with a coordinator pays a proportion of its revenue to the coordinator as a commission for the searching service. While some large Web sites negotiate their ad contracts with the advertisers directly and are able to provide customized ads, most mid-size to small Web sites subscribe to a coordinator service to circumvent the searching and negotiating costs.

The advertiser wants to promote its product or service through the medium of the Internet. Like the publisher, the advertiser can use a coordinator and pay its fee or can negotiate a contract with the publisher and bear the searching costs.

The third entity in this model is the body of Internet users whose purchases drive the entire model. The advertiser benefits directly from the Internet users’ patronage. If the advertiser uses a coordinator, it pays a fee to the coordinator. The coordinator retains a portion of the revenue as commission fee and pays the rest to the publisher.

Internet advertisers nowadays face inflated advertising fees in the form of the on-line fraud known as click fraud. Click fraud usually involves programs that automatically surf Web sites and click on the ads therein to increase traffic figures for an advertiser [7, 12, 19, 20]. Sometimes a click fraud perpetrator will hire cheap human labor to do the job (see, e.g., [22]). This leads to exaggerated fees for the advertisers based on nonexistent consumers. The publisher and the coordinator benefit from the crime because they share the excess paid fees from the advertiser.

Pricing Mechanism: Auction vs. Contractual Arrangement

In the early days of Internet advertising, ads were largely sold on a CPM basis with predesigned contracts. Starting in the late 1990s, a new model based on auction was introduced, and since then it has been the most popular method for selling Internet ads. In the auction-based model, each advertiser place a bid indicating its willingness to pay per click. The links to advertisers are arranged in descending order of bids such that highest bidder has the most outstanding position. Although the auction-based mechanism is easy to use and has very low entry costs, it is unstable because bids can be changed very frequently [11].

This paper investigates a principal agent contractual arrangement between the three parties—the advertiser, the publisher, and the coordinator. The coordinator knows both the publisher and the advertiser. It is assumed that the coordinator knows the approximate per click profit for the advertiser, charges a proportion of the profit (from zero to one) for its service, and distributes a share of the service charge to the publisher as the latter’s rent, retaining the rest for itself. A simple double-sided moral hazard model is used because the contractual arrangement involves revenue or profit sharing [4]. The publisher-coordinator relationship can therefore be described as a double-sided moral hazard problem, whereas the advertiser-coordinator relationship is modeled as a double moral hazard problem with the agent’s effort publicly observable. The model is further extended by adding the element of click fraud. The results demonstrate, theoretically, that the equilibrium pricing strategy has the power to deter click fraud.

Literature Review

Researchers have only recently begun to study the Internet advertising industry. Hoffman and Novak introduced several pricing models for Web advertising based on the relative degree of risk taken by the publisher and the advertiser [13]. One of these was the CPM pricing model, which originated from traditional media advertising. In this model, advertisers pay a fixed fee to the publisher in exchange for space for their ads on its Web page. The publisher does not bear any risk in this arrangement, with the advertiser taking all the risks. In contrast, in a performance-based pricing model (e.g., cost-per-click [CPC]), the advertiser is paid more for better ad performance. Chickering and Heckman used a hybrid pricing model, collecting statistical data on click-throughs and estimating the click-through probability for each ad in each segment to maximize the click-through rate, given the inventory-management constraints in the form of ad quotas [5].

Several researchers have looked at the implications for the placement of on-line ads. For example, Varian analyzed the equilibria of a game based on the advertisement auction used by Google and Yahoo, while Mehta et al. considered the problem for the advertisement coordinator on deciding on which advertisements to display so as to maximize revenue [15, 21]. Of interest too are Ilya's results, which proved that the optimal pricing mechanism in a multi-unit auction (like the ones observed in the Google and Yahoo ad auctions) sets a price for each buyer on the basis of the demand distribution inferred statistically from other buyers' bids [14].

The potential revenue of advertisement-supported Web sites is maximized by optimization schemes that place more ads on the same Web page by space sharing, using the same advertising space to display several different ads. A mechanism for effective scheduling of advertisement space was introduced by Adler, Gibbons, and Matias [1]. Menon and Amiri further explored the optimization problem when planning horizons are smaller than scheduling horizons [16]. A basic heuristic for space sharing is to allow customers to specify the number of copies of an ad to be displayed and then have the selected ads run exactly that number of times. Aggarwal, Goel, and Motwani noted that a truthful auction is equivalent to a nontruthful auction in terms of the revenue each generates [2].

Advertisements are not absolutely free to the users. As in other media, ads clutter up the Web page, reduce the amount of valuable content visible, and increase download time, causing disutilities to the end-user [9]. Dreze and Zufryden showed that the number of ads on a Web page affects the effectiveness of advertising [10]. Dewan, Freimer, and Zhang further studied the trade-off between the amount of advertising and its effect on Web site profitability and attractiveness to potential visitors [8]. They found that an initial investment in the intrinsic quality of the Web content with fewer ads brings in more ads later.

