

Running and Chasing - The Competition between Paid Search Marketing and Search Engine Optimization

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Abstract

As search engine is leading the revenue growth in online marketing field, the competition of search engine marketing between paid search marketing (PSM) by search engine providers (SEPs), and search engine optimization (SEO) provided by search engine optimization firms, is white-hot. While PSM is simply for advertisers to buy the top ranks in sponsored links, SEO tries to optimize advertisers' websites by free-riding search engine's organic searching results. This study aims to investigate this competition by analytical modeling regarding organic search quality. We focus on sustainability conditions of SEO firms, investment analysis of SEO firms, and profit analysis of SEP. We find that a search engine advertising market is led by SEP, and the competition between PSM and SEO is a game of running and chasing. Specifically, better algorithm effectiveness of search engines promotes profitability of both PSM and SEO, and algorithm robustness of search engines negatively affects the survival of SEO firms in the market.

Keywords: search engine marketing, search engine optimization, sponsored links, paid search.

1. Introduction

Empowered by constantly evolving information technologies, particularly the mobile technology, Internet search engines have been both an information-seeking vehicle and a versatile online marketing instrument for all kinds of businesses [1]. According to Search Engine Marketing Professional Organization (SEMPO) [2], the total search engine marketing industry size estimate in 2011 is \$19.3 billion, with an increase of 16% from that of 2010 (\$16.6 billion).

There are two main types of online marketing services associated with search engine marketing: Paid Search Marketing (PSM) by search engine providers (SEP) and Search Engine Optimization (SEO) by the third party. PSM is also called sponsored links or sponsored list, which is operated by search engines in the form of sponsored or paid results, where an

advertisement is displayed in a pre-specified region of a search result page along with web search results. Search engines charge placement fees tied to the price of the relevant keywords, which is primarily determined by keywords auction and measured by cost per click (CPC), and the number of click-through the advertisement receives. This kind of service is also called pay per click (PPC) advertising services.

SEO, on the other hand, is the practice of optimizing web pages in a way that improves their ranking in the organic search results, also known as natural or algorithmic search results for targeted keywords. SEO firms optimize advertisers' websites to reflect specific query terms that are relevant to their business based on search engines' ranking mechanism. After the optimization, the websites can appear on the top positions in the organic search results page when users use the specific queries on search engine, and more visitors can be led to these websites.

Compared to search engine services which are dominant in the search engine advertising market, SEO is more likely a kind of unofficial service provided by many small SEO firms adhered to main services of search engine. As the contingent and secondary service providers, SEO firms have difficulties to survive. Think about that why advertisers should optimize their web site to get a high rank with some uncertainty when they can just "buy their high rank" [3]. However, SEO firms did have their market share in search engine advertising market. The survey conducted by SEMPO indicates that the number of companies which engaged in SEO has remained steady since 2007, while the proportion of companies carrying out PSM has increased from 78% in 2009 and 70% in 2008 to 81% in 2010[2]. Therefore, in search engine marketing, the competition between PSM and SEO is fierce. In 2008, among \$13.48 billion SEM spending, paid search spending is \$11.91 billion, with a market share of 88%, while organic SEO service spending is \$1.42 billion, with a market share of 10.6% [4].

In order to improve the rank of their customers' web sites in organic search outcomes of search engines,

SEO firms must continuously test and acquire search engine's ranking algorithm in order to deliver the good-enough services to their clients. In this way, the effect of SEO on PSM is two-folded. If it is properly applied, SEO will improve the efficiency of SE's algorithm; or if it is overused, such as ranking manipulation, it lowers the precision of search results. Because ranking algorithms play a very important role in the search engine retrieval performance [5], SEPs have to constantly modify their ranking algorithms to protect the robustness of their services from the negative effects of SEO. In 2007, most SEPs began to consider a wide range of undisclosed factors for their ranking algorithms, to reduce the impact of link schemes. Google, as an example, has been changing its organic search algorithm periodically to keep the organic searching equitable. As Google posted on its website, it ranks sites using more than 200 different signals¹. In 2010, Google made over 500 algorithm changes – almost 1.5 per day [6].

Recently, there is a sign that SEO firms are gaining momentum, which is primarily for two reasons. First, the price of keywords for CPC in the search engine market has increased tremendously over years. According to a Fathom Online report, keyword cost has risen 19% in a single year since September 2004 [7]. From the advertiser perspective, more than a half of advertisers and agencies said that in 2010 Google keywords have become more expensive over the last year [2]. Second, it has been realized that organic results are more appealing to searchers because these results are considered more objective and unbiased than sponsored results. According to an online survey by Georgia Tech University, over 70% of the search engine users prefer clicking organic results to sponsored results [8]. The SEMPO survey concurs with this finding, showing that organic listings are chosen first by 70% of the people viewing search results, while sponsored listings receive about 24.6% of clicks [9].