The auction mechanism continues to be the predominant pricing model in the on-line advertising industry. Edelman, Ostrovsky, and Schwarz investigated the generalized second-price (GSP) auction used by on-line advertising coordinators such as Google [11]. Their analysis showed that GSP has a unique equilibrium—an *ex post* equilibrium with the same payoffs for all players as the dominant strategy equilibrium of the Vickrey-Clarke-Groves (VCG) mechanism.

The contractual arrangement problem in the on-line advertising industry involves a form of profit sharing that can be described as a double-sided moral hazard model. Bhattacharyya and Lafontaine examined resale price maintenance using the double moral hazard model [4]. Romano studied the double-sided moral hazard problem and the nature of shared contracts [18]. They developed a simple double moral hazard model of contractual arrangements involving revenue or profit sharing, such as franchising, sharecropping, and author-publisher contracts. Their research proved that a linear contract can be optimal and that the optimal contract terms are independent of the scale of operation or cost of effort of the parties to the contract.

Structure and Pricing Models

The discussion in this section develops a model that can describe the profit-sharing contractual arrangements among the advertiser, coordinator, and publisher. The model is extended to include click fraud. A comparison of the market efficiency of this contractual-arrangement model and the currently popular auction-based model finds that there is a stable and unique price equilibrium in the contractual-arrangement model. With this model, introducing click fraud breaks the market equilibrium, which causes the advertiser to lose money, while the coordinator and publisher gain. In the long run, the coordinator will lower the contract term in order to keep advertiser participating. Advertiser and publisher both receive reserved utilities that are the same as before the click fraud was introduced because the click fraud does not generate real production. The cost of committing click fraud would deter further fraudulent clicks.

In contrast, the price equilibrium, if any, of the current auction model is far from efficient. Thus the reason click fraud has become a serious problem in the on-line advertising industry is largely because of the inefficiency of the auction-based pricing model.

Contractual-Arrangement Model

Assumptions

Two contractual arrangements are considered: the publisher-coordinator contract and the coordinator-advertiser contract. In both of these contractual arrangements, the coordinator is the principal who has the power to set the price. The publisher and the advertiser are the agents who decide whether or not to use the coordinator's service. It is assumed that the coordinator knows the advertiser's per click profits and so designs a profit-sharing contract with the advertiser in the form of CPC or CPM. The publisher-coordinator contract is based on a commission fee that is also described as a profit-sharing contract.

The sequence of activities in this process consists of the following elements:

- The advertiser and the publisher subscribe to a coordinator's service with an agreement on payment.
- An Internet user comes to the publisher's Web site.
- The coordinator selects a set of ads and places them on the publisher's Web site.
- The Internet user either clicks or does not click on the ads.

- If the Internet user clicks on the ad, the coordinator calculates the rent for the publisher and the advertiser.
- The money is paid as promised.

The information structure of the arrangement is as follows:

- The publisher and the coordinator know the statistics of the publisher's Web site.
- The advertiser and the coordinator know the advertiser's approximate per-click proceeds.
- The coordinator knows all the publishers and advertisers.
- The advertiser does not know the publisher until the click takes place.
- The publisher does not know the advertiser until the Web page is visited.
- The efforts of the publisher and the coordinator are not publicly observed.
- The efforts of the advertiser are publicly observed, with the assumption that the quality of the ad can be gauged by knowledgeable professionals in this area.

The list below is an easy reference for the parameters used in the model:

$Z = f(A, e_P, e_C)$: Production function, i.e., the value creation of an ad, where
  A: Quality level of the ad
  e_P: Effort from the publisher
  e_C: Effort from the coordinator
$c_A(A)$: Advertiser's cost of effort function
$c_C(e_C)$: Coordinator's cost of effort function
$c_P(e_P)$: Publisher's cost of effort function
ω_{CA}: Coordinator-advertiser's contractual arrangement, coordinator receives ω_{CA} of the production function
ω_{CP}: Coordinator-publisher's contractual arrangement, coordinator retains ω_{CP} of the income
$U_A(\cdot)$: Advertiser's utility function
$\overline{U}_A$: Advertiser's reserve utility
$U_P(\cdot)$: Publisher's utility function
$\overline{U}_P$: Publisher's reserve utility
$U_C(\cdot)$: Coordinator's utility function
θ: Rate of nonexistent "production" through click fraud
Production function: $Z = f(A, e_P, e_C)$
$\partial f/\partial A > 0, \partial^2 f/\partial A^2 < 0$
$\partial f/\partial e_P > 0, \partial^2 f/\partial e_P{}^2 < 0$
$\partial f/\partial e_C > , \partial^2 f/\partial e_C{}^2 < 0$
Advertiser: efforts are publicly observed
  Cost function: $c_A(A)$
  $c_A' > 0, c_A'' > 0$
  Utility function: $U_A = (1 - \omega_{CA})f(A) - c_A(A)$

Coordinator:
Cost function: $c_C(e_C)$
$c_C' > 0$, $c_C'' > 0$
Utility function: $U_C = F + \omega_{CP}\omega_{CA} f(e_C) - c_C(e_C)$
Publisher: double moral hazard
Cost function: $c_P(e_P)$
$c_P' > 0$, $c_P'' > 0$
Utility function: $U_P = (1 - \omega_{CP})\omega_{CA} * f(A^*, e_P, e_{CP}) - F - c_P(e_P)$
Click fraud: $f_{cf} = (1 + \theta) \cdot f$

In the C-P (coordinator-publisher) contract, the coordinator is responsible for searching relevant ads for the publisher. This involves investing in research and development for better ad-searching algorithms and hiring human experts for customized search. The publisher, on the other hand, is responsible for managing the Web content on a day-to-day basis. This involves hiring and supervising employees, keeping track of the interest of Internet users, and updating Web contents. Both sets of inputs affect the performance of the output. However, the level of effort devoted to such activities is not easily monitored by parties other than the individual providers of the effort.

In the C-A (coordinator-advertiser) contract, the coordinator is responsible for searching relevant publishers for the advertiser. This involves designing the ads, investing in research and development for better publisher searching algorithms, and hiring human experts for customized search. The advertiser is responsible for choosing a certain quality level for its advertisement. The Internet advertising quality level involves the size, position, duration, and graphical design of the ad. The advertiser's choice of quality level is publicly observable, but the coordinator's effort level is not seen by the advertiser.

This is modeled by assuming that the production function has three arguments: the coordinator's effort level, denoted by e_C, the publisher's, e_P, and the advertiser's choice of quality level, A. e_C can be divided into two parts, e_{CP} and e_{CA}, that represent, respectively, the effort level in the coordinator-publisher contract and the coordinator-advertiser contract.

Bhattacharyya and Lafontaine proved that optimal production can be achieved via a linear contract [4]. Assuming a certain advertising quality level A^* and coordinator-advertiser's contract term ω_{CA}, using ω_{CP} to denote the coordinator's share of the monetary return, the coordinator's problem in the coordinator-publisher contract can then be written as follows:

Publisher and coordinator (double moral hazard problem)

$$\underset{f, w_{cp}(\cdot), e_P, e_{CP}}{Maximize} \left\{F + \omega_{CP}\omega_{CA} * f\left(A^*, e_P, e_{CP}\right) - c_C\left(e_{CP}\right)\right\} \tag{1}$$

Subject to:

$$\frac{\partial}{\partial e_{CP}} \omega_{CP}\omega_{CA} * f\left(A^*, e_P, e_{CP}\right) = c_C'\left(e_{CP}\right) \tag{2}$$

$$\frac{\partial}{\partial e_P}(1-\omega_{CP})\omega_{CA} * f\left(A^*, e_P, e_{CP}\right) = c_P'\left(e_P\right) \tag{3}$$

$$\left(1-\omega_{CP}\right)\omega_{CA} * f\left(A^*, e_P, e_{CP}\right) - F - c_P\left(e_P\right) \geq \bar{U}_P \tag{4}$$

$$\left(1-\omega_{CP}\right)\omega_{CA} * f\left(A^*, e_P, e_{CP}\right) - F - c_P\left(e_P\right) \geq \bar{U}_P. \tag{5}$$

Constraints (3) and (4) represent the coordinator's and publisher's incentive-compatibility constraints, respectively, and (5) is the publisher's individual-rationality or participation constraint. As a result, the C-P contract term, publisher's effort level, and coordinator's effort level can be described as a function of (A^*, $\omega_{CA}{}^*$), such that

$$\omega_{CP}{}^* \sim g_{\omega_{CP}}\left(A^*, \omega_{CA}{}^*\right) \tag{6}$$

$$e_P{}^* \sim g_{e_P}\left(A^*, \omega_{CA}{}^*\right) \tag{7}$$

$$e_{CP}{}^* \sim g_{CP}\left(A^*, \omega_{CA}{}^*\right). \tag{8}$$

(A^*, $\omega_{CA}{}^*$) will be solved by backward induction from the coordinator-advertiser contract. Therefore, it is possible to design an optimal contract ($\omega_{CA}{}^*$, $\omega_{CP}{}^*$, A^*, $e_P{}^*$, $e_{CP}{}^*$) that maximizes the coordinator's utility.