While SEO is drawing much of the attention in online advertising industry, there have been little published academic research works in this area. To address this gap, this study aims to understand the impact of SEO on search engine advertising market. Two research questions naturally arise: Under what condition will SEO firms survive? How do SEO and other factors impact the profit from paid search? These questions are important to both SEPs and SEO firms, because they share the revenue of the search engine advertising market. Insights in answering these questions will help managers of the counterparts make informed strategic decisions.

¹ <http://www.google.com/about/corporate/company/tech.html>

2. Related works and research background

Existed research about search engine marketing can be divided into two aspects. One aspect is about organic searching, like ranking algorithm design or improvements, anti-spamming, user click behaviors on search engines [10]. The other aspect is about sponsored searching results, like keyword auctions design [11-17] or bidding behavior in keyword auctions [18]. Most recent study by Yong & Ghose [19] discusses the relationship between organic and sponsored search of search engines. This important issue has also been mentioned in the recent research of Xu et al.[15]. These researches are mainly about search engines. Few literatures mentioned search engine optimization.

Our research problem regarding the competition between PSM and SEO is an extension from several prior active research threads. The most fundamental issue behind the competition is the quality of organic search [17]. Organic search quality determines the number of users who are the revenue source of both SEPs and SEO firms. Meanwhile, the existence of SEO obviously disturbs organic search results and affects the quality of search engines. As free online services to cope with explosive online information, search engines strive to improve user satisfaction with search experience through quality search results. The ability of a search engine in doing so largely depends on whether it can find value pages for web users, because each search engine only contains a fraction of the index-able information on the Internet [20]. User satisfaction is primarily determined by the quality of top results.

From online advertisers' perspective, they are faced with two choices: PSM vs. SEO. Sen finds that, in equilibrium, SEO is not an optimal choice, even if SEO fees are not higher than paid search [3]. Xu et al. also proved that organic listing might hurt search engine's revenue [17]. In this way, SEO which parasites to organic search will absolutely affect search engines' profit. For a low quality search engine, SEO firms may actually boost the ranking. For a high quality search engine, on the other hand, SEO are often regarded as spam. However, the impact of SEO from the business perspective is still not well addressed in the published research, and the impact of SEO on search users' satisfaction is unclear. Therefore, we focus on advertisers' net payoff from PSM services in the presence of SEO to investigate the impact of SEO and the competition between SEPs and SEO firms in the SEM market.

3. An integrated view of organic search quality

Existing literature on search engines marketing is insufficient in explaining the effect of SEO on the market because organic search quality has been exclusively associated with user satisfaction. So far, studies in search engine market have uniformly adopted the user-based approach to model quality and its impacts. This dimension of quality is a major domain expertise of search engines in satisfying the information need of searchers, reflecting “crawling and indexing algorithms, the database index, and search and retrieval algorithms” [21]. In this study, we call this quality dimension *algorithm effectiveness*, an aggregated and reduced form of user-based quality. The higher algorithm effectiveness is, the more likely searchers will be satisfied. With zero access price, the demand in the search market increases with algorithm effectiveness [22].

In the search engine advertising market, Internet search engines attempts to make their page ranking unbiased with regard to their own relevancy standards. They form the foundation of the market, and the businesses of SEO solely reply on their performance [23]. The involvement of SEO distinguishes the difference between search engines in their ability to exclude these “noises”; the greater this ability is, the less likely the noises SEO make deteriorate the search engine service quality. We call this ability *algorithm robustness*. This dimension of quality is a distinct attribute of Internet search engines. A search engine with higher algorithm robustness is less vulnerable to SEO’s noises; on the other hand, when algorithm robustness is low, SEO firms have more chance of cannibalizing SEP’s advertising revenue.

In the case of Internet search engines, the effects of algorithm robustness are twofold. First, since users’ satisfaction with search results is stochastic, so is the SEO practice in improving page ranking. No SEO firm knows the ranking algorithm of the search engine, and therefore, SEO practice only improves the chance of ranking improvement, rather than guarantees top ranking. Given an advertiser and advertising requirement, algorithm robustness denotes the effectiveness of SEO with the search engine.

Second, because SEO requires constant learning and adjustment of inter- and intra-website structures on the side of SEO firms, the efforts of optimization are expected to increase as algorithm robustness rises. It follows that algorithm robustness of a search engine alters the marginal cost of SEO with the search engine in question. As algorithm robustness of a search engine rises, it becomes more expensive to optimize results in

it. In other words, algorithm robustness is a “counter-quality” for SEO firms. As will be shown in the analytical model, algorithm robustness significantly affects a search engine’s advertising revenue in a competitive market. Overall, the higher algorithm robustness is, the more expensive SEO service is.