Coordinator and advertiser contract as a double-sided moral hazard problem with agent's behavior observable

$$\underset{w_{cA}(\cdot), A, e_{CA}}{\text{Maximize}}\left\{\omega_{CA} f\left(A, e_{CA}, e_P{}^*, e_{CP}{}^*\right) - c_C\left(e_{CP}{}^* + e_{CA}\right)\right\} \tag{9}$$

Subject to:

$$\left(1-\omega_{CA}\right) f\left(A, e_{CA}, e_P{}^*, e_{CP}{}^*\right) - c_A\left(A\right) \geq \bar{U}_A \tag{10}$$

$$\frac{\partial}{\partial e_{CA}}\omega_{CA} f\left(A, e_{CA}, e_P{}^*, e_{CP}{}^*\right) = c_C'\left(e_{CP}{}^* + e_{CA}\right). \tag{11}$$

Constraint (10) represents the advertiser's individual-rationality constraint, and (11) represents the coordinator's incentive-compatibility constraint. As a result, if the advertiser participates, the coordinator will push the advertiser's utility to its reserve. Using backward induction, the solution of (6), (7), and (8) is substituted in the C-A contract and the problem can be modified as:

$$\underset{w_{cA}(\cdot),A,e_{CA}}{\text{Maximize}}\Big\{\omega_{CA} f\left(A, e_{CA}, g_{e_P}(A,\omega_{CA}), g_{e_{CP}}(A,\omega_{CA})\right) - c_C\left(g_{e_{CP}}(A,\omega_{CA}) + e_{CA}\right)\Big\} \tag{12}$$

Subject to:

$$(1-\omega_{CA}) f\left(A, e_{CA}, g_{e_P}(A,\omega_{CA}), g_{e_{CP}}(A,\omega_{CA})\right) - c_A(A) \geq \bar{U}_A \tag{13}$$

$$\frac{\partial}{\partial e_{CA}} \omega_{CA} f\left(A, e_{CA}, g_{e_P}(A,\omega_{CA}), g_{e_{CP}}(A,\omega_{CA})\right) = c_C'\left(e_{CP}^{*} + e_{CA}\right). \tag{14}$$

Solving (12), (13), and (14) gives the optimal contract (ω_{CA}*, ω_{CP}*, A*, e_P*, e_{CP}*), such that while the advertiser and publisher both participate and receive their reserved utility, the coordinator maximizes its own utility.

It is difficult to get a closed-form solution of the generalized problem. However, as will be seen below, approximations of the production, cost, and quality functions can be employed to obtain some insights into the problem in typical real-life setups of the model.

Production, Quality, and Cost Functions

The production function is described as the profit before the commission and service fee that the advertiser earns from Internet advertising. It is a function of several factors, including (1) demand for the product/service advertised, (2) traffic on the Web page, (3) approximate profit per product/service advertised, (4) publisher's quality of efforts, (5) ad's quality level, and (6) coordinator's quality of efforts. A simple multiple-factor model is used to describe the production function:

$$f(A, e_P, e_C) = \nu \cdot r^{*} \cdot Tr \cdot \left(\beta_0 + \beta_A Q_A(A) + \beta_P Q_P(e_P) + \beta_C Q_C(e_C)\right). \tag{15}$$

ν is the advertiser's profit per click. Assume that a buyer with income b_l for quality $q(p)$ is willing to buy $r\{b_l, q(p)\}$ of the product/service advertised. So, for a population of n users, the aggregated demand, r^*, is the sum from all the individuals, $r^* = \Sigma_n r_l$.

The production is measured over a fixed time period, say one month. It is assumed that Tr, the traffic (number of viewers) on the publisher's Web page during this time period can be approximated from a history performance log. (From a technical perspective, estimating the real number of viewers from Web site traffic can be very difficult because a person may use different computers, IP addresses, and accounts to access the Web site.) Only a proportion of the viewers will pay attention to the ads besides the content, and it is assumed that the ratios are determined by the ad's quality level $Q_A(A)$, quality of Web content $Q_P(e_P)$, and quality of searching $Q_C(e_C)$. A multiple-factors model is used to estimate this ratio.

For all parties, the quality function was set to be increasing and concave, and the cost function to be decreasing and convex. Figure 1 plots the cost functions and quality functions of all the parties.

$$Q_C(e_C) = 1 - e^{-a_C \cdot e_C} \tag{16}$$

$$Q_A(A) = 1 - e^{-a_A \cdot A} \tag{17}$$

$$Q_{Pi}(e_{Pi}) = 1 - e^{-a_{Pi} \cdot e_{Pi}} \tag{18}$$

$$C_C(e_C) = \psi_c {e_c}^2 \tag{19}$$

$$C_A(A) = \psi_A A^2 \tag{20}$$

$$C_P(e_P) = \psi_P {e_P}^2. \tag{21}$$

Figure 2 plots the production function of advertiser and coordinator. The optimal effort level for the coordinator and the advertiser can be found as the first-order condition in the model. A unique solution for all three parties is found such that the advertiser and publisher both receive their reserved utility, and the coordinator's utility is maximized.