To a certain extent, while algorithm robustness can be improved over time primarily through learning on the search engine’s side, algorithm effectiveness is highly sensitive to initial investment and less flexible. For example, Google’s core ranking algorithm is based on PageRank, a patent of information retrieval filed when Google was founded. Algorithm robustness is dynamically affected by the competition between search engines and SEO firms, because both parties engage in constant learning and improvement. Lower algorithm robustness, therefore, reflects a lack of learning and investment on the search engine’s side, or a lack of accumulated experience on the SEO firms’ side, or both. Although algorithm robustness secures algorithm effectiveness, once a search engine service provider has chosen the effort levels in each of them, we can assume that these two components are stable with regard to the equilibrium status of advertisers and searchers. This definition of organic search quality expands former works in the literatures of search engine.

4. Basic model setting for search engine market

Table 1 summarizes most notations used in this study.

Table 1. Summary of Notations

q_e	Algorithm effectiveness, user-based quality
q_r	Algorithm robustness, manufacturing-based quality
ν	An advertiser’s willingness-to-pay for a click by a referred customer
$D(\cdot)$	The demand function for searcher
$g(\cdot)$	Market clearing price of the per-click fee the search engine charges. It is a function of ν and other factors related to keyword auction.
f	Per-period fee SEO firms charge
u	Net payoff for an advertiser
C	Cost function of PSM
r_o	Click through rate of organic searching results for the links provided by SEO
r_s	Click through rate of sponsored results

Suppose there are one SEP and multiple SEO firms in the market in a period of time, in which they both offer advertising services in the search market. Let q_e ($0 < q_e < 1$) denote algorithm effectiveness and q_r ($0 < q_r < 1$) algorithm robustness of the search engine. Beside the SEP and SEO firms, the market also contains advertisers and searchers. Advertisers are formally

defined as merchants paying advertising fee to either SEP or SEO firms.

It is assumed that advertisers are heterogeneous only in their valuation of online advertisement. This difference can be attributed to conversion rate, industry as identified by advertising keywords, and other idiosyncratic and advertiser-specific factors. Given a keyword, advertisers differ in their conversion rate, or the ratio of the number of sales to the number of distinct advertising clicks, and their valuation of the keyword, both of which can be reduced into willingness-to-pay for online advertisement. Across industry, one would normally expect that a referred customer from “attorney service” or “Caribbean travel” to worth a lot more than that of “mp3”, which, nevertheless, might be more popular.

In this study, we use the random variable v to denote the advertiser type in certain market segmentation in terms of its willingness-to-pay for the click from the search engine. For simplicity, v is assumed to be uniformly distributed over the interval $[0, V]$, and used to denote a particular advertiser’s willingness-to-pay in a certain industry. Compared to classical definition of type in economics, the advertiser type in this study is broader, incorporating within industry and across-industry willingness-to-pay.

The next variable, D , denotes the demand for PSM in terms of the total number of searchers who will click the organic results or sponsored results in a period of time. These searchers are potential referred customers from the search engine through either organic results or sponsored results. Since searchers do not pay a fee to the search engine, we assume that searcher demand is a function of q_e , which has a direct effect on the probability that a searcher will be satisfied with the search experience. In equation, $D(q_e) = \alpha + \beta q_e$, where $\alpha > 0$ and $\beta > 0$. Because $0 < q_e < 1$, $\alpha < D(q_e) < \alpha + \beta$. α is the demand when the search engine’s quality is the lowest ($q_e=0$). β is the slope of the function.

In search engine, the click through of result link depends on both its relevance and its rank within the search section, because web users are inherently more likely to click on higher-ranked items [12][24]. Therefore, the higher rank the item gets, the higher click through rate it has. In detail, from the angle of advertisers, the click through rate is different between organic searching results and sponsored results. We denote them as r_o and r_s . In organic results, whether advertisers’ link can be ranked higher depends on the relevance. If the advertiser chooses SEO firms, it depends on algorithm robustness of the search engine. Therefore, the r_o for the links serviced by SEO is negatively correlated to q_r . Based on the definition of q_r , we simply assume that r_o is $\gamma(1-q_r)$, where γ is a parameter that measures the sensitivity of r_o with

regard to $1-q_r$. In sponsored results, the rank has a positive relationship with the bid price. We simply assume that r_s equals δg . g is the CPC fee the search engine charges, and δ is the increment when g increases by one unit.

Let f be the per-period SEO fee charged by a SEO firm. Consistent with the keyword auction setting, the search engine does not set g . Instead, it is determined by keyword auction. As previously assumed, SEO does not directly affect q_e because the impact of an optimized link on q_e may be positive, or negative, depending on the relevance of the link.