Ineffective Clicks

Concept of Efficiency

The efficiency of on-line advertising is generally measured by a conversion rate (CR) that can be obtained by dividing the number of conversions by the number of times the ad is delivered (impressions). For example, if a Web page is viewed 100 times, two people click on it, and one person completes the transaction, then the resulting efficiency of the ad will be 1 percent. The conversion rate measures the real production of an on-line advertising campaign.

The conversion rate can be divided into two parts: the click-through rate (CTR) and the conversion efficiency rate (CER). The click-through rate is defined as the number of clicks divided by the number of impressions. The conversion efficiency rate is defined as the number of conversions divided by the number of clicks. If the CER is stable, advertisers will not care about the position or size of their ads, so long as they receive a number of clicks that meets their expectations.

Therefore, the conversion rate is simply the product of CTR and CER.

$$CR = CTR \times CER. \tag{22}$$

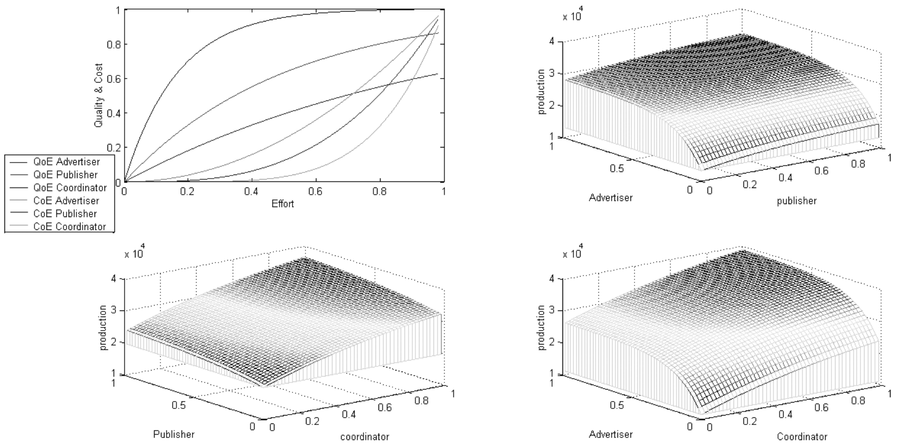

Figure 1. Cost Functions and Quality Functions

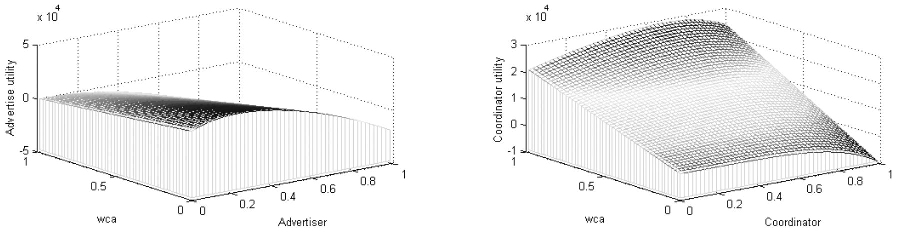

Figure 2. Production Function

CTR represents the number of clicks, and CER represents the quality of clicks, so CR represents the real production. Click fraud, as an example, artificially increases the number of clicks, thus increasing CTR and decreasing CER. While the real production is the same with or without click fraud, CR remains the same if it is assumed that the number of fraudulent clicks is trivial to the total traffic flow of the Web page.

Click Fraud Problem

Click fraud occurs when a person or an automated program imitates a legitimate click on an ad in order to generate charges per click without actual interest in the target of the ad's link. Click fraud is ineffective. In contrast, an effective click is defined is one that is clicked by a human with genuine interest in the advertised product or service and that adds value to the advertiser.

The efficiency of clicks can be represented by CER. For example, if everyone who clicks on an ad completes the desired transaction, CER equals 1. Conversely, if all the clicks generated from a Web site are click frauds, CER for this on-line advertising campaign equals 0. Because of the difficulty of determining the true intent of a click (e.g., a person might click on an ad more than once), the concept of ineffective click includes any means of clicking that does not add value, such as click fraud and excessive clicks by one user. The economic effect of ineffective clicking is examined below in an effort to find a contractual deterrence mechanism.

It is assumed that ineffective clicks do not change the real advertising production, but do increase the advertiser's cost by not adding any value. However, ineffective clicks increase the coordinator's and publisher's revenue. If the market is efficient such that both the advertiser and the publisher receive their reserved utilities, the emerging ineffective clicks squeeze the advertiser's utility to below its reserved utility. Consequently, the advertiser either leaves the market or the coordinator marks down the contract term ω_{CA} with the advertiser in order to keep the business.