4.1 Advertisers’ Choice Problem

In order to analyze advertisers’ problem, we make a classical assumption that advertisers have perfect knowledge of the payoff of either type of advertisement through learning and past experience. This is reasonable because advanced web technologies allow advertisers to track and count link referrals periodically and calculate profit per referred customer. We do analysis in certain market segmentation. Let u denote the payoff for advertisers. It increases as the search engine attracts more searchers. This is in line with the widely accepted theory of indirect network externality [25] which determines the value of a network. In this case, each search engines is a network of searchers. The payoff that an advertiser gets from sponsored links per period depends on the size of the searcher pool of the engine. In specific, it equals the total advertising value from sponsored links net of the total advertising cost. Here, the number of users arriving at the search engine in a period of time is $(\alpha + \beta q_e)$; r_s is the click-through rate of sponsored results. To advertisers, each click through generates a net payoff that is the difference between the value of a click through less its cost ($v - g$). In equation, the net payoff from sponsored links, u_1 , is:

$$u_1 = r_s (\alpha + \beta q_e)(v - g) = \delta(\alpha + \beta q_e)g(v - g) \quad (1)$$

Denote the net payoff from SEO by u_2 . It equals the payoff that the advertiser gets from organic results per period net of the SEO fee. Likewise, the number of users arriving at the search engine in a period of time is $(\alpha + \beta q_e)$; r_o is the click through rate of the natural results. Different from equation 1, advertisers pay f , a lump-sum fee per period. In equation:

$$u_2 = r_o (\alpha + \beta q_e)v - f = \gamma(1 - q_r)(\alpha + \beta q_e)v - f \quad (2)$$

Advertisers’ problem is to choose the advertising vehicle that maximizes its net payoff.

Since there are many SEO firms, it is assumed that the SEO market is perfectly competitive. In addition, optimization of search results, the product of SEO firms, is homogeneous regardless of the specific SEO firm, the industry, or the keyword chosen. Therefore, the price of SEO equals its marginal cost, which is assumed to be strictly increasing with respect to q_r . With zero fixed cost, it is assumed that the marginal cost of SEO is εq_r ($\varepsilon > 0$). Here, ε is a parameter that measures the sensitivity of cost with regard to q_e . This parameter is directly affected by SEO technologies and is assumed to be consistent across all SEO firms. In a perfectly competitive market, therefore, these firms charge f , the per-period SEO fee, where $f = \varepsilon q_r$. Plug f into (2), we have:

$$u_2 = \gamma(1 - q_r)(\alpha + \beta q_e)v - \varepsilon q_r \quad (2')$$

where εq_r is the marginal cost of SEO firms.

According to net payoff, the advertiser now chooses one of the three alternatives: no advertisement, paid search, and SEO. In equation, the problem is

$$\max \begin{cases} \text{No Advertisement} \\ \text{Paid Placement} \\ \text{SEO} \end{cases} = \max \begin{cases} u_0 \\ u_0 + u_1 \\ u_0 + u_2 \end{cases} = \max \begin{cases} u_0 \\ \delta(\alpha + \beta q_e)g(v - g) + u_0 \\ \gamma(1 - q_r)(\alpha + \beta q_e)v - \varepsilon q_r + u_0 \end{cases} \quad (3)$$

Where u_0 is the payoff of no advertisement which means organic listing without either PSM or SEO services.

4.2 Market share analysis

Based on the above assumption and analysis, we can go on to discuss about market shares of SEP and SEO firms in search engine advertising market, focusing on the partition of the online advertising market based on v , the advertiser type.

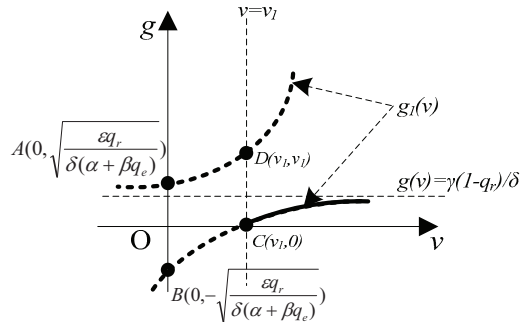


Figure 1. Indifference Curves of Advertisers in Search Engine Marketing

Let $g(v)$ be the market clearing price for the indifferent advertiser of type v between no advertisement and paid search. Since prices of paid advertisement are determined by auction, $g(v)$, the market clearing price for the indifferent advertiser of type v who use PSM services, can be solved with the equation (4), which is derived from $u_1 = u_2$:

$$g^2 - vg + \frac{\gamma(1 - q_r)}{\delta} - \frac{\varepsilon q_r}{\delta(\alpha + \beta q_e)} = 0 \quad (4)$$

$g_1(v)$ is the equilibrium price of paid search when advertisers are indifferent to the services of PSM and SEO.

Lemma 1. *There exists an indifference curve of $g_1(v)$ and v that advertisers will get the same net payoff whether they choose PSM or SEO.*

The market partition between PSM and SEO is showed in Figure 1. The equilibrium function is a quadratic curve which is similar to a hyperbola. Let $v=0$, we can obtain two points $A(0, \sqrt{\frac{\varepsilon q_r}{\delta(\alpha + \beta q_e)}})$ and

$B(0, -\sqrt{\frac{\varepsilon q_r}{\delta(\alpha + \beta q_e)}})$ on g axis. They represent the quadratic curve has two intersections with g axis. Let $g=0$, we have $v_1 = \frac{\varepsilon q_r}{\gamma(1 - q_r)(\alpha + \beta q_e)}$. So the quadratic

curve has only one intersection with v axis. Let $g=v$, we can get the coordinates of the point of tangency: $(\frac{\varepsilon q_r}{\gamma(1 - q_r)(\alpha + \beta q_e)}, \frac{\varepsilon q_r}{\gamma(1 - q_r)(\alpha + \beta q_e)})$. From the function we know the equilibrium curve has an asymptote $g(v) = \frac{\gamma(1 - q_r)}{\delta}$.