Assume that the number of ineffective clicks is a proportion θ of the real production, such that $f_{cf} = \theta \cdot f$. The advertiser's total cost equals the sum of its cost of effort, cost of effective clicks, and cost of ineffective clicks, $c_A(A) + \omega_{CA}(f + f_{cf})$. Thus the advertiser's utility equals

$$U_A = \left[1-(1+\theta)\omega_{CA}\right]f - c_A(A) \tag{23}$$

The coordinator and publisher receive $\theta\omega_{CA}f$ more revenue in total and further divide it by the C-P contract term, ω_{CP}. Thus the utility functions for coordinator and publisher are described, respectively, as:

$$U_C = F + \omega_{CP}(1+\theta)\omega_{CA}f - c_C(e_{CA} + e_{CP}) \tag{24}$$

$$U_P = (1-\omega_{CP})(1+\theta)\omega_{CA}f - F - c_P(e_P). \tag{25}$$

If θ is stable over time, the new contractual arrangement problem with ineffective clicks can be extended as:

C-P contract

$$\underset{F,w_{cp}(\cdot),e_P,e_{CP}}{\text{Maximize}}\left\{F, \omega_{CP}\tilde{\omega}_{CA}{}^*(1+\theta)f\left(A^*, e_P, e_{CP}\right) - c_C(e_{CP})\right\} \tag{26}$$

Subject to:

$$\frac{\partial}{\partial e_{CP}}\omega_{CP}\tilde{\omega}_{CA}{}^*(1+\theta)f\left(A^*, e_P, e_{CP}\right) = c_C'(e_{CP}) \tag{27}$$

$$\frac{\partial}{\partial e_P}(1-\omega_{CP})\tilde{\omega}_{CA}{}^*(1+\theta)f\left(A^*, e_P, e_{CP}\right) = c_P'(e_P) \tag{28}$$

$$(1-\omega_{CP})\tilde{\omega}_{CA}{}^*(1+\theta)f\left(A^*, e_P, e_{CP}\right) - F - c_P(e_P) \geq \bar{U}_P. \tag{29}$$

C-A contract

$$\underset{w_{cA}(\cdot),A,e_{CA}}{\text{Maximize}}\left\{\tilde{\omega}_{CA}(1+\theta)f\left(A,e_{CA},e_P{}^*,e_{CP}{}^*\right)-c_C\left(e_{CP}{}^*+e_{CA}\right)\right\} \tag{30}$$

Subject to:

$$\left[1-\tilde{\omega}_{CA}(1+\theta)\right]f\left(A,e_{CA},e_P{}^*,e_{CP}{}^*\right)-c_A(A)\geq\bar{U}_A \tag{31}$$

$$\frac{\partial}{\partial e_{CA}}\tilde{\omega}_{CA}(1+\theta)f\left(A,e_{CA},e_P{}^*,e_{CP}{}^*\right)=c_C{}'\left(e_{CP}{}^*+e_{CA}\right). \tag{32}$$

By substituting ω_{CA} as $\tilde{w}_{CA}(1+\theta)$, the problem with ineffective click becomes the same as earlier except that the new C-A contract term $\tilde{w}_{CA}{}^*$ equals $\tilde{w}_{CA}{}^*/(1+\theta)$. This indicates that with click fraud or other ineffective clicks, the coordinator is able to design the contract so that the advertiser and publisher only receive their reserved utility, assuming that the rate of ineffective clicks is stable over time. With click fraud, the coordinator will lower the commission rate ω_{CA} to compensate the advertiser for any additional nonproductive clicks that the advertiser has to pay for.

The publisher may gain profit by introducing click fraud at the beginning, but the market will soon observe a decrease in click efficiency. The coordinator will lower the commission rate ω_{CA} in order to keep the business with the advertiser. As a result, the revenue the publisher receives will decrease to its reserved utility. The extra cost the publisher has to bear for committing click fraud will deter it from going further.

Auction Model and Contractual Arrangements

Auction is the most popular on-line advertising pricing mechanism these days because it has low entry costs and is easy to use. In an on-line advertising auction design, each advertiser submits a bid reporting its willingness to pay on a per-click basis. The position, size, and time period each ad receives is sorted in order of bids, with the highest bids the most outstanding. One of the drawbacks of this auction model is that the price fluctuates. Google solved this problem by adopting a modified auction model whereby an advertiser will only need to pay a price per click that equals the bid of the advertiser in the next-inferior position. The second-price structure makes the market smoother and more user-friendly.