4.2.1 SEP's Market Share

Advertisers will pay search engine to get sponsored links service only if $u_1 > 0$ and $u_1 > u_2$:

$$\begin{cases} \delta(\alpha + \beta q_e)g(v - g) > 0 \\ \delta(\alpha + \beta q_e)g(v - g) > \gamma(1 - q_r)(\alpha + \beta q_e)v - \varepsilon q_r \end{cases} \quad (4)$$

From (4) we can get:

$$\begin{cases} g < v \\ g^2 - vg + \frac{\gamma(1 - q_r)}{\delta} - \frac{\varepsilon q_r}{\delta(\alpha + \beta q_e)} < 0 \end{cases} \quad (4')$$

(4') is the necessary condition for advertisers to choose PSM services.

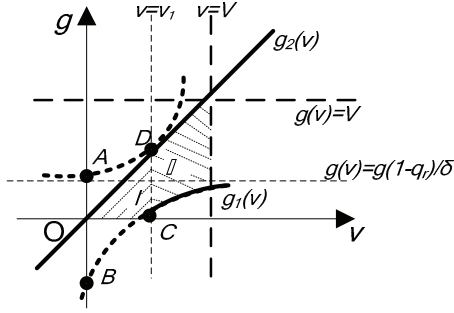


Figure 2. The market share of SEPs

v is assumed to be uniformly distributed over the interval $[0, V]$. Because $g(v)$ is the price of paid search and it is determined by keyword auction, $g(v)$ will never be greater than V , since V is the maximal willing-to-pay in the certain market segmentation. We add $g_2(v)=v$ which is derived by $u_1=0$ into Figure 2. Therefore the market share of the search engine company can be shown as shadow part in Figure 2.

Let u_2 equals 0, we can get a line $v_1 = \frac{\epsilon q_r}{\gamma(1-q_r)(\alpha + \beta q_e)}$.

The market share of SEP can be divided into two areas by this line: Area I and Area II. In area I, the payoff (u_2) for advertisers who choose SEO firms is less than 0. Therefore, advertisers within interval $(0, v_1)$ will not choose SEO firms. Advertisers within interval $(0, v_1)$ totally belong to SEP firms. Advertisers within interval (v_1, V) may possibly choose SEO firms, because the payoff may be greater than 0. Therefore, this part of market is shared by SEP and SEO firms. Area II falls in this interval but still belongs to SEP, because $u_1 > u_2$, though $u_2 > 0$.

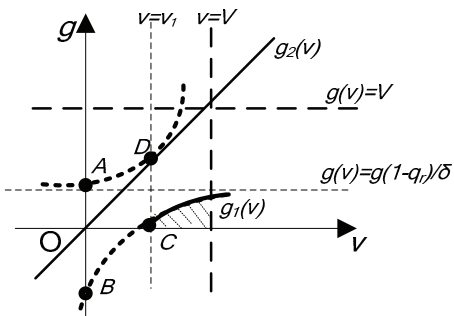


Figure 3. The market share of SEO firms

4.2.2 SEO Firms' Market Share

Similarly, advertisers will choose SEO firm to optimize its rank on organic searching side when $u_2 > 0$ and $u_2 > u_1$:

$$\begin{cases} \gamma(1-q_r)(\alpha + \beta q_e)v - \epsilon q_r > 0 \\ \delta(\alpha + \beta q_e)g(v-g) > \gamma(1-q_r)(\alpha + \beta q_e)v - \epsilon q_r \end{cases} \quad (5)$$

We can get (5') from (5):

$$\begin{cases} v > \frac{\epsilon q_r}{\gamma(1-q_r)(\alpha + \beta q_e)} \\ g^2 - vg + \frac{\gamma(1-q_r)}{\delta} - \frac{\epsilon q_r}{\delta(\alpha + \beta q_e)} > 0 \end{cases} \quad (5')$$

The market share of SEO firms is shown as the shadowed area in Figure 3, which only exists within interval (v_1, V) . Advertisers within this interval choose SEO firms as $u_2 > u_1$.