In a predesigned contract, the price (cost per click) is set by the coordinator, whereas in an auction it is set by the next-highest bidder. If the market has sufficient competition, the price in an auction will reach the reserved utility of the last-highest bidder. If the conversion efficiency rate (CER) is stable, the advertiser will not care about the position and size of its ads as long as the combined number of clicks on different Web sites reaches expectation. This means that if the auction is based on positions, advertisers will treat all positions on a Web page the same, knowing that the only difference will be the volume of clicks on each position. Thus the bidding price is reduced on a Web page with a stable CER. Consequently, the winning bidders pay prices lower than their reserves, making it profitable for the publisher to commit click fraud. If there is not much competition, the bidding price will be much lower than the winning bidder's reserve. Thus more space is left for potential click frauds. Therefore, regardless of whether the market is small or large, there is always a click fraud opportunity in an auction.

When there is a predesigned contractual arrangement between the publisher, advertiser, and coordinator, the coordinator will design the contract such that the advertiser and publisher both receive their reserve. Thus there is no opportunity for click fraud, and as a result, the market under this model will run at full efficiency.

Conclusion and Future Research

This paper introduces a new contractual-arrangement model derived from the negotiable CPM pricing model of the early years of the on-line advertising industry. Based on pay-per-click, it differs from the old per-impression contract model. Because of the complexity and difficulty of solving for a complete closed-form solution, this principal-agents problem will be extended to future research in economics. As was proved, under the contractual-arrangement model, the coordinator is able to design a contract such that advertiser and publisher both receive their reserves. Such a contract has the power to deter click fraud in the process described as follows: (1) the market runs on equilibrium price, (2) the publisher commits click fraud, (3) the advertiser has to pay more and its utility will reach below its reserve, (4) either the advertiser leaves the market or the coordinator lowers the commission rate ω_{CA} to $\tilde{w}_{CA}^{*}/(1 + \theta)$, and (5) the publisher receives a smaller payment per click and will eventually reach its reserve. If committing click fraud is not cost-free, the publisher will have no motivation to go further.

Given the popularity of the auction design for on-line advertising, the online advertising industry was examined under the auction model. The study found that the market is not very efficient if there is not enough competition. Even with sufficient competition, advertisers will always gain a surplus above their reserve because of second-price properties,. The inefficiency of the auction design, therefore, is indeed the soil where click fraud grows.

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Appendix A

Solution

The Lagrangian for this problem is:

$$\begin{aligned} L = {} & F + \omega_{CP}\omega_{CA} * f\left(A^*, e_P, e_{CP}\right) - c_C\left(e_{CP}\right) \\ & + \lambda\left(\frac{\partial}{\partial e_{CP}}\left[\omega_{CP}\omega_{CA} * f\left(A^*, e_P, e_{CP}\right)\right] - c_C'\left(e_{CP}\right)\right) \\ & + \mu\left(\frac{\partial}{\partial e_P}\left[\left(1-\omega_{CP}\right)\omega_{CA} * f\left(A^*, e_P, e_{CP}\right)\right] - c_P'\left(e_P\right)\right) \\ & + \zeta\left(\left(1-\omega_{CP}\right)\omega_{CA} * f\left(A^*, e_P, e_{CP}\right) - F - c_P\left(e_P\right) - \bar{U}_P\right). \end{aligned} \tag{A-1}$$

(i) With respect to F, $1-\zeta = 0$, which implies $\zeta - 1 = 0$, hence the publisher's individual-rationality constraint must be binding, i.e.,

$$\left(1-\omega_{CP}\right)\omega_{CA} * f\left(A^*, e_P, e_{CP}\right) - F - c_P\left(e_P\right) = \bar{U}_P. \tag{A-2}$$

This implies that there are no rents left downstream.

(ii) With respect to e_P,

$$\begin{aligned} & \omega_{CP}\omega_{CA} * \frac{\partial}{\partial e_P} f\left(A^*, e_P, e_{CP}\right) + \lambda\omega_{CP}\omega_{CA} * \frac{\partial^2}{\partial e_{CP}\partial e_P} f\left(A^*, e_P, e_{CP}\right) \\ & + \mu\left[\frac{\partial^2}{\partial {e_P}^2}\left[\left(1-\omega_{CP}\right)\omega_{CA} * f\left(A^*, e_P, e_{CP}\right)\right] - c_P''\left(e_P\right)\right] = 0. \end{aligned} \tag{A-3}$$

Given the publisher's incentive-compatibility constraint, the last term in the Lagrangian

$$\zeta\left[\left(1-\omega_{CP}\right)\omega_{CA} * \frac{\partial}{\partial e_P} f\left(A^*, e_P, e_{CP}\right) - c_P'\left(e_P\right)\right] = 0$$

is equal to zero.