Lemma 2. The necessary condition in which advertisers choose SEO is that the level of their willingness-to-pay (v) meets the following condition:

$$v > \frac{\epsilon q_r}{\gamma(1-q_r)(\alpha + \beta q_e)} \quad (6)$$

5. Sustainability Conditions of SEO Firms

In order to study the sustainability of SEO, the model allows SEO firms to exist in the boundary condition as they are doing in reality. According to (5') if v_1 is greater than V , there is no market share for SEO firms. Therefore, we can obtain the sustainability condition of SEO firms:

$$\frac{\epsilon q_r}{\gamma(1-q_r)(\alpha + \beta q_e)} < V \quad (6)$$

$\alpha, \beta, \gamma, \epsilon$ and q_r are all greater than 0; then equivalently,

$$q_e > \frac{\epsilon q_r}{\beta \gamma V (1-q_r)} - \frac{\alpha}{\beta} \quad (6')$$

As SEO firms passively accept the decisions by SEP firms, their sustainability condition of SEO firms only depends on two aspects of search engine's quality: algorithm robustness ($0 < q_r < 1$) and algorithm effectiveness ($0 < q_e < 1$). Based on (6'), the critical curve $q_e > \frac{\epsilon q_r}{\beta \gamma V (1-q_r)} - \frac{\alpha}{\beta}$ denotes for all the (q_r, q_e) that the

SEO firms are driven out of the market.

Figure 4 demonstrates the "acceptance area" in which SEO firms may survive in the market. It can be calculated as:

$$\psi = \frac{(\alpha + \beta)\gamma V}{(\alpha + \beta)\gamma V + \varepsilon} - \int_{q_r^B < q_r < q_r^A} \frac{\varepsilon q_r}{\beta \gamma V (1 - q_r)} - \frac{\alpha}{\beta} dq_r = 1 - \frac{\varepsilon}{\beta \gamma V} \ln\left(1 + \frac{\beta \gamma V}{\alpha \gamma V + \varepsilon}\right) \quad (7)$$

The coordinates of point Q_A are $\left(\frac{(\alpha + \beta)\gamma V}{(\alpha + \beta)\gamma V + \varepsilon}, 1\right)$,

which means if algorithm effectiveness of the search engine can reaches 1 which level algorithm robustness should be when SEP can just drive SEO firms out of the search engine advertising market. When algorithm robustness of search engine is greater than $\frac{(\alpha + \beta)\gamma V}{(\alpha + \beta)\gamma V + \varepsilon}$, no matter which level algorithm

effectiveness is, SEO firms would not have living space in the market. The coordinates of point Q_A are $\left(\frac{\alpha \gamma V}{\alpha \gamma V + \varepsilon}, 0\right)$, which means if algorithm robustness of

PSM is less than $\frac{\alpha \gamma V}{\alpha \gamma V + \varepsilon}$, no matter which level

algorithm effectiveness is, SEO firms would have living space in the market.

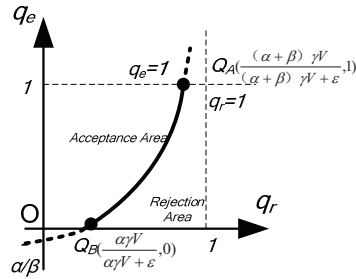


Figure 4. Operation Areas of SEO firms

Proposition 1: SEO firms can only survive in an “acceptance area” in accordance with their organic search quality, and the sustainability of SEO firms is

$$\psi = 1 - \frac{\varepsilon}{\beta \gamma V} \ln\left(1 + \frac{\beta \gamma V}{\alpha \gamma V + \varepsilon}\right).$$

From (7), we can prove that both q_r^A and q_r^B are increasing functions of V . Therefore, when V is getting greater, point Q_A and point Q_B will move rightwards in Figure 4, and the acceptance area will becomes larger.

In formula (6’), by plugging into $f = \delta q_r$, we have:

$$q > \frac{f}{\alpha b V (1 - q_r)} - \frac{a}{b} \quad (8)$$

From (8) we know that the greater f , greater the rejection area.

As algorithm effectiveness is the key competence of a SEP in the competitive PSM market, a leading SEP will be more likely preferred by SEO firms, provided its algorithm effectiveness meets (6’). The situation of SEO firms associated to Yahoo after Google entered the market closely matches this situation. After Google became a clear leader in algorithm effectiveness, it has been a major target of SEO firms. Google Dance Syndromes [26], or events that Google drastically revises its ranking algorithm and updates its index, are explicit attempts in counteracting SEO practice. In contrast, such events have seldom occurred in Yahoo in the early stage. According to the model, this is because Yahoo had the lower algorithm effectiveness and so as less searcher demand. This made SEO with Yahoo less sustainable.

6. Equilibrium Analysis of PSM-SEO Competition

Based on the above run-and-chase situation, it is worth studying the equilibrium of the game between PSM and SEO. Differentiated from the model we discussed so far, in which SEO could do little in the game, we assume that a SEO firm can make efforts to reduce the robustness of a SEP firm’s algorithm. This then increases the organic search quality. We further assume that the organic search quality is positively correlated to the effort a search engine input on it, including money, technique, and so on. Denote the SEP’s effort on its service quality as I_1 , and the SEO firm’s effort on its service quality as I_2 . Regarding the two dimensions of organic search quality, we assume that both algorithm effectiveness and algorithm robustness are non-decreasing with regard to the investment I_1 . In another aspect, organic search quality is negatively correlated to I_2 , because SEO firms as a whole tend to lower algorithm effectiveness of search engines with the “noises”, such as keyword stuffing, link spamming, etc., to the search results. Also, the improvement of optimizing technique leaves more challenges to search engines on their algorithm robustness. Since both q_e and q_r are functions of I_1 and I_2 with $\frac{\partial q_e}{\partial I_1} > 0$, $\frac{\partial q_e}{\partial I_2} < 0$, $\frac{\partial q_r}{\partial I_1} > 0$, $\frac{\partial q_r}{\partial I_2} < 0$, according to Taylor expansion formula², we can get:

² P. M. Hummel, and C. L. Seebeck, Jr, “A Generalization of Taylor’s Expansion”, The American Mathematical Monthly, 1949, 56, 4, pp.243-247.

$$q_e = q_e^0 + \eta_1 I_1 - \eta_2 I_2 \quad (9)$$

$$q_r = q_r^0 + \theta_1 I_1 - \theta_2 I_2 \quad (10)$$

Customer satisfaction is very important to SEO firms because it directly influences word of mouse and profit of SEO firms. Therefore, SEO firms will try their best to enhance the net payoff of advertisers who choose SEO. It is clear that the relationship between the SEP and SEO firms is not symmetric. SEP is leading and the SEO firm is following. In this way, the SEO firm can optimize its investment to improve their customers' net payoff by SEP's actions by with some delay.

By setting the SEO firm's investment $I_2 = I_2^*$ which satisfies

$$\text{F.O.C.: } \frac{\partial u_2}{\partial I_2} = 0 \text{ and S.O.C.: } \frac{\partial^2 u_2}{\partial I_2^2} < 0,$$

It can be derived that:

$$I_2^* = \frac{1}{2} \beta \left(\frac{\eta_1}{\eta_2} + \frac{\theta_1}{\theta_2} \right) I_1 + \frac{\alpha + \beta q_e^0}{2\beta\eta_2} - \frac{1 - q_r^0}{2\theta_2} + \frac{\varepsilon}{2\beta\eta_2\gamma} \quad (11)$$

From (11), we can see that the optimal investment of SEO, I_2 , is an increasing function of the search engine's investment I_1 . Therefore, we have:

Proposition 2: *If SEP increases its investment on organic search quality, SEO firms will also increase its investment to catch up with the search engine in order to let their customers to get the maximal net payoff.*

In the search engine marketing, the relationship between the SEP and SEO firms is like the one between runners and chasers. From a perspective of search algorithm, SEO firms keep on trying to find out the algorithm which search engines are using for ranking, on the contrary, search engines are already trying to keep a distance away from SEO firms.

Let $C(q_e)$ be the cost function of the SEP. This cost is a quadratic function of q_e , denoted by $C(q_e) = \zeta q_e^2$. It is also assumed that q_r , algorithm robustness of the search engine is a long-term investment decision and thus does not affect $C(q_e)$. By definition, the revenue of the search engine from a given keyword is the equilibrium price of paid advertisement multiplied by the number of clicks received by the sponsored results of the keyword. Suppose no SEO firms exist, SEP earns the monopolistic profit. We can derive from previous results:

$$\pi_0(q_e, q_r) = \frac{1}{V} \int_{0 < v < V} r_s(\alpha + \beta q_e) g_1(v) dv - \zeta q_e^2 = \frac{1}{V} \int_{0 < v < V} \delta(\alpha + \beta q_e) v^2 dv - \zeta q_e^2 \quad (12)$$

by setting its algorithm effectiveness, $q_e = q_e^*$, that satisfies

$$\text{F.O.C.: } \frac{\partial \pi(q_e, q_r)}{\partial q_e} = 0 \text{ and S.O.C.: } \frac{\partial^2 \pi(q_e, q_r)}{\partial q_e^2} < 0.$$

It can be derived that:

$$q_e^* = \frac{\beta \delta V^2}{6\zeta} \quad (13)$$

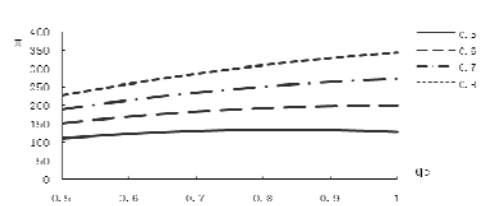
$$\pi_0^* = \frac{\beta \delta V^2}{3} + \frac{\beta^2 \delta^2 V^4}{36\zeta} \quad (14)$$

In the presence of SEO firms, SEP's profit can be expressed as:

$$\begin{aligned} \pi(q_e, q_r) &= \frac{1}{V} \int_{0 < v < V} r_s(\alpha + \beta q_e) g_1(v) dv - \frac{1}{V - v_1} \int_{v_1 < v < V} r_s(\alpha + \beta q_e) g_2(v) dv - \zeta q_e^2 \\ &= \frac{\delta(\alpha + \beta q_e)}{V} \int_{0 < v < V} g_1^2(v) dv - \frac{\delta(\alpha + \beta q_e)}{V - v_1} \int_{v_1 < v < V} g_2^2(v) dv - \zeta q_e^2 \end{aligned} \quad (15)$$

Figure 5 shows the simulation results Using Maple 10. We can observe that as q_e increases, SEP's profit also increases when algorithm robustness (q_r) level is getting higher ($q_r > 0.6$). However, when algorithm robustness is low, an optimal quality emerges where the search engine achieves maximal, albeit lower profit.