(iii) With respect to e_{CP},

$$\begin{aligned}
&\omega_{CP}\omega_{CA} * \frac{\partial}{\partial e_{CP}} f\left(A^*, e_P, e_{CP}\right) - c_C{}'\left(e_{CP}\right) \\
&+ \lambda\left[\omega_{CP}\omega_{CA} * \frac{\partial^2}{\partial e_{CP}{}^2} f\left(A^*, e_P, e_{CP}\right) - c_C{}''\left(e_{CP}\right)\right] \\
&+ \mu\left(1-\omega_{CP}\right)\omega_{CA} * \frac{\partial^2}{\partial e_P e_{CP}} f\left(A^*, e_P, e_{CP}\right) \\
&+ \zeta\left(1-\omega_{CP}\right)\omega_{CA} * \frac{\partial}{\partial e_{CP}} f\left(A^*, e_P, e_{CP}\right) = 0,
\end{aligned} \tag{A-4}$$

where the first term in the brackets is equal to zero, given the coordinator's incentive-compatibility constraint. Since $\zeta = 1$, it is possible to rewrite (A-4) as

$$\begin{aligned}
&\lambda\left[\omega_{CP}\omega_{CA} * \frac{\partial^2}{\partial e_{CP}{}^2} f\left(A^*, e_P, e_{CP}\right) - c_C{}''\left(e_{CP}\right)\right] \\
&+ \mu\left(1-\omega_{CP}\right)\omega_{CA} * \frac{\partial^2}{\partial e_P e_{CP}} f\left(A^*, e_P, e_{CP}\right) \\
&+ \left(1-\omega_{CP}\right)\omega_{CA} * \frac{\partial}{\partial e_{CP}} f\left(A^*, e_P, e_{CP}\right) = 0.
\end{aligned} \tag{A-5}$$

(iv) With respect to ω_{CP},

$$\begin{aligned}
&\omega_{CA} * f\left(A^*, e_P, e_{CP}\right) + \lambda\omega_{CA} * \frac{\partial}{\partial e_{CP}} f\left(A^*, e_P, e_{CP}\right) \\
&- \mu\frac{\partial}{\partial e_P}\omega_{CA} * f\left(A^*, e_P, e_{CP}\right) - \zeta\omega_{CA} * f\left(A^*, e_P, e_{CP}\right) = 0,
\end{aligned} \tag{A-6}$$

which, given $\zeta = 1$, can be rewritten as

$$\lambda\omega_{CA} * \frac{\partial}{\partial e_{CP}} f\left(A^*, e_P, e_{CP}\right) = \mu\frac{\partial}{\partial e_P}\omega_{CA} * f\left(A^*, e_P, e_{CP}\right). \tag{A-7}$$

From these conditions, the multipliers λ and μ for the incentive-compatibility constraints must be nonzero.

Note that the incentive-compatibility conditions on the two parties imply that

$$\omega_{CP} = \frac{c_C{}'(e_{CP})/\left[\omega_{CA} * \frac{\partial}{\partial e_{CP}} f\left(A^*, e_P, e_{CP}\right)\right]}{c_P{}'(e_P)/\left[\omega_{CA} * \frac{\partial}{\partial e_P} f\left(A^*, e_P, e_{CP}\right)\right] + c_{CP}{}'(e_{CP})/\left[\omega_{CA} * \frac{\partial}{\partial e_{CP}} f\left(A^*, e_P, e_{CP}\right)\right]}. \tag{A-8}$$

Using the first-order conditions laid out in Equations (A-3), (A-4), and (A-7), an expression is obtained for the optimal level of ω_{CP}, denoted by ω_{CP}*

$$\omega_{CP}{}^* = \frac{f_{e_{CP}}{}^2\left(\left(1-\omega_{CP}{}^*\right)\omega_{CA} * f_{e_P e_P} - c_P{}''\right)}{f_{e_P}{}^2\left(\omega_{CP} * \omega_{CA} * f_{e_{CP} e_{CP}} - c_{CP}{}''\right) + f_{e_{CP}}{}^2\left(\left(1-\omega_{CP}{}^*\right)\omega_{CA} * f_{e_P e_P} - c_P{}''\right)}, \tag{A-9}$$

where all quantities on the right-hand side are evaluated at the optimal levels for e_P and e_{CP}. While this equation can, in principle, be solved for ω_{CP}*, the resulting expression fails to yield any intuition behind the factors determining the optimal royalty rate without further structure on the production function and the disutility functions.

$$\omega_{CP}{}^* \sim g_{\omega_{CP}}\left(A^*, \omega_{CA}{}^*\right)$$

$$e_P{}^* \sim g_{e_P}\left(A^*, \omega_{CA}{}^*\right)$$

$$e_{CP}{}^* \sim g_{CP}\left(A^*, \omega_{CA}{}^*\right)$$

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