Proposition 3: *Algorithm robustness of a search engine influences the relationship between the search engine's algorithm effectiveness level and SEP's profit. Specifically, algorithm robustness influences SEP's optimal algorithm effectiveness and maximum profit.*



($\alpha = 100, \beta = 1000, \varepsilon = 10, \gamma = 0.01, \delta = 0.001, \zeta = 200$)

Figure 5. Effect of q_r

SEO firms will not invest in algorithm effectiveness, and they are just "free riders". As increasing a web site's page views will increase the share of SEP [27], SEPs will tend to invest in their algorithm effectiveness in order to get more profit. However, when algorithm robustness is low, investment in

algorithm effectiveness will not be as efficient as expected, because of the “free-riding” effect. Therefore, algorithm robustness has an effect of protecting the search engine’s investment in algorithm effectiveness.

Corollary 3.1: *Given a high algorithm robustness level, algorithm effectiveness of the search engine leads to greater profit of the search engine.*

Corollary 3.2: *Given a certain algorithm effectiveness level, algorithm robustness of a search engine leads to greater profit of the SEP.*

Another effect on the profit of SEP is the willingness-to-pay for online advertisement at large. This effect is interesting because over time, advertisers begin to realize the value of search engine advertising and therefore bear higher valuation on online advertisement. In reality, the increase in CPC in recent years reflects this trend. In the model, V captures this effect with a positive effect on the overall profit of SEP. As V increases, the search engine advertising market expands and SEP is able to reap more profit.

Due to limit of the paper size we omit the figures from simulation results.

7. Discussion and conclusion

PSM and SEO are two main advertising services available to advertisers in search engine marketing. In this study, we build two mathematical models, one in microeconomic method and another in game theoretic method, to analyze the competition between PSM and SEO. Search engine quality, which is divided into two dimensions: algorithm effectiveness and algorithm robustness, is introduced as an important factor in the model. Based on search engines, algorithm effectiveness brings in online searchers which are recipients of online advertisements that are the revenue source of both PSM and SEO. Algorithm robustness helps search engines to keep away from SEO firms’ chasing and reduce the noise made by SEO firms in organic searching. This enhances the searching experience of online searchers in organic searching, and also positively influences the searchers’ clicks of sponsored links[19]. SEO firms always have motivations to chase search engines in search algorithm, so search engines have to keep running away to maintain their algorithm robustness. However, when a search engine has a relatively low level of algorithm effectiveness, keep investing in algorithm robustness contrarily reduces the total revenue.

SEO is an interesting but not well studied issue in the online advertising area. In this study, we attempt to analyze the sustainability of SEO firms, and investigate the impact of SEO and other factors on SEP’s profit.

Several interesting insights emerge from the analysis of the SEO firms’ sustainability. First, the sustainability of SEO firms depends, in the first place, on the advertisers’ willingness-to-pay for online advertising. As this valuation rises over time, SEO firms offer an advantage over paid search. This result is primarily due to the different pricing policies adopted by the search engine and SEO firms. Secondly, algorithm robustness has a monotonic negative effect on the sustainability of SEO because it directly confines the practice of SEO. The practical implication, therefore, is that SEP could improve its profit through constant learning and “outsmart” SEO firms, so that its results are less vulnerable to SEO practice in general. Thirdly, algorithm effectiveness positively affects the sustainability of SEO firm. More importantly, a search engine is potentially subject to “free-riding” effect from SEO firms, because of the parasitic nature of these firms. As the search engine invest in algorithm effectiveness improvement, SEO firms may also benefit from this investment because more search engine user means more clicks in both sides of search engine. In order to reap a fuller benefit from investment, SEP has the incentive to improve its algorithm robustness at the same time. This phenomenon has been frequently observed in *Google Dance Syndrome* [26], a deliberate attempt at improving its algorithm robustness.

Due to the scope constraint and the type of the study, there are several limitations to this study. First, the uniform distribution assumption of advertisers’ willingness-to-pay is simplistic in reality. Second, the model is limited in advertisers in one industry. One possible extension is to model industry difference and advertiser difference with a hierarchical distribution and thereby, separate the two effects. The result could yield managerial insights in terms of market segmentation. Alternatively, horizontal differentiation model could be used to address the advertiser heterogeneity in keyword preferences.

